CP1

A Note on the use of Lagrangian-Averaged Navier-Stokes-Alpha Model for Wind-Driven Surface Waves

The Lagrangian-averaged Navier-Stokes-α model was introduced in 1998. Since then, some developments have been made in mathematical and computational analysis of the α-model. There, however, are few examples of the use of the model for real fluid problems. One of the obstacles is in the fact that the α-model is a system of fourth-order partial differential equations and needs additional boundary conditions for the well-posedness. We apply the α-model to the generation of sea surface waves by winds and illustrate that such conditions might not be feasible, when the regularizing parameter α is constant. We try to consolidate the Lagrangian-averaging modeling concept and look for possible alternatives.

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CP1

Resonant Surface Waves

Interaction of resonant surface waves in an oscillating container is considered. Using the framework of Hierarchy of Bifurcations the averaged two-mode amplitude equations are studied. The analysis explains globally the role of initial profile properties vs forcing parameter magnitude. For several regimes of initial conditions it reconciles with the Simonelli-Gollub experiment. Moreover, it proposes that several new types of solutions may appear.

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CP1

Dynamics of Waves in a Shallow Layer of Inelastic Non-Newtonian Viscous Fluid of Shear-Thinning Type Flowing Down An Inclined Plane

The nonlinear waves in a shallow layer of inelastic non-Newtonian viscous fluid of shear-thinning type flowing down an inclined plane are examined using dynamical systems approach. A set of exact averaged equations from the complete Navier-Stokes equations for modified power-law fluid flowing down an inclined plane is derived using Energy Integral method. The linear stability of primary flow is investigated by the normal-mode formulation and the critical condition for the linear instability is obtained. The permanent waves are investigated at the leading-order approximation in which the surface tension is absent and therefore serves as a model for large-scale continuous bores in mud flows. The analysis shows the existence of two types of propagating bores. For weakly non-Newtonian mud flows, the retreating type exists only in the regime of linear-instability while the advancing type exists only in the regime of linear-stability. On the otherhand, both types exist in the neighbourhood of linear instability threshold for strongly non-Newtonian mud flows. Many bifurcation scenarios exhibited by the permanent wave equation obtained at the second order approximation for film flows with moderate surface tension are identified, examined and delineated in the parameter space and compared with the Newtonian results(R. Usha and B. Uma, Physics of Fluids, Vol 16, 2679-2696, 2004)

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CP2

Drift-Diffusion Models for the Dynamics of Decision Making

Behavioral and neural data from humans and animals attempting to identify randomly-presented stimuli can be described by a simple stochastic differential equation: the drift-diffusion (DD) process. In the two-alternative, forced-choice task the DD process describes how the logarithm of the likelihood ratio evolves as noisy incoming evidence accumulates. DD and related Ornstein-Uhlenbeck processes emerge as reductions of multi-component neural networks on stochastic center manifolds, and also as continuum limits of an optimal decision maker: the sequential probability ratio test. I will outline some background from cognitive psychology and neuroscience, and explain how DD models with variable drift rates can represent 'bottom-up' information on stimulus identity and reward magnitudes for correct choices, can capture such 'top-down' phenomena as attention and cognitive control, and can also describe changes that occur during learning. This is joint work with Juan Gao, Philip Eckhoff, Sophie Liu, Angela Yu, Rafal Bogacz and Jonathan Cohen.

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CP2

Kuramoto-Sivashinsky Equation with Drift

The Kuramoto–Sivashinsky equation is an important model for pattern formation in cases where the pattern forming instability has a preferred (non-zero) wavenumber. This equation has been studied extensively with periodic boundary conditions. Here we study the dynamics of the Kuramoto–Sivashinsky equation in a finite domain with reflectional symmetry broken by the addition of a drift term. The results will be compared with those found in the periodic case where the effect of drift may be removed by changing to a moving frame.

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CP2

Combat Modelling with Pdes

Limitations of Lanchester's ODEs for modelling combat have long been recognised. We present work seeking to more realistically represent troop dynamics, enabling a deeper understanding of the nature of conflict. We extend Lanchesters ODEs, constructing a new PDE system and describe simulation results obtained by introducing spatial force movement and troop interaction components as nonlocal terms. The spatial dynamics component takes advantage of swarming behaviour proposed by Mogilner et al, producing cohesive realistic density profiles.

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CP3

How Tadpoles Swims: Simple But Biologically Realistic Model

A new model of tadpole swimming based on experimental studies of the spinal cord (Alan Roberts Lab, Bristol University, UK) is developed. We first consider a system of two coupled Morris-Lecar neurons in the regime of post-inhibitory rebound. Bifurcation analysis shows that this simple model can generate robust anti-phase oscillations. A model of 2000 Morris-Lecar neurons of four different types is then developed. Experimental measurements and realistic computer simulations of developmental processes in the spinal cord provide evidence for the connection architecture and parameter values of the model. Simulations show that the model can generate a metachronal wave resembling the tadpole swimming pattern.

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CP3

The Iron Cycle and Thiobacillus Ferrooxidans Bacteria

A non-spatial model for the iron cycle including pyrite as waste rock is proposed. The biotic chemical reactions and reaction rates are based on experimental papers. The analysis of the system indicates the possibility of bistability and the existence of a Hopf bifurcation indicates the presence of periodic orbits in ferric ion, bacteria and pH as suggested in the literature. It is possible to show that the properties of the system are generic.

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CP3

Transport and Aggregation of Self-propelled Particles in Fluid Flows

The distribution of swimming microorganisms represented as self-propelled particles in a moving fluid medium is considered. It is shown that the particles concentrate around flow regions with chaotic trajectories. When the swimming velocity is larger than a treshold, dependent on the shape of the particles, all particles escape from regular elliptic regions and participate in global transport. For thin rod-like particles the threshold velocity vanishes and arbitrarily weak swimming destroys all transport barriers. We derive an expression for the swimming velocity required for escape based on a cicular flow approximation.

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CP4

Non-Linear Modelling of Cable Stayed Bridges

Cable-stayed bridges frequently experience vibrations due to a variety of mechanisms. Following on from previous research at the University of Bristol, this paper studies nonlinear dynamics in a neighbourhood of multiple parametric resonances. We examine a previously established cable-deck model, looking at the validity of the derivation and compare the behaviour of the model to data obtained from parallel experimental work.

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CP4

Driving a Chain from Stasis to Chaos

We examine the dynamics of an inextensible hanging chain, driven at one end. Although the physical system is quite simple, the dynamics are rich, with solutions ranging from rodlike motion to chaos, with swinging and whirling modes in between. We discuss the use of angular momentum in diagnosing symmetry breaking bifurcations and the role which different forms of dissipation have in determining the behavior of the system.

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CP4

On the Stability of the Track of the Space Elevator

Since 1991 the time of the discovery of “carbon nanotubes” it is technologically feasible to form a connection from the surface of the Earth to a satellite rotating with geostationary angular velocity around the Earth which could be used as track of an elevator. Using the Reduced Energy Momentum Method we investigate for defective ”carbon nanotubes” whether a continuous massive tapered string has a stable radial relative equilibrium in geostationary motion around the Earth.

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CP5

Numerical Study of Chaotic Response in Sdes

The proposed paper will present an efficient version of path integration (PI) where the detailed structure of chaotic response PDFs can be attained. This method will be applied to three systems where a small noise term is added to differential equations that are known to exhibit chaotic response; an equation of the Duffing kind, a piecewise linear system generated from gear dynamics, and a version of the Lorentz attractor. The additive noise term allows the use of the fast Fourier Transform (FFT) to reduce computation time. One of the main characteristics of chaotic systems is a positive largest Lyapunov exponent, and this also extends to stochastic systems. The authors' interpretation of the largest stochastic Lyapunov exponent will be discussed, together with the challenges in computing it in a reliable way based on the path integration idea.

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CP5

Effective Approximation of the Solution of Inverse Helioseismology With Noisy Data

The goal in inverse helioseismology is to compute the internal structure and dynamic of the sun through using the noisy measurements of the oscillations of the surface of the sun. For the purpose of the computation of the solar angular velocity, the dynamical model of the system is a Fredholm integral equation of the first kind. Due to the presence of the noise, application of the the classical solution methods would lead to meaningless solutions. We extend the Tikhonov regularization method to a new localized approach which lead to a more effective solution scheme for this problem.

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CP5

Coherence Resonance Via Harmonic and Stochastic Parametric Forcing in Sir

We consider a 2-parameter 2-dimensional SIR model. When the parameters are constant the system possesses two fixed points, one of which is a spiral node. When one of the parameters varies with time, either harmonically or stochastically, we find that a stable limit cycle appears. When the spectrum of the forcing contains energy at the frequency corresponding to half the imaginary part of the eigenvalue(s) associated with the spiral node, coherence resonance occurs. We analyze this resonance in detail in the case of harmonic forcing. This analysis provides insight into the behavior of the system when subjected to stochastic forcing.

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CP6

Modeling Cerebral Hemodynamics in Traumatic Brain Injury (tbi): Comparison of a Patient and a Rodent Model

Mathematical models of cerebral hemodynamics, applicable to humans and rats, including several arterial regulatory mechanisms were developed to gain mechanistic insight into the pathophysiology of TBI. The bifurcation analysis of the human model shows that a vasodilatory stimulus and not an impairment in cerebrospinal fluid reabsorption and in intracranial compliance is necessary to initiate plateau waves in intracranial pressure (P_{ic}). By contrast, the rat model does not predict the existence of periodic solutions with critical high P_{ic}.

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CP6

Phase Dynamics of a Neocortical Neural Network As a Possible Model for Epileptic Seizures

Epileptic seizures are generally considered to result from excess and synchronized neural activity. We develop a model of drug-induced seizures in the neocortex based on a model suggested by Wilson (1999). Phase reduction analysis is used to study the stability of the phase difference between two synaptically coupled neurons. We discuss the implications of noise-induced transitions between multistable states, observed in the two-neuron case, for models of seizure-like behavior in a larger network of neurons.

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CP6
The Role of Glia in Seizures

Brain tissue is composed of neurons and glial cells whose role is to regulate the extracellular environment especially potassium concentration. We present an ionic current model, composed of Hodgkin-Huxley type neurons and glia, designed to investigate the role of potassium in the generation and evolution of neuronal network instability leading to seizures. We show that such networks reproduce seizure-like activity if glial cells fail to maintain the proper extracellular potassium concentration.

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CP7
A Dominant Predator, a Predator, and a Prey

A two predator, one prey model in which one predator interferes significantly with the other predator is analyzed. The dominant predator is harvested and the other predator has an alternative food source. The Holling-like reponse functions include the effects of interference and are predator dependent. The analysis of the dynamics centers on bifurcation diagrams in which the level of interference, the amount of harvesting of the dominant predator, and level of alternative food are varied.

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CP7
Characterization of the Fractal Dimension in Dissipative Chaotic Scattering

The effect of weak dissipation on chaotic scattering is a relevant issue in situations of physical interest. We investigate how the fractal dimension of the set of singularities in a scattering function varies as the system becomes progressively more dissipative. A crossover phenomenon is uncovered where the dimension decreases relatively more rapidly as a dissipation parameter is increased from zero and then exhibits a much slower rate of decrease. We provide a heuristic theory and numerical support from both discrete-time and continuous-time scattering systems to establish the generality of this phenomenon. Our result is expected to be important for physical phenomena such as the advection of inertial particles in open chaotic flows.

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CP7
A Chaotic Lock-in Amplifier

The "reference" signal of a conventional lock-in amplifier is a periodic signal with a narrow power spectrum. In this paper we describe the construction of a lock-in amplifier that uses a chaotic reference signal. Since a "chaotic lock-in amplifier" uses a broad-band reference signal it might have some advantages in terms of signal capture time compared with a conventional lock-in amplifier that typically makes use of a swept-sine method to capture the response signal over a wide-bandwidth. The key ingredient of a lock-in amplifier is a phase-sensitive-detector, so in this paper we address the related questions of how to "phase-lock" the stimulus and response signals from the "chaotic" lock-in amplifier, and how to modulate and demodulate the stimulus and response signals making use of the chaotic reference. Not surprisingly, the inspiration for this measurement technique comes from recent discoveries showing how to synchronize chaotic systems—the phenomenon known as chaotic synchronization.

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CP8
The Brachistochrone Problem with Coulomb Friction and Aerodynamic Resistance

The brachistochrone problem that considers a body traversing from the top of an inclined plane to an arbitrary position at the bottom of the inclined plane in minimum-time and its solution are well-known for various formulations. Example formulations include the case of no friction, speed-dependent friction, and Coulomb friction (recently). Using a state-space formulation, this Zermelo problem with 2 types of friction was solved for the optimal control input (yaw acceleration).

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CP8
Saari's Conjecture for the Restricted Three-Body

Problem

In 1970, Don Saari conjectured that every solution to the Newtonian n-body problem that has a constant moment of inertia (constant size) must be a relative equilibrium (rigid rotation). This conjecture, adapted to the restricted three-body problem, is proven analytically using Bernstein-Khovanskii-Kushnirenko (BKK) theory. Specifically, we show that it is not possible for a solution of the planar, circular, restricted three-body problem to travel along a level curve of the amended potential function unless it is fixed at a critical point (one of the five libration points.) Equivalently, the only solutions with constant velocity are equilibria.

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CP8

A Map Approximation for the Restricted Three-Body Problem

We derive a family of area-preserving maps to approximate a particle's motion in the circular restricted three-body problem. The maps capture well the dynamics of the full equations of motion; the phase space contains a connected chaotic zone where intersections between unstable resonant orbit manifolds provide the template for lanes of fast migration between orbits of different semimajor axes. Particle motion in a planet-moon binary system is used as a numerical example.

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CP9

The Effect of Fast Threshold Modulation on Generation and Synchronization of Map-Based Neuron Bursts

The fast-slow dynamics and the bifurcation analysis have been widely applied to neuron networks of ordinary differential equations, but less attention has been paid on map-based neuron networks. A system consisting of two Rulkov's map-based neurons coupled through electrical junctions and a fast threshold modulation of reciprocal excitatory or inhibitory chemical synapses is discussed. The mechanism behind generation and synchronization of bursts is explained by means of the asymmetric solutions of the two-dimensional fast subsystem.

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CP9

Slow Modulation of Neuronal Activity Through Potassium Dynamics

Intra- versus extracellular potassium partitioning modifies neuronal network excitability. Elevated extracellular potassium regulates seizure maintenance and generation. Potassium dynamics consists of flux through neuronal and glial membranes and diffusion through the extracellular matrix. A reduced model, incorporating these mechanisms, reveals a phase space where sustained activity ranges from relatively short lived events to more persistent events linked to potassium concentration. These dynamics play an important role in pathological behavior including bursting, seizures and spreading depression.

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CP9

Existence and Stability of Limit Cycles in a Macroscopic Neuronal Population Model

We present rigorous results concerning the existence and stability of limit cycles in a macroscopic model of neuronal activity. Limit cycles have been demonstrated to be important in the study of certain generalized epilepsies, notably absence seizures. In particular we focus on a specific reduction of Freeman's KII sets, denoted RKII sets. Developing a theoretical understanding of the onset of limit cycles in models of this type has important implications in clinical neuroscience.

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CP10

Synchronization in Gradient Networks

The contradiction between the fact that many empirical networks possess power-law degree distribution and the finding that network of heterogeneous degree distribution is difficult to synchronize has formed a paradox in the study of network synchronization. Surprisingly, we find that this paradox can be well solved when proper gradients are introduced to the network links, i.e. heterogeneous degree distribution is in favor of synchronization in gradient networks. We analyze the general properties of gradient networks and explore their functions in enhancing network

sychronizability. Based on these understandings, we outline the basic principles for constructing efficient gradient networks and propose a specific coupling scheme as a verification. A detail comparison between the proposed coupling scheme and the previous asymmetric coupling schemes is conducted, where the new scheme is distinguished by using less network information while achieve higher synchronizability. Moreover, under the framework of gradient network, the factors which had been employed in former studies to improve synchronizability can be well unified and their functions can be well identified. The validity of our findings is verified by analytical estimates as well as directed simulations of coupled nonidentical oscillators. Our study therefore suggests that, in addition to the topology advantage, scale-free networks also manifest their dynamical advantage when proper gradients are considered.

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CP10

Percolation in Hierarchical Scale-Free Nets

In this work we study percolation on a family of deterministic scale-free networks, the (u, v)-flowers, of degree distribution $P(k) \sim k^{-\gamma}$, $\gamma = 1 + \ln(u + v)/\ln 2$. Because these networks are self-similar, they allow us to study the critical exponents of percolation by means of exact renormalization group techniques. Since (u, v)-flowers are small-world for $u = 1$ and fractal for $u > 1$, we analyze how percolation is affected by a change in scale.

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CP11

Chattering in Impact Oscillators

Impact oscillators are important examples of non-smooth dynamical systems which have behavior quite different from smooth systems. In an impact oscillator a solution trajectory evolves smoothly until it intersects a surface where it is instantaneously mapped to a new point. In a chattering trajectory the solution intersects the surface an infinite number of times in a finite time. We show that such behavior is common and has a profound effect on the overall dynamics of the system, leading to intricate domains of attraction.

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CP11

Towards a Qualitative Bifurcation Theory for Piecewise Smooth Systems

In the past 20 years or so there has been a large research literature on bifurcation behaviour of non-smooth systems both continuous and discrete. Different terms are used; border-collisions, impact, sticking, grazing, sliding, chattering, zeno-ness, etc. These are all defined via different analytic criteia given certain classes of nonsmoothness. In this talk we shall attempt to propose a qualitative, or geometric, theory just like that which exists for smooth flows. First we shall need to define different classes of nonsmooth system, by their degree of discontinuity as we cross discontinuity manifolds in phase space. Then we shall define a new concept of a discontinuity induced bifurcation as a loss of piecewise structural stability. Finally we need to explain what we mean by an unfolding of such bifurcation events. We show how various nonsmooeth bifurcations can be brought into this framework and how it is useful for describing dynamics observed in a wide classes of system.

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CP11

Discontinuity-induced Bifurcations and the Farey Sequence in Discontinuous Maps

Nonsmooth dynamical systems arise quite naturally when studying mechanical systems and modelling them often leads to a discontinuous map. These piecewise-smooth maps can display a rich bifurcation behaviour which I shall discuss. For example varying a bifurcation parameter over a finite interval can have the effect of passing through an infinite number of periodic orbits. Assigning the orbits a rotation number then produces the Farey sequence with exact ordering.

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CP12

Thermocapillary Migration of a Droplet Trapped at a Fluid-Fluid Interface

Employing the thermocapillary effect to manipulate a droplet trapped at a fluid-fluid interface has been proposed as a foundation for an optically controlled microfluidic device. We solve the Stokes equations for such a system, subject to a constant temperature gradient at infinity. The velocity and temperature fields are calculated numerically using a boundary collocation scheme. We analyze the dependence of the flow structure and the drop migration velocity on the dimensionless parameters characterizing the problem.

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CP12

Detection of Lagrangian Coherent Structures in 3D Turbulence

Direct Lyapunov Exponents (DLE) are used to identify Lagrangian coherent structures (LCS) in three-dimensional fluid flows. Compared with commonly used Eulerian methods, LCS are objective, provide greater detail, and do not depend on arbitrary thresholds to define structure boundaries. Additionally, LCS do not require velocity derivatives, which are often too noisy to be useful. We also show that a loss of hyperbolicity along the LCS indicates a qualitative change in the fluid dynamic structures.

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CP12
Quenching of Unsteady Vortex Breakdown

Vortex breakdown is a phenomenon inherent to many practical problems, such as leading-edge vortices on aircrafts, atmospheric tornadoes, and flame-holders in combustion devises. There have been many attempts to control the onset of vortex breakdown, but these have mostly concentrated on the steady regime, whereas the unsteady regime is of prime interest. We shall present both numerical and experimental results of an open-loop protocal in which unsteady vortex breakdown is quenched.

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CP13
Variational Approach to the Speed of Fronts in the Scalar Reaction Diffusion Equation with a Cutoff

We consider the effect of a cutoff on the speed of fronts of scalar reaction diffusion equations of the form $u_t + \mu\phi(u)u_x = [D(u)u_x]_x + f(u)$ where f(u) is a positive reaction term with a cutoff. We study the effect of the cutoff by means of an integral variational principle for the wave speed. We make a comparison with recent asymptotic results obtained by other methods.

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CP13
Verification of a Group Pod-Galerkin Model for Burgers Equation

An accurate and tractable reduced order model for real fluid systems has the potential to play an integral part in closed-loop flow control. In this work, a POD-Galerkin type reduced order model of Burgers equation is developed using group finite element techniques. The model is implemented in Matlab and positively verified by comparing computational results with mathematical expectations of standard POD-Galerkin models.

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CP13
Extensive Chaos in Rayleigh-Benard Convection

Spatiotemporal chaos is studied using large-scale numerical simulations of Rayleigh-Benard convection (a fluid layer heated from below) for experimentally realistic conditions. The Lyapunov spectra and fractal dimension are calculated over a large range of system sizes to yield extensive chaos. An analysis of the Lyapunov vectors show that the chaos is extensive even though there is a transition from boundary to bulk dominated dynamics as the system size is increased.

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CP14
Inverse Dynamical Analysis for Cell Biology

Given an ODE model of a gene regulatory network, relating its dynamical properties to the network structure is a challenging task. However, such problems commonly arise in the study of biological systems: e.g., how is the regulatory mechanism encoded in the interaction network? We propose a method for computationally performing such nonlinear inverse dynamical analyses. To infer the possible causes of a given physiological property/condition, solution behaviors or bifurcation diagrams are mapped to the parameter space via sparsity-promoting regularization functionals, allowing one to identify small sets of "influential" interactions. In combination with hierarchical strategies, the function of network components can be elucidated.

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CP14

Dynamics of Regulatory Pathways During Monocyte Cells Differentiation

We present results of in vitro cellular differentiation of stimulated monocyte cells. We use genome wide microarray data and a priori protein interactions to infer new regulatory pathways and to study regulatory network dynamics. A probabilistic model of protein-protein interactions is initially constructed from expression and a priori data. New regulatory pathways are inferred using a stochastic gradient algorithm. Quality of pathway prediction is evaluated on experimental results from several cell differentiation processes.

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CP14

Modelling Auxin Transport in Plant Leaves

Veins in plant leaves are specified by the flow of the hormone auxin. Auxin flow is polar, relying on the asymmetric localization of auxin transport proteins. The positioning of the transporters is itself mediated by auxin, leading to a very dynamic and plastic developmental system. I will present simulation results from a model based on the known auxin transport and signalling interactions in the model plant *Arabidopsis thaliana*.

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CP15

Controling Wing Rock Via External Excitation

Wing rock is a self-excited roll motion of a delta-wing aircraft during a high angle of attack maneuver. A proposed method to control this dangerous motion by an external excitation is presented. The excitation is introduced in the form of a harmonic term in the roll-moment equation which affects the equation of motion. The governing equation of motion is nonlinear. The perturbation method of multiple scales is used to obtain an approximate solution of this equation subject to three roll-moment models which are believed to represent the wing rock phenomenon. The results show the feasibility of controlling this undesired motion by applying external excitation.

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CP15

Task Encoding and Motion Planning for Metamorphic Robots

Metamorphic (or reconfigurable) robots represent a particularly interesting class of dynamical systems. We are interested in the problem of task encoding and planning the process of specifying the dynamical evolution of the robot's shape. Towards this end, we present two technical contributions: (a) a technique for characterizing the geometry of shape spaces of metamorphic robots that allows us to design dynamical control strategies as vector fields in this space and (b) techniques for optimally sampling such spaces, which admit a manifold structure, enabling the application of efficient approximation algorithms.

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CP15

Automatic Two-Plane Balancing for Rigid Rotors

We present an analysis of a two-plane automatic balancing device for rigid rotors. Ball bearings, which are free to travel around a race, are used to eliminate imbalance due to shaft eccentricity or misalignment. The rotating frame is used to derive autonomous equations of motion and the symmetry breaking bifurcations of this system are investigated. Stability diagrams in various parameter planes show the coexistence of a stable balanced state with other less desirable dynamics.

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CP16

Synchrony of Systems Driven by Common Noise

We present miscellaneous results on synchrony of oscillators subject to common noisy driving (noise is assumed to be white Gaussian). We study noise-induced synchronization and desynchronization of (i) smooth limit-cycle

oscillators with no inherent chaotic properties, (ii) neuron-like systems, and (iii) bursting systems which, for vanishing noise, possess an unstable chaotic set and a stable steady state. In all of these cases, we compare analytical results with numerical simulations.

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CP16

Stationary Solutins for Random Boussinesq-Glover Equation

We study the random Boussinesq-Glover equation in infinite dimensional spaces, driven by a real noise and with random initial condition. The noise is defined as stationary solution of a stochastic differential equation in finite-dimensional spaces (or Hilbert spaces). Under suitable assumptions, we prove the existence of stationary solution for random Boussinesq-Glover equation. Similar results arise in random reaction-diffusion equations.

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CP16

Universal Description of Noisy Supercritical Bifurcations: Theory and Experiments

We propose a universal description of the supercritical bifurcations of 1-Dimensional transverse systems in presence of noise that is also valid for temporal systems. More precisely, we give a unified expression for the most probable amplitude describing the supercritical bifurcations in presence of noise, including the noise level and the bifurcation point location. Comparison with experimental results obtained in a Kerr-like slice subjected to 1D optical feedback leads to an excellent agreement.

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CP17

Model for the Joint Development of Ocular Dominance Columns and Co Blobs in V1

We present an activity–dependent model for the joint development of ocular dominance (OD) columns and cytochrome oxidase (CO) blobs in primate V1. We show how the formation of an OD map interacts with the formation of the CO blob lattice, and ultimately results in the CO blobs aligned with the centers of the OD columns.

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CP17

Modeling of Axonal Pathfinding in the Olfactory System: Sorting and Convergence

We propose models with attracting and repulsive interactions which are able to reproduce the experimental findings of sorting and convergence during axonal pathfinding in the olfactory system. Many axon species, each represented by a huge number of axons, are spatially disordered at the beginning of their growth at the receptor neurons and converge by a self-organized process to a sorted state, i.e. axons of the same receptor type converge to a common position.

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CP17

How to Analyse a Dynamical System Typical for Brain Organization

We describe and simulate the visual correspondence problem with a system of differential equations. The system is typical for pattern formation in general and brain organization in particular. We start from an analytical treatment of a simple version with highly regular boundary conditions in terms of normal modes and their non-linear interactions, and will present semi-numerical methodology applicable to more general situations.

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CP18

Where Is Chaotic the Lorenz System?

The Lorenz system is the most classical chaos problem and it presents three parameters. Therefore, one interesting question is: which is the behaviour of the system for any

parametric value? This question has been partially answered by several researchers but for fixed values of some of the parameters. In this talk we analyse numerically the chaotic behaviour in the three-parametric phase diagram of the Lorenz system by the combined use of different numerical techniques.

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CP18

Shear-Induced Chaos

This talk is about a natural mechanism for producing chaos. Periodic pulsatile forcing applied to dynamical systems with intrinsic shear produces sustained, observable chaos in many settings. We will discuss this paradigm in the context of Hopf bifurcations. Both the supercritical Hopf bifurcation and the degenerate Hopf bifurcation will be considered.

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CP18

State-Dependent Delay in Regenerative Cutting Models

Models with state-dependent delays are rarely used in engineering since even their linearisation may cause problems. Still, the simplest 2 degree-of-freedom model of high-performance turning includes a time delay that depends on the tangential displacement of the cutting edge while the delay itself causes the variation of the normal displacements. The governing equation is a 4 dimensional system of RFDEs in the form:

$$\dot{x}(t) = f(x(t), x(t - \tau(x_t))$$

where the state dependent time delay is given in the implicit form

$$c\tau = h + x_1(t) - x_1(t-\tau)\,,\ c, h \in R^+ \quad \Rightarrow \quad \tau(x_t)\,,$$
$$x_t(\vartheta) = x(t+\vartheta),\ \vartheta \in (-\infty, 0]\,.$$

Stability analysis is presented and the effect of the state dependent delay is given.

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CP19

Non Integrability of Non Autonomous Hamiltonians Systems Via Morales-Ramis Theory

Morales-Ramis theory relate two differents kinds of integrability: integrability of autonomous hamiltonian systems in the sense of Liouville theorem and the integrability of ordinary linear differential equations in the sense of Picard-Vessiot theory. In this talk hamiltonian systems with $1+\frac{1}{2}$ degrees of freedom will be analyzed adding a new conjugated variable that transforms this hamiltonian system in a new hamiltonian system with 2 degrees of freedom. Particularly some examples will be analyzed such as the harmonic oscillator with exponential waste and the second Painlevé trascendent.

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CP19

Dynamical Evolution of Spatiotemporal Patterns in Mammalian Middle Cortex

The spatiotemporal structure of brain oscillations are important in understanding neural function. Oscillatory episodes from isotropic preparations from middle layers of mammalian cortex display irregular and chaotic spatiotemporal wave activity, within which spontaneously emerge spiral and plane waves. The dimensionality of these dynamics decreases during the middle of these episodes, regardless of the presence of simple spiral or plane waves. It is important to define the relevant biological order parameters which govern these dynamical bifurcations.

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CP19

Using Lyapunov Functions to Study the Stability of Visual Cortex

Our laboratory has developed a large-scale, biologically realistic model of turtle visual cortex consisting of approximately 12,000 differential equations. We have reduced the dimensionality of the model by deriving a family of linear, non-autonomous ordinary differential equations that describe the behavior of the large-scale model. This presentation develops a family of Lyapunov functions that can be used to study the stability, persistence and permanence of these equations. Supported by NSF grant 0218479.

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CP20

Selective Attention Model with Spiking Elements

A biologically plausible model of selective attention is presented. The model comprises a star-like architecture with a Central Assembly (CA) and several Peripheral neural Assemblies (PAs), all of which are constructed from interactive Hodgkin-Huxley neurons. An adaptation current is proposed which enables the CA to adjust its gamma frequency and become partially synchronised with particular PA. Synaptic homeostasis switches the attention sequentially between different PAs. The developed model works with both static and moving object.

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CP20

Dynamics of Synchronization in an Inhibitory Network

We consider a biophysical model describing a network of hippocampal basket cells (X. J. Wang and G. Buzski, J. Neurosci. 16:6402, 1996) and attempt to determine conditions under which certain specific modes of activity can be observed. We use the fast/slow structure of the equations involved to derive a simpler neuronal model that captures the essential features of the Wang-Buzski model interneuron and allows an analytical treatment. We then consider a pair of such neurons coupled through GABA-A type synapses and describe how the synaptic time scales interact with the intrinsic dynamics to generate various configurations (in-phase and out of phase synchrony, suppression) depending on initial conditions and parameters. We also discuss the implications of this analysis for larger networks.

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CP20

A Computational Approach to Dendritic Spine Motility: By Immersed Boundary Method with Advection-Electrodiffusion

Dendritic spines are small protrusions in dendritic branches of neurons. Influenced by internal and external signals and forces, even adult spines are not static but dynamically move. The dorminant driving force for dendritic spine motility is known to be actin-based polymerization/depolymerization. Here, without the reactions of actin fibers, actomyosin-based motility with calcium signaling is investigated. The simulation begins with influx of calcium ions through glutamate receptors. Calcium Induced Calcium Release (CICR) with IP_3(inositol-1,4,5-trisphosphate) dynamics is also considered. The sensitivity of elasticity of actomyosin networks is assumed to follow a Hill-type function of Ca^{2+}. On the computational framework of the immersed boundary method with advection-electrodiffusion, diverse combinations in size of spine head and neck, functioning of Endoplasmic Reticulum, and distribution of receptor/channels/exchangers are applied. Different functions of a spine as absorber, pumper and/or diffuser are observed.

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CP21

Sustainment of Activity in Neuronal Networks Coupled by Gap Junctions

We study the circumstances under which a network of excitable cells coupled by gap junctions exhibits sustained activity. We first investigate how network connectivity and refractory length affect the sustainment of activity in an abstract network. We then extend the analysis to spatially dependent neurons to show how cable diameter affects sustainment. We find that diameter regulation allows neurons to selectively transmit action potentials in gap junctionally connected networks.

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CP21

Studying the Role of Glial Cells in Neural-Glial Networks

In the brain, glial cells are known to affect neuron firing patterns, however the mechanism(s) remain unknown. One hypothesis is that the glia facilitate neuron communication in nearby neurons while suppressing communication at more distant neurons via a reaction-diffusion process. We consider this proposed mechanism using simple PDE and ODE models. After studying parameter ranges over which the observations are reproduced in the ODE model, we apply these results to simulations of the PDE model.

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CP21
Decorrelation of Odor Stimuli in Simple Network Models of the Olfactory Bulb

The olfactory bulb is the first stage in the processing of olfactory information in the brain. Experiments indicate that one important function of the bulb is to aid distinguishing similar odors by transforming the excitation patterns the bulb receives from the population of sensory neurons into less correlated output patterns. Within a simple, experimentally supported firing-rate model we study how this decorrelation depends on the network connectivity and interpret the results using a mean-field approach.

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CP22
Nonsmooth Bifurcations in a Zad-Strategy Lateral Pulse Buck Converter

This paper shows some nonsmooth bifurcations (also named discontinuity-induced bifurcations) appearing in a Buck DC-DC electronic converter with a novel ZAD strategy. The differential equations of the system are nonsmooth due to a switching action. Depending on the values of a bifurcation parameter, smooth and nonsmooth bifurcations of periodic cycles are found. Since the differential equations are piecewise-linear, closed-form solutions are efficiently used for computing the stability and detecting the bifurcations.

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CP22
Bifurcation Curves in Power Electronic Converters

We consider a DC/DC buck converter controlled by the ZAD (zero-average dynamics) strategy with two parameters: the reference voltage v_r and a constant k_s, controlling approach to zero average. Using averaging methods for non-smooth systems we compute exactly the duty cycle for a periodic orbit. We calculate curves in (v_r, k_s) space at which the periodic orbit undergoes period doubling and corner collision bifurcations. A codimension two bifurcation occurs when a corner collision and a saddle node bifurcation collide.

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CP22
Instabilities of Travelling Waves in a Brake-Like System

As a simple model of a disc-clutch we consider an elastic tube, which is in frictional contact with a rigid cylinder, rotating inside the tube about their common axis. Several types of rotating slip-stick and also slip-stick-separation travelling waves with different wave numbers can be observed. We try to locate the stability boundaries in parameter space and determine the oscillatory motion in the unstable regime.

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CP23
On the Chaotic Motion of Inertial Particles in Laminar Flows: Analytical Investigation of the Combined Effect of Inertia and Sedimentation

The chaotic motion of perfect tracers in laminar flows, namely chaotic advection, has received a wide interest in the last decades. In contrast, the chaotic advection of non-ideal tracers is much less documented. Some numerical analyses reveal complex and unexpected behaviours which strongly depend on the particle characteristics. In the present work the motion of a tiny solid sphere evolving under the effect of gravity and of a linear hydrodynamic force is investigated by means of asymptotic methods. The particle dynamics is re-written in the form of a perturbed Hamiltonian system, taking advantage of the fact that the response time is small. Two generic flow structures are considered : (1) vertical streamline displaying a strict local maximum, (2) horizontal elliptic point. It is observed that the phase portrait of particle dynamics can display homoclinic or heteroclinic trajectories, even though the phase portrait of pure tracers is structurally stable in these cases. Chaotic particle motion is therefore likely to occur, and the occurence of this chaos is investigated by using classical tools of Dynamical Systems theory, like Melnikov's method. The combined effect of particle sedimentation and inertia, as well as the contribution of the various terms of the hydrodynamic force, are discussed.

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CP23

Inertia-Induced Coherent Structures in a Time-Periodic Viscous Flow

Three-dimensional advection of passive tracers in time-periodic viscous flows serves as model problem for laminar mixing in industrial processes. An important issue in this context is the response of invariant surfaces (typically tori or spheres) in the tracer-path topology that may occur in the non-inertial limit ($Re = 0$) of such flows to fluid inertia ($Re > 0$). These surfaces form transport barriers and their destruction (by e.g. inertia) is imperative for efficient mixing. Flows with invariant tori have been studied extensively; flows with invariant surfaces other than tori have not. Non-toroidal cases are likely in practice and may behave differently from the toroidal case, however. The presented study concerns a flow with spheroidal invariant surfaces for $Re = 0$ and investigates the changes in topology during transition from the non-inertial state (inefficient mixing) towards an inertial state devoid of transport barriers (efficient mixing).

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CP23

Reaction Enhancement of Point Sources from Vortex Stirring

We investigate a class of reactive advection-diffusion problems motivated by ecological mixing. For two initially distinct scalar point masses stirred by a 2D vortex, the aggregate second-order reaction rate in the low-concentration limit is enhanced relative to that predicted by an equivalent eddy diffusivity. The peak rate grows as $P^{1/3}$, and the time to reach the peak decreases as $P^{-2/3}$, where P is the Peclet number.

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CP24

Domain Relaxation in Langmuir Films

We report on an experimental, theoretical and computational study of molecularly thin polymer Langmuir layer domain on the surface of a subfluid. When stretched (by a transient stagnation flow), the Langmuir layer takes the form of a bola consisting of two roughly circular reservoirs connected by a thin tether. This shape relaxes to the circular minimum energy configuration. The tether is never observed to rupture, even when it is more than a hundred times as long as it is thin. We model these experiments as a free boundary problem where motion is driven by the line tension of the domain and damped by the viscosity of the subfluid. The problem has a boundary integral formulation that allows an efficient numerical simulation of tether relaxation; comparison with our experiments allow estimation of the driving line tension.

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CP24

Analysis and Simulation of Barchan Sand Dunes

Barchan sand dunes are distinctive landforms found on Earth and Mars, in unidirectional wind and low sand supply environments. We attempt to understand the essential features of barchan dune growth, morphology, and migration, using an idealized 2D BCRE-type model. Evolutionary equations describe transport (saltation, creep, reptation), diffusion (avalanching), and exchange in moving sand and static sand layers. We analyze our model using dynamical systems methods and numerical simulations, and compare results with empirical data.

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CP24

Mixing-Induced Instabilities in Reaction-Advection-Diffusion Systems

We address new mixing-induced instabilities in reaction-advection-diffusion systems in open and closed flows: a competition of spatial mixing due to advection-diffusion and chaotic in time reaction, a competition of convective and absolute (birth of a global mode) instabilities in open reactive flows, a chemical instability induced by a mixing flow, where we prove that mixing can result in a destabilization of a homogeneous state and lead to nontrivial pattern formation. The effects found are generic: they ex-

ist in different geometries and at different scales and should be relevant to biological applications.

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CP25

A Hexapedal Jointed-Leg Model for Insect Locomotion

We develop an actuated hexapedal jointed-leg model for insect locomotion. Actuation is by torsional joint springs or by Hill-type muscles. We study the stability of periodic gaits and response to impulsive force perturbations and random foot placements. Incorporation of a CPG will provide an integrated locomotion model, and allow study of proprioceptive feedback pathways.

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CP25

Human Biomechanical Modeling Using Maple DynaFlexPro

Many researchers have developed rigid body models for human musculoskeletal dynamics and motor control. In this research, we are using Maple 10 with toolbox DynaFlexPro to develop the rigid body biomechanical models. This scheme generates model in sagittal plane consist of foot segments, lower limbs, upper limbs, a pelvic junction and a head arm torso (HAT) link in a bipedal skeletal configuration. The connections between links are treated as revolute joints for generating input torques.

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CP25

Analysis of a Biosensor Model

We analyze a nonlinear biosensor model involving a parabolic equation with Robin boundary condition and an ODE. The existence and uniqueness of the solution is obtained by topological methods. The long-time behavior and system case are also discussed. A finite volume method is applied and convergence, stability and error estimates, and some numerical simulations are obtained for the approximate solution. The work is base on the earlier consideration of S. JONES etc. Journal of Engineering Math, 1996.

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CP26

Nanoparticle Dep Dynamical Focusing: Model and Theory

Dynamic trapping of nanoparticles can be achieved by using the combined effect of diffusion, circular fluid flow and dielectrophoresis. We derived a dynamical model that predicts the intensity of the focusing of particles which fits our experimental measurements. We observe that the existence and location of the trapping regions depend not only on the size of the particles but also on the physical and design parameters.

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CP26

Coupled Cell Systems: A Paradigm for Developing Advanced Magnetic Sensors

A large class of dynamic sensors exhibit nonlinear characteristics. Examples include: magnetic field sensors and mechanical sensors. As new technologies emerge, more powerful and more efficient sensors are required. In response, we use ideas and methods from nonlinear dynamics and bifurcation theory, to demonstrate (theoretically and experimentally) that higher sensitivity and lower power-consumption can be achieved through an integrative approach that combines a novel coupled-sensor network architecture with a new sensing mechanism.

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CP26

Equilibrium Solutions of Smoluchowski Equations for Rigid Nematic Polymers

We study the equilibrium solutions of Smoluchowski equations for rigid rodlike nematic liquid crystalline polymers.

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CP27

Numerical Bifurcation Analysis of An Integro-Differential Equation

Consider the integro-differential equation (IDE)

$$u_t(x,t) = \epsilon \int_\Omega J(x-y)\,(u(y,t)-u(x,t))\,dy + f(u),$$

with initial condition $u(x,t_0) = u_0(x)$, $x \in \Omega$, $t > 0$, $\Omega \subseteq \mathbf{R}$, $\epsilon > 0$, $J(x) = J(-x)$ and $f(u)$ is a bistable function (e.g. $f(u) = u - u^3$). This type of initial value problem (IVP) arises in the modelling of various physical and biological process such as phase transitions. We investigate the long time dynamics of the IDE, and give a numerical bifurcation analysis of the steady states of this IDE in a periodic domain.

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CP27

Predictive Differential Equations

We study differential equations whose dynamics are governed by predictions of its future states. A general formalism, a linear stability analysis, and concrete examples are presented. We find that the dynamical characteristics and the stability of fixed point depend on how to shape the predictions as well as on how far ahead in time to make them. It is also found that noise can induce oscillatory behavior, which we call "predictive stochastic resonance".

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CP27

Chaotic Transport in Quasiperiodically Forced Systems

We consider transverse intersections of saddle-type torus braids as an extension of our earlier work on quasiperiodically driven oscillators (J. Nonlinear Sci. 15(6):423-452; Chaos 15, 033108; Physica D, 197(1-2):69-85). We study especially quasiperiodic forcing of a nonlinear oscillator by two incommensurate frequencies, which yields two 3D Poincaré sections in our construction. We consider the 3D cross-sections of the 4D lobes defined by the stable and unstable manifolds, and the geometry of transport.

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CP28

Dynamics of Plant Border Formation

We construct a model to investigate how different plant species construct borders when competing for the same spatial location. We show that the overlap in border between two native species is smaller than that of a native and a non-native species pair. In particular, we propose a novel hypothesis that border formation may be affected by a form of self-inhibition allowing native species to minimize resources used to directly compete with other native species.

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CP28

Aerial Displays of Thousands of Starlings: A Model and Data

We apply methods of complexity science to improve our understanding of the extensive aerial displays that starlings perform at a roosting place. We adapt common models of swarming for the physical constraints of bird flight. The patterns emerging in the model, both static and dynamic, resemble those observed in real starlings in Rome. Thus, we obtain an indication for which patterns local information is sufficient and for which ones more global, auditory information is needed.

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CP28

Particle Tracking Algorithm for Ecological Network Analysis

We present a novel algorithm for analyzing ecological networks. We label each mass (biomass or C, N, P) or energy packet in the system, and track their locations as they flow through the network. This method enables us to investigate system wide properties of ecological networks; such

as cycling index, residence time, and dominance of indirect effects. Unlike agent based models (IBM, ABM), this stochastic method is compatible with the ODE representation and master equation.

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CP29
Mixed-Mode Oscillation in the Olsen Model for Peroxidase Reaction

Olsen (Phys. Lett. A94, 454 (1983)) proposed a four-variable model for the dynamics of the oxydase-peroxydase reaction. The system exhibits mixed-mode oscillations which has previously been linked to the presence of homoclinic trajectories. In the present paper we consider a singular perturbation view of the equations, and obtain an understanding of the dynamics based on recent progress in the theory of mixed-mode oscillations based on canards.

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CP29
Relaxation Oscillations with Symmetry

Systems with disparate timescales may exhibit relaxation oscillations—recurrent periods of slow $O(\epsilon)$ drift separated by rapid switching events. One scenario, relevant to certain reflection-symmetric fluid systems, e.g., relies on "delayed loss of stability"; trajectories drift past a Hopf bifurcation (in the slow variable) before jumping to an attracting (symmetry-related) slow manifold. Additional symmetry, such as D_2 or D_4, increases possibilities. We examine such systems using three-dimensional models and find that the multiplicity of solutions is organized by the phase space structure of the reduced (fast) system and a simple scaling law deriving from the $\epsilon \to 0$ limit.

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CP29
Ghost Manifolds in Slow-fast Systems, with Applications to Fluid Flow Separation

We describe a peculiar type of dynamics near a non-hyperbolic invariant slow manifold of a two dimensional time-dependent slow-fast dynamical system. The peculiar dynamics results from presence of an attracting invariant manifold (ghost manifold) that lies off the slow manifold yet influences the boundary-layer dynamics near the slow manifold. Such ghost manifolds turn out to have a footprint on the underlying slow manifold that can be studied via a combination of an averaging technique and a wavelet decomposition. We show how ghost manifolds arise in the study of moving unsteady separation in fluid flows with no-slip boundaries.

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CP30
A Massera Type Theorem for Linear Impulsive Delay Differential Equations

In this paper, we consider linear impulsive delay differential equation which involves delay not only through the state variable but also through the indices of the jumps. This is naturally possible since at any discontinuity point the solution value will be also determined by its history. We construct an appropriate adjoint equation that enables us to obtain the representation of solutions. A Massera type theorem for the existence of periodic solution in case it admits bounded solution is proved.

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CP30
Approximating the Fundamental Solution for a Delay Differential Equation by Pseudospectral Collocation

When approximating periodic solutions for a nonlinear delay differential equation, the need to solve a variational equation about the periodic solution leads to a variation of parameters formula. However, the formula requires the determination of the fundamental solution for a variational equation with periodic coefficients. This talk describes an algorithm, based upon pseudospectral collocation methods, for approximating the fundamental solution. An example, based on a Van der Pol equation with delay, will be given.

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CP30
Computation of Invariant Manifolds in Delayed Systems

We consider two different approaches for approximating higher-dimensional manifolds of delay-differential equations (DDEs). In case of small delays, we use a locally accurate ODE-approximation whose invariant manifolds

can be then computed by standard methods. For arbitrary delays, we extend prior methods by Krauskopf and Osinga for computing higher-dimensional manifolds of vector fields. Both approaches are illustrated by approximating two-dimensional unstable manifolds of hyperbolic equilibria for DDEs with a single delay in R^3.

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CP31

Patterns on Growing Square Domains Via Mode Interactions

In this talk, I will consider reaction-diffusion systems on growing square domains with Neumann boundary conditions (NBC). As suggested by numerical simulations, I will study a relevant mode interactions in steady-state bifurcation problems with both translational symmetry and square symmetry, combined with the symmetry constraint imposed by NBC. I will show that the transition between different types of squares can be generically continuous. Also, I will show that transitions between squares and stripes can occur generically only via steady-states and time-periodic states. I will point out the differences between the transitions from squares to stripes in the NBC problem and in the periodic boundary conditions problem.

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CP31

Turing Patterns in a Linear Reaction System with Nonlinear Cross Diffusion Coefficients

To date most postulated models for Turing patterns have used nonlinear chemical reactions coupled with a fickian diffusion model. We have found a system that creates Turing patterns with a linear chemical reaction system with equal diffusion coefficients. Pattern formation is driven by the use of nonlinear concentration dependent cross diffusion. Both mathematical analysis and numerical simulation results are presented.

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CP31

Quasipattern Selection Mechanisms

We examine two mechanisms that have been proposed to explain quasipattern selection in single and multi-frequency forced Faraday wave experiments. Both mechanisms can be used to generate stable quasipatterns in a model partial differential equation with parametric forcing. One mechanism, which is robust and works with single-frequency forcing, does not select a specific quasipattern. The second mechanism, which requires more delicate tuning, can be used to select particular angles between wavevectors in the quasipattern.

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CP32

Identifying Direct Interactions and Their Directions in Networks of Neurons

Understanding the dynamics of neural networks is of particular interest in neuroscience. We present an approach to infer the network structure from measured time series. The method disentangles direct and indirect interactions and allows for the determination of the direction of the interactions. The performance will be demonstrated by means of a tremor application.

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CP32

Activity Patterns in Inhibitory Networks of Neurons

We study the dynamics of medium-size networks of inhibitory bursting neurons (typical of central pattern generators) coupled through fast threshold modulation. Linear analysis allows us to understand how the patterns of bursting are determined by network topology and the strength

of synaptic connections. We also discuss the properties of the neuron model that underlie the described phenomena, comment on the limitations of the technique of analysis, and point to some ways to overcome them.

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CP32

Specificity of Synaptic Connections Formed During Development of a Functioning Neuronal Network

We want to understand how accurate synaptic connections have to be between different classes of neuron in the spinal network controlling swimming of the young frog tadpole. Using dynamical systems, we build models for the different neurons and synapses in this network. We construct networks, where the connection probabilities follow simple rules based on anatomically determined contact probabilities of axons and dendrites of different neurons. These networks produce "swimming" more reliably than randomly connected networks.

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CP33

Computing the Inertial Manifold of a Genetic Regulatory Model

Genetic regulatory models often take the form of a set of delay-differential equations in which delays model time-consuming processes like transcription and translation. As in ordinary biochemical models, the governing equations are often stiff, resulting in the appearance of an inertial manifold which attracts solutions in the state space. The construction of such a manifold reduces the model to a small set of ordinary differential equations. Using a small-delay expansion and an iterative solution method, the inertial manifold of a genetic regulatory model is constructed. The error in the approximation is studied numerically.

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CP33

Dynamical Equivalence of Chemical Reaction Networks

A chemical reaction network can be described by a system of nonlinear ODEs with rate functions given by the principle of mass-action kinetics. Classical theorems of Horn, Jackson and Feinberg relate the existence, uniqueness, and stability of equilibria of certain reaction networks to their topology. It will be shown that considerations of dynamical equivalence of reaction networks can be used to enlarge substantially the class of reaction networks to which the theorems can be applied.

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CP33

The Dynamics of Schelling-Like Population Models

We study the dynamics and geometry of Schelling-like population models. Thomas Schelling won the 2005 Nobel Prize in Economics. The Schelling model is one of a small number of "agent based" population models, where individual members of the population (agents) interact directly with other agents and move in space and time. This model serves as a paradigm for modeling population movement via non-local aggregation. We will present several results on the prevalence and structure of the limit sets in one and two dimensional models.

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CP34

Bifurcation Diagrams of Network Dynamics – Coarse Graining by Automated Moment Closure

We propose an approach that allows us to use standard numerical tools to study the emergent-level, long term dynamics of complex networks. The approach circumvents the derivation of closed models. We combine a moment expansion of the network with a numerical algorithm that uses short bursts of individual based simulation to generate appropriate closure terms on-the-fly. We illustrate the approach by considering an epidemiological example, which combines dynamics on the network with topological evolution.

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CP34

Equation-Free Modelling of Inelastic Collapse

A hard sphere gas whose particles collide inelastically lacks a straightforward hydrodynamic limit and its evolution is poorly described by PDEs. Such gasses undergo "inelastic collapse", after which most particles are restricted to slow-moving, high-density clusters. Here we apply the recent, equation-free methods of Kevrekides and collaborators—which combine stochastic simulation with time stepping—

to a prototypical example of inelastic collapse, a one-dimensional gas originally studied by Du, Li and Kadanoff.

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CP34

Using Newton-Krylov Methods in the Lifting Step of the Equation-Free Approach

Equation-free computing allows us to extract the macroscopic dynamics from a microscopic model when a macroscopic description is unavailable. An essential component is the lifting (initialization) step in which macroscopic fields are mapped to an appropriate microscopic initial state. Depending on the microscopic model parameters, the earlier proposed constrained runs iteration may converge slowly or even diverge. We show that these issues are resolved when using an alternative implementation based on a preconditioned Newton-Krylov method.

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CP35

Stability of Blowup Solutions of the Ginzburg-Landau Equation

In this talk we study, the stability of radially symmetric blowup solutions of the Ginzburg-Landau equation. Upon writing the Ginzburg-Landau equation as a small perturbation of the nonlinear Schrödinger equation, the existence of multi-bump blowup solutions, especially of ring-like solutions, has already been established. So far, the stability of these blowup solutions had only been examined numerically. We use Evans function techniques developed for perturbations of Hamiltonian systems to study the stability of the ring-type solutions depending on the parameters in the system.

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CP35

Time Delay Effects on the Dynamics of the Nonlocally Coupled Complex Ginzburg-Landau Equation

The influence of time delay on the dynamical evolution of nonlinear "hole" solutions of the nonlocal complex Ginzburg-Landau equation is investigated by incorporating a distance dependent propagation delay term in the coupling kernel. Time-space plots show spatial patterns with clustering behaviour and modulations in phase. A parametric study in the state space of time delay and coupling strength is presented and the nature of phase turbulence in different regimes is delineated.

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CP36

A Bifurcation Analysis of Pattern Formation in the Developing Inner Ear

Predecessor cells in the developing inner ear have the potential to differentiate into either hair cells or supporting cells. As development proceeds, through an unknown mechanism, the hair cells position themselves on a hexagonal lattice surrounded by supporting cells. A bifurcation analysis of a model for signaling between predecessor cells arranged on both regular and slightly perturbed hexagonal and square lattices provides insight into the mechanism driving the formation of the hexagonal patterns.

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CP36

Nonlinear Dynamics of a Double Bilipid Membrane

The nonlinear dynamics of a double biological membrane that consists of two coupled lipid bilayers, typical of some intra-cellular organelles such as mitochondria, is studied. A phenomenological free-energy functional is formulated in which the curvatures of the two parts of the double membrane are coupled to the lipid densities. The derived nonlinear evolution equations for the double membrane dynamics are studied analytically and numerically. The linear stability analysis is performed and the domain of parameters is found in which the double membrane is stable. For the parameter values corresponding to an unstable membrane we perform weakly nonlinear analysis and numerical simulations that reveal various types of complex dynamics.

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CP37

Optimal Deployment of Carbon Capture and Storage Sites

A production-inventory optimal control framework is coupled with a network optimization model for the deployment of carbon capture and storage infrastructure. This engineered system couples industrial organization with geologic organization for the long-term storage of anthropogenic carbon dioxide. The model includes the relevant engineering, geophysical, thermodynamic, and economic parameters, and the dynamics (including deployment bifurcations and path dependencies) of how much carbon dioxide can be stored at what cost by what time are investigated.

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CP37

Shape Control of Particles

This paper demonstrates a technique for configuration control of N agents with collision avoidance. The control law for the individual agent consists of three parts corresponding to (a) attraction towards a target subset, (b) collision avoidance with other agents and (c) dissipation terms leading to two kinds of asymptotic behaviour. The controls are chosen such that the closed loop system is Hamiltonian and the corresponding Hamiltonian is used as a Lyapunov function for stability analysis.

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CP37

Coarsening Dynamics of Evolving Faceted Surfaces

When a large anisotropy of surface energy is added to standard models of surface evolution, faceting can result which, counterintuitively, allows the evolution to be reduced to a simple dynamical system. We examine this phenomenon for the problem of directional solidification of a dilute binary alloy, where evolution follows a simple geometric law associated with facet height. In the supercooled regime, this law leads to coarsening – the gradual increase in system lengthscales as small facets shrink and vanish. Simulations in one and two dimesions are performed using a novel computational geometry tool, which reveals a rich variety of topological events. Although observed behavior is complex, the surface quickly settles into a scale-invariant state, where statistical distributions of scaled geometric quantities exhibit constant shape even as lengthscales continuously increase. After showing some surface evolution movies and examples of scale-invariant data, we conclude with a brief mean-field theory which qualitatively describes the scaling state.

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CP38

The Effect of Discretisation on Cellular Buckling

The strut on a non-linear foundation is an example of a mechanical system that exhibits cellular buckling and is described by a fourth order Hamiltonian differential equation. This continuous mechanical system can be viewed as the continuum limit of a similar discrete mechanical system. I will talk about our use of numerical discretisation and continuation to understand the effect that this discreteness has on the original strut model.

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CP38

The Newton-Picard Method for Navier-Stokes Flows

We will describe two applications of numerical bifurcation analysis with the Newton-Picard method on Navier-Stokes flows using velocity and pressure variables. In this variable set, the Navier-Stokes equations are a differential-algebraic equation, so we needed to be careful when applying the Newton-Picard method, designed for large systems of ordinary differential equations. We considered 2D flow behind a cilinder and axisymmetric flow in a combustor and used existing simulation codes with minimal changes.

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CP38

Development of Variational Lie-Poisson Integrators

We introduce three categories of variational integrators for finite dimensional Lie-Poisson Hamiltonian systems. These integrators are different discrete versions of the Lie-Poisson variational principle [Cendra et al. 2003], or a modified Lie-Poisson variational principle given here. One category of the integrators is Lie-Poisson, and certain schemes of the other two categories are symplectic. Two applications, on free rigid body rotation and the dynamics of N point vortices on a sphere, are also discussed.

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CP39

Network Mechanisms of Contrast Adaptation in Visual Cortex

The response firing rate of visual cortical neurons is usually reduced after exposure to high-contrast stimuli. This "contrast adaption" has been attributed to adaptation in the thalamocortical input, to the intrinsic adaptation properties of visual cortical neurons, or to network mechanisms.

Here we show that many of the features of extant data can be explained by bifurcations in a large-scale network model.

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CP39

Isochronal Synchrony and Bidirectional Communication with Delay-Coupled Nonlinear Oscillators

We achieve isochronal synchrony between two mutually delay-coupled Ikeda ring oscillators (IROs) by injecting into each the signal from a third IRO. This isochronal synchrony, unstable for the two oscillators alone, now enables simultaneous, bidirectional communication of chaos-masked messages. We generalize our results to larger systems of coupled oscillators and for dynamically varied drive signals. Our Ikeda systems, models of fiber ring lasers, have potential extension to experimental realization of bidirectional communication with optical chaos.

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CP40

Chaotic Behavior for An Electrostatically Actuated Microelectromechanical Oscillator

A variety of microelectromechanical (MEM) oscillators are governed by a version of the Mathieu equation that harbors both linear and cubic nonlinear time varying stiffness terms, which typically arise from electrostatic or magnetic excitation. We predict that chaotic behavior will occur for such oscillators by using Melnikov's method. Numerical simulations and experimental results for an electrostatically actuated MEM oscillator verify that chaos occurs in certain regions of parameter space, which are consistent with our predictions.

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CP40

Quantifying the Dynamics of Tapping Mode Atomic Force Microscopy

The nonlinear dynamics of the oscillating cantilever used in tapping mode atomic force microscopy are studied using available lumped-mass models including adhesive, repulsive, and hysteretic capillary force interactions. Using numerical continuation techniques specialized for discontinuous systems and forward time simulations we calculate the bifurcation diagram and quantify the possible solutions. We focus on the role of capillary forces and seek solutions with minimal contact velocities to minimize tip-sample interactions.

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CP40

Complex Nonlinear Oscillations in Microelectromechanical Systems

We study nonlinear dynamic properties of an electrostatistically actuated micron scale beam under superharmonic excitations using numerical simulations. Application of a large dc bias signal can bring the beam to a nonlinear state. Once a steady nonlinear state is reached, application of an ac signal with specific frequency and amplitude around ac-symmetric breaking gives rise to rich dynamical behaviors of the beam including chaotic motion. We present several interesting beam dynamic phenomena and their possible applications.

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CP42

Counter-propagating Solitons in the Fermi-Pasta-Ulam Lattice

It is known that the completely integrable dispersive wave equation $u_t = u_{xxx} + 6uu_x$ (KdV) resolves arbitrary initial data into multi-soliton solutions plus linear radiative waves. It is widely conjectured that this behavior holds for many non-integrable dispersive wave equations as well. An important intermediate aim of this program is to understand the interaction between pairs of soliton solutions for particular non-integrable dispersive wave equations. Using recent work of Pego and Friesecke on the existence and stability of single solitary waves in the Fermi-Pasta-Ulam (FPU) lattice, we examine the interaction between counter-propagating pulses in the FPU model

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CP42

Persistence of Travelling Waves in Nonlinear Schrödinger Lattices

The existence of truly localised travelling solitary waves in generalised discrete nonlinear Schrödinger lattices is investigated. Persistence from a singular translationary invariant limit is investigated rigorously using a Melnikov-like method, as nonlinear terms are varied. The results show good agreement with numerical computation using pseudospectral methods that resolve the vanishing of the radiation tail carefully. The results are reinforced by computation of the Stokes constant in a singular limit.

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CP42

Non Local Effects for Trapping Dissipative Localized Structures

Optical parametric oscillators are sources aimed to produce coherent and frequency tunable light beam by nonlinear three-wave interaction in a crystal. We demonstrate that the combined effect of spatial inhomogeneties in the incident pump beam and convection (walk-off of the beams) leads to the formation of trapped localized structures. Analytical expressions of the trapping position and the characteristics of the localized structures are given. The predictions are in excellent agreement with numerical simulations.

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CP45

Mixing And Transport In The Kelvin-Stuart Cat Eyes Driven Flow

Transport rates for the Kelvin-Stuart Cat Eyes driven flow are calculated using the Topological Approximation Method (TAM) developed by Rom-Kedar. Transport rates per iteration, and cumulative transport per iteration, are calculated for 100 iterations for frequencies $\omega = 1.21971$ to $\omega = 3.27532$ and structure indices L = 2 to L = 10. The transport rates exhibit strong frequency dependence in the frequency range investigated, decreasing rapidly with increase in frequency.

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CP45

Topological Chaos and Fluid Mixing in Cavities and Channels

Moving three or more stirrers around in a 2D fluid domain can generate chaos that cannot be removed by continuously deforming the fluid while holding the boundaries fixed. The motions that generate this topological chaos are determined using the Thurston–Nielsen classification theorem. We explore the application of topological chaos to mixing in time-dependent 2D lid-driven cavity flow, and we examine how these results can be extended to steady 3D channel flow.

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CP45

Resonance Induced Mixing in Microdroplets

We consider microdroplets suspended at the free surface of a liquid substrate and mixed through chaotic advection induced by the thermocapillary effect. We illustrate that the mixing properties of the flow inside the droplet can vary dramatically as a function of the physical properties of the fluids and the imposed temperature profile. We show that to properly characterize the mixing requires the introduction of two different measures. The first measure determines the relative volumes of the domains of chaotic and regular streamlines. The second measure describes the time for homogenization inside the chaotic domain. Both measures are computed using pertubation theory in the limit of weak temperature dependence of the surface tension coefficient at the free surface of the substrate.

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CP46

Cell's Chaos-Like Dynamic System: The Dna-Rna-Protein Cycle and Its Uncertainty

Author is primary developer of the first useful and usable systems model for a cell's DNA-RNA-Protein Cycle plus its position in a very-preliminary systems model for Nature's

"Dance of Life", and he introduced uncertainty as a factor in cell behavior (The Scientist 19(12): 20-21). Democritus first said, Everything existing in the universe is the fruit of chance and necessity, and Leibniz prompted Bernoulli to discover the "Law of Large Numbers" by a silmilar quote. Far too much biology, chemistry and physics must all succeed for cell behavior to be determined. Uncertainty is due to cells nonlinear dynamic complexity with the changing initial conditions, and it interacts with its own complexity. Major cell variables are random, their equations are random, and probability and statistics are required to handle such randomness. Systems models, the inclusion of uncertainty in them, and serious collaboration across cultures are essential components of the bridge, which is now needed between cell biology's diametrical cultures of classical biology (that analyzes the parts of cell behavior) and systems biology (that synthesizes collections of cell behavior's parts).

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CP46

Development of a Time-Delay Model of Protein Translation Starting from First Principles

Incorporating time delays in reduced models of gene networks is often essential to capture the whole range of behavior. From a mechanistic model for protein translation in the form of a large system of ODE's, we systematically derive a reduced time-delay model by approximating the ODE system by a linear PDE with a nonlinear, integral boundary condition. We find quantitative agreement in protein synthesis rates between models. Applications to modeling synthetic gene networks are discussed.

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CP46

Oscillations in a Self-Regulated Gene Induced by Transcriptional Dynamics

When modeling genetic circuits, it is generally assumed that transcription rates adapt instantaneously to the concentration of regulatory proteins. However, recent experiments have shown the existence of transcriptional bursts on relatively slow time scales. Revisiting the dynamics of the gene repressed by its own protein, we find that when gene activity is a dynamical variable, oscillations may require degradation mechanisms much less nonlinear than is usually assumed.

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CP46

Modelling of mRNA Translocation in the Nucleus

We study a model for mRNA translocation in the nucleus from the site of synthesis to a nuclear pore where it is exported to the cytoplasm. The free diffusion model which has been the dominant hypothesis for quite some time is compared to one in which non-specific binding of RNA to the nuclear matrix is considered. The biological basis and implications of the second model are also discussed.

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CP47

Dielectro-Kinetic Concentration of Quantum Dots

We report experimental results on dielectrokinetic concentration of 10 nanometers particles performed in planar electrodes titanium based micro-device. With optimized signal, we show the concentration of nanometer particles onto the middle of the electrodes despite strong Brownian motion. The concentration process takes place in few hundreds of milliseconds. This experiment is the first step for control of nanometers particles. We discuss the advantage of nano-concentration, present quantitative results and explain the mechanism involved.

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CP47

Silnikov Chaos in the Semiconductor Laser Equations

The behavior of a free-running semiconductor laser is described by a system of two first-order ODEs, while a laser subject to injection is governed by three. The extra dimension accounts for the Silnikov chaos which arises as

the device is made to lase in a neighborhood of a Silnikov trajectory. I will present an analytical method for detecting the presence of these Silnikov homoclinic orbits. This is joint work with C. K. R. T. Jones.

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CP47

Statistics of Polarization-Induced Outages in Installed Optical Fiber Communication Systems

Recent measurements of installed fiber transmission links show that these systems often consist of stable long fiber sections joined by short sections, called hinges, subject to environmental conditions. The statistics of polarization-induced transmission penalties in such kinds of systems, however, differ from those of traditional models, and are not well-understood. Here we propose a hybrid analytical-computational model to overcome this difficulty and we use it in importance-sampled simulations to characterize the outage statistics of multi-channel systems.

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CP47

Rare Events in Dispersion-Managed Nonlinear Lightwave Systems

The dispersion-managed nonlinear Schrödinger equation (DMNLS) is an averaged version of NLS which models the dynamics of light in dispersion-managed communication systems and mode-locked lasers. In both systems performance demands require that errors be extremely rare events ($P(\text{error}) < 10^{-10}$). One can utilize the linear modes associated with DMNLS to guide importance-sampled Monte-Carlo simulations of rare events in DM lightwave systems, and generate pdfs accurate to very small probabilities.

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CP48

Topological Permutation Entropy and Applications

Order patterns, the patterns of relations of smaller or larger among consecutive orbit points, produce a symbolic description of a time-series or orbit which is different from conventional symbolic dynamics, which requires an externally specified partition. Similar to entropies of symbolic systems, permutation entropy quantifies the diversity of order patterns a system can generate. We discuss recent results of our investigation of topological aspects of permutations, such as topological permutation entropy and forbidden patterns. The orbits of one-dimensional deterministic maps have always forbidden patterns, i.e., order patterns that cannot occur, in contrast with random time series, in which any order pattern eventually appears with probability one. Interestingly enough, the existence of an anchor forbidden pattern of a given length triggers a cascading chain of ever longer forbidden patterns, the set of which grows superexponentially with the length. Consequently scaling laws of allowable order patterns is different between deterministic and noisy systems. Also, forbidden patterns are robust against noise, which makes possible to see them even with high levels of noise. We will address the possible application of order patterns to the discrimination of deterministic and random time series, as well as other more theoretical aspects.

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CP48

Online Parameter Identification in Odes and Pdes

Online parameter identification in time-dependent systems of differential equations plays a central role in adaptive control and means to identify model parameters at the same time as the data are collected. We present an online parameter identification method that works both for finite and infinite-dimensional dynamical systems, e.g., both for ODEs and PDEs. It allows for partial state observations and does neither require a linear parameterization of the underlying model nor data differentiation or filtering.

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CP48

A New Method for Rigorous Numerics of Topological Invariants of Dynamical Systems

We show how direct transporting of homology generators in rigorous numerics of dynamical systems may be used to substantially speed up the computation of topological invariants of Poincaré maps in dynamical systems such as the

Lefschetz number and the Conley index. This is in contrast to standard methods, wich require expensive enclosures of long trajectories. An example of an application to the existence of chaotic dynamics in a time periodic ODE will be presented.

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CP48

Application of Isomap in Dynamical Systems, Despite Non-Uniform Invariant Measure

When the attracting set is embedded in a lower dimensional manifold, we will show how ISOMAP [Tenenbaum] can be applied to reduce the dimensionality of useful models of the system. We will also show how experimental data can be handled to meet the major convergence theorem of ISOMAP. Our proofs will be for dynamical systems with hyperbolic invariant sets, which we believe give some insight into how the same methods can be applied more widely.

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CP49

Resynchronization Transients in Ensemble of Phase Oscillators

We study the transient dynamics between two ensembles of synchronized phase oscillators after phase reseting them in anti-phase. We study how this transient states depend on the natural frequencies of these oscillators and their coupling intensities. To understand the possible dynamical mechanisims for these different transients we propose a low dimensional reduction of the ensemble of oscillators to only a few oscillators. This reduction also suggest other possible dynamical phenomenon such as stochastic resonance in the original model.

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CP49

On Synchronization Via Dynamical Relaying

In a recent publication, Fisher et al. [Phys. Rev. Lett, vol. 97, 123902 (2006)] described a new phenomenon in which two distant lasers are able to synchronize with zero-lag if a third one is added between them as a relaying element. We have studied such a phenomenon in coupled limit cycle oscillators, that is the Kuramoto system, and in coupled chaotic Rossler oscillators. We have found that the phenomenon of synchronization via dynamical relaying can be explained by the fact that the addition of a third element increases the number of attractors in the system, making synchronization possible where it was not possible in a smaller system. We have found the same phenomenon in other types of coupling and verified that the Liapunov exponents determine the boundary where synchronzation is possible.

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CP49

Optimal Synchronization in Complex Clustered Networks

Recent research has revealed that complex networks with smaller average distance and more homogeneous degree distribution are more synchronizable. However, a complex clustered networks is most synchronizable when the number of inter-cluster and intra-cluster links match each other approximately. Mismatch, for instance caused by an increase in the number of intra-cluster links, can suppress or even destroy synchronization. We provide numerical evidence and an analytic theory to establish the generality of this phenomenon.

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CP49

Producing Robust Synchronization by Reducing Symmetry

It is well established that synchronous behavior in a dynamical system is related to its underlying symmetries. But can symmetry considerations tell us anything about stability or perhaps even robustness of a synchronous solution? Recent studies of fiber laser arrays and vibrations in jet engines suggest that significant progress can be made in this direction. We investigate these problems further and propose a more systematic approach to produce robust output by changing system's symmetry.

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CP50
The Dynamics and Control of Internet Attacks

The internet's design did not anticipate malicious behavior; as a result, it is vulnerable to the effects of "malware" like viruses. Viewing the internet as a complex, distributed, nonlinear adaptive system is an effective way to understand the dynamics of these kinds of attacks and develop viable defenses against them. Our strategy uses a nonlinear adaptive model-reference controller to help a resource survive attacks gracefully, and with mathematically guaranteed performance. It is currently deployed in commercial webserver hardware.

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CP50
Feedback Control of Pattern Formation

A global feedback control of pattern formation in a wide class of systems described by the Swift-Hohenberg (SH) equation is investigated theoretically, by means of stability analysis and numerical simulations. Two cases are considered: (i) feedback control of the competition between hexagon and roll patterns described by a supercritical SH equation, and (ii) the use of feedback control to suppress the blow-up in a system described by a subcritical SH equation. In case (i), it is shown that feedback control can change the hexagon and roll stability regions in the parameter space as well as cause a transition from up- to down-hexagons and stabilize a skewed (mixed mode) hexagonal pattern. In case (ii), it is demonstrated that feedback control can suppress blow-up and lead to the formation of spatially-localized patterns in the weakly nonlinear regime. The effects of a delayed feedback are also investigated for both cases, and it is shown that delay can induce temporal oscillations as well as blow-up.

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CP50
Using Safe Sets to Control Transient Chaos

We propose a method to keep the trajectories of a system with a chaotic saddle close to this set and far from the attractor. The method is based on the stabilization of the trajectories on a particular set of points, the *safe set*. The main advantage of this method is that trajectories remain close to the chaotic saddle even if the control applied is *smaller* than noise intensity. We show that this technique can be applied in a variety of situations.

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CP51
Inductive Games As Influenza Models

We propose an inductive reasoning game of voluntary yearly vaccination to establish whether or not a population of selfish individuals could prevent influenza epidemics. We find that epidemics are rarely prevented and discuss market incentives that may ameliorate epidemics. Vaccinating families increases the frequency of severe epidemics. However, a public health program requesting prepayment of vaccinations may ameliorate influenza epidemics by changing the epidemiological dynamics through border-collision bifurcations.

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CP51
Stability Regions of Delay Systems Modeling Immune Dynamics in Leukemia

We developed a model for the dynamics of T cells and leukemia cells in patients undergoing bone marrow transplant. Delay differential equations are used to account for the delays associated with cell interactions. We examined the initial conditions leading to cures. With a simplified version of the model, we analyzed the dependence of asymptotic stability on the delays and characterized the regions in delay-space that correspond to stable and unstable solutions of the linearized system.

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CP51

Improving Outbreak Predictability Of Multistrain Diseases using Dimension Reduction

Multistrain diseases have multiple distinct coexisting serotypes. Serotypes may interact by antibody-dependent enhancement (ADE), in which infection with a single serotype is asymptomatic, but contact with a second serotype leads to greater infectivity. Using a nonlinear model for multiple serotypes exhibiting ADE, we show the dynamics collapses to a lower dimensional system. We explain previously observed synchrony between certain primary and secondary infectives. Deterministic and stochastic versions of the analysis enable prediction of asymptomatic individuals.

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CP51

Modeling the Granuloma Formation As An Immune Response to M. Tuberculosis

Tuberculosis is a disease that is caused by the Mycobacterium tuberculosis (Mtb), an aerobic bacterium that infects mainly alveolar macrophages. The specific immune response to the Mtb results in the granuloma formation, a structure built by immune cells at the site of infection. The granuloma inhibits the spread of the bacteria in the lungs by controlling its replication. Despite all the efforts made up to now to understand the dynamics of the granuloma formation, the mechanisms underlying its growth and maintenance are still unknown. Here we introduce a discrete mathematical model to describe the granuloma formation in mice taking into account the main cells (macrophages and T cells) involved in the immune response to the Mtb [1], as well as the influence of the chemokines and cytokines on the process. This model is able to reproduce the three distinct dynamics observed in nature: elimination, containment and dissemination of the bacteria. It is also able to reproduce qualitative and quantitative experimental results, concerning the growth of bacteria[2] and the increase of the number of immune cells during the process[3], obtained from experiments with mice.

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CP52

Coupling and Noise Induced Patterns in O(2) Symmetric Domains

The Kuramoto-Sivashinsky equation is an example of a pattern-forming dynamical system with O(2) symmetric domain. Integration of the pure KS equation leads to predominantly static cellular patterns. The introduction of noise greatly increases the propensity of dynamic states, which partially explains the generic behavior observed in laboratory experiments. Coupling to the heat equation induces additional dynamics. We report on simulations and analysis of recently found dynamic patterns, including modulated rotations, hopping, and homoclinic intermittent states.

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CP52

Superlattice Patterns in Oscillatory Systems with Resonant Three-Frequency Forcing

Superlattice patterns, while well-studied in Faraday waves in viscous fluids, have found little attention in forced oscillatory systems. We find stable subharmonic supersquares in the near-resonantly forced complex Ginzburg-Landau equation. Using Floquet theory and weakly nonlinear analysis we obtain the amplitude equations for patterns comprised of 2, 3, or 4 modes of different orientation. Employing three forcing frequencies, we stabilize superlattices via spatiotemporal resonances. Numerical simulations in small and large systems confirm our analysis.

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CP52

Late Stage Dynamics of Unstable Thin Films

Liquid films may be destabilized by either van der Waals or gravitational forces. The late stage of the instability is characterized by a complex interaction of droplets. Asymptotic and variational arguments lead to a reduced dynamical system, which can exhibit behaviors ranging from coarsening to pattern formation. Connections to experiments and Ostwald ripening in solids will be drawn.

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CP52

Modeling of Spatio-Temporally Driven Patterns on Surfaces of Growing Solid Films

Spatial organization of structures takes place on growing surfaces of thin solid films irradiated by weak, pulsed laser beams that are made to interfere on a substrate. The proposed model for morphology evolution in the presence of weak spatio-temporal nonuniformity of the surface heating is formulated in terms of regularized, unstable evolutionary PDE. The interference heating is factored in through established dependences of the adatom diffusivity and the surface energy anisotropy on temperature, and manifests in space-dependent coefficients. The evolutionary PDE can be reduced to high-order, convective Cahn-Hilliard equation in the special case of constant temperature and after long wave length approximation and, subsequently, to the Mullins surface diffusion equation (when growth is absent). The proposed model allows morphological evolution studies of faceting of two- and three-dimensional, thermodynamically unstable surfaces as a function of external parameters, such as the separation distance of interference fringes, strength of interference, power intensity of radiation and absorptivity of the surface. The model is aimed to help understanding of the fundamental crystal growth mechanisms and kinetics in the presence of spatio-temporal external "forcing" and of the conditions impeding reproducible growth of high quality lattices of nanostructures.

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CP53

Boundary Layer Dynamics: Low-Dimensional Description of Klebanoff Modes

The spanwise evolution of a generic Klebanoff mode in a three-dimensional boundary layer attached to a flat plate is examined. These modes are known to be induced by free stream turbulence and correspond to three-dimensional perturbations of the (two-dimesional) steady Blasius solution, and exhibit low-frequency and long-wavelength perturbations in the streamwise direction, but oscillate rapidly in the spanwise direction. We present a low-dimensional Galerkin description of the Klebanoff modes. The comparison with results obtained through an optimization procedure applied to the adjoint problem (Luchini, JFM 2000), seems to indicate that the development of the instability may be understood on the basis of amplitude equations associated with the relevant Galerkin modes.

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CP53

Effective Ode Zones in a Multi-Agent System

Simulations which contain a large number of agents with rules for agent-agent interactions may grow to a level of complexity where it is cumbersome to extract useful information, difficult to split or agregate parts, and taxing on computational resources. We present here an example where a coarse graining of the system, and replacement of individual interactions with ODEs describing dynamical processes between effective zones, leads to a fast and useful alternate model of the original complex system.

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CP53

Analysis of Bifurcation and Stability of Equlibria in Energy Conserving Low-Order Models: Volterra Gyrostat

Starting with the pioneering work of Lorenz in 1963 great strides have been made in the analysis of complex fluid dynamical system. The basic idea behind this approach is to apply Galerkin-type projection technique to a system of partial differential equations to obtain a system of ordinary differential equations (ODE) describing the time evolution of a set of n Fourier amplitudes. The resulting class of ODE has come to be known as the low-order models, LOM(n). Despite the wide spread popularity of this approach, apparently there is no guide lines for the choice of the order n in LOM(n) that would guarantee conservation of energy in the system. It has been observed that lack conservation often leads to non-physical solution for LOM(n). Gluhovsky et. al. have also shown through several examples that energy conserving LOM(n) arising in convection can be rewritten as a system of coupled gyrostats. Following this lead the present authors have derived a set of sufficient conditions of LOM(n) to conserve energy and have derived a simple algorithm to show that every LOM satisfying these conditions can be rewritten as a system of coupled gyrostats. Motivated by the importance and the central role played by the Volterra gyrostat, in this paper we provided a complete picture of the stability of equilibria of the energy conserving Volterra gyrostats and nine of its special cases.

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CP53

Equation-Free Calculation of a Phase Diagram

In this presentation we propose an equation-free method for reproducing the phase diagram for the adsorption of helium on graphite. We perform a dimension reduction through our choice of a coarse variable (an order parameter), which is then used to map the the effective free-energy landscape for the solid/gaseous transition via a coarse molecular dynamics approach. We then sketch how dynamical systems techniques can be used to compute branches of the phase diagram.

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CP54

Generalized Quasi-Geostrophy for Spatially Anisotropic Rotationally Constrained Flows: Non-Hydrostatic Flows

Large-scale geophysical flows often exhibit balanced motions that reflect an underlying reduced dynamic contained within the primitive equations. The identification of reduced equations that accurately capture these balanced motions can offer dramatic theoretical and computational advantages over the primitive equations and a greater understanding in probing large-scale flows. A classic example is provided by the quasigeostrophic equations for rotationally constrained flows where high-frequency, spatio-temporal, inertial-gravity waves are filtered. In this talk closed reduced equations analogous to the QGE are derived in the extratropics for small Rossby numbers and vertical scales comparable to or much larger than horizontal scales. On these scales significant vertical motions are permitted an found to couple to balanced geostrophic dynamics. These equations are located by a systematic exploration of different aspect ratio, Froude numbers and bouyancy numbers. Results from numerical simulations will also be presented.

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CP54

Bifurcations in An Air-Filled Differentially Heated Rotating Annulus

We discuss the bifurcations from axisymmetric to wave solutions in a mathematical model of an air-filled differentially heated rotating annulus. In particular, normal form coefficients for Double Hopf and generalized Hopf (Bautin) bifurcations are computed. We use the Navier-Stokes equations in the Boussinesq approximation to model the flow of the air. The axisymmetric solutions and the corresponding eigenvalues and eigenvectors are approximated numerically from the large sparse systems that result from the discretization of the partial differential model equations. These results, obtained using this O(1) Prandtl number fluid, are compared to previous studies which used fluids with large Prandtl number.

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CP54

Traveling Waves in Modulated Rotating Convection

Recent experiments in rotating convection have shown that the spatio-temporal bulk convective state with Küppers-Lortz dynamics can be suppressed by small amplitude modulations of the rotation rate. The resultant axisymmetric target patterns develop into axisymmetric traveling wave states as the modulation amplitude and Rayleigh number are increased. Using fully 3D time-dependent Navier-Stokes Boussinesq equations with physical boundary conditions, we are able to numerically reproduce the experimental results and gain physical insight into the responsible mechanism, and relate the traveling wave state to a saddle-node-on-an-invariant-circle bifurcation.

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CP54

Motion of the N-Vortex Points in Ring Formation on a Rotating Sphere

We study numerically the evolution of ring configuration of the N-point vortices when it is embedded in a background flow field that initially corresponds to solid-body rotation on a sphere. We describe how the coupling creates a mechanism by which energy is exchanged between the ring and the background. The evolution of the ring strongly depends on whether it rotates the same direction or the opposite direction to that of the background solid body rotation.

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MS1

Multicould Models for Tropical Convections and Convectively Coupled Waves

Organized cloud systems in the tropics are believed to effect many tropical and extratropical weather and climate patterns. Despite today's super-computers, the numerical models (GCMs) used for long term weather and climate predictions poorly represent these important tropical waves. The interactions across scales between convection and large scale circulation are sub-grid effects unresolved on the GCM grid box, whose typical size is 100-200 km, which are poorly understood. Idealized models with a crude vertical resolution are commonly used for both theoretical and numerical studies. In this talk, we present a new generation of simplified convective parametrizations using all the three cloud-types observed to play an important role in tropical convection: deep convective, stratiform, and congestus clouds.

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MS1

Spectra of Passive and Reactive Tracers in Ocean Turbulent Flows

Zooplankton concentration at the ocean surface shows more patchiness than phytoplankton concentration. This difference is traditionally explained in terms of a longer reaction time scale for zooplankton, that allows for a cascade of power to very small spatial scales. Following this reasoning, temperature field, which varies on even longer time scales, would be expected to have a relatively flat spectrum, contrary to what it is observed. The incongruence is explained, discussing the role of diffusion.

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MS1

The Multicloud Parameterization in a Next Generation GCM

We report early results concerning the multicloud parameterization scheme of Khouider-Majda and its coupling to a next generation atmospheric GCM based on the spectral element method (HOMME: High-Order Method Modeling Environment). The latter is ran in aquaplanet mode to examine the organization of coherent convection in the simplest possible setting. Hopefully, this will help understand the role of bimodal heating in the upscale organization of equatorial wave modes and the Madden Julian Oscillation (MJO).

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MS1

An MJO Analog and Intraseasonal Variability in a Multi-cloud Model above the Equator

In the Tropics, changes in clouds and rain on intraseasonal timescales are dominated by the Madden-Julian Oscillation (MJO). However, despite its extreme importance, successful numerical simulation of the MJO and a theory explaining its structure are still major challenges. Here, using the recent multi-cloud model of Khouider and Majda, an MJO analog is shown that agrees with the observational record, captures multiscale features of the MJO, and should be useful for predictability studies.

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MS2

Structural Inference and Hierarchical Clustering in Complex Networks

One property of networks that has received comparatively little attention is hierarchy, i.e., the property of having vertices that cluster together into groups, which then join to form groups of groups, and so forth, up through all levels of organization in the network. Here, we give a precise definition of hierarchical structure, give a generic model for generating arbitrary hierarchical structure in a random graph, and describe a statistically principled way to learn the set of hierarchical features that most plausibly explain a particular real-world network. By applying this approach to two example networks, we demonstrate its advantages for the interpretation of network data, the annotation of graphs with edge, vertex and community properties, and

the generation of generic null models for further hypothesis testing. This is joint work with Cristopher Moore and Mark Newman.

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MS2

Community Structure in Social Networks

Important questions about communities and groupings in networks have led to a number of competing techniques for identifying communities, structures and hierarchies. We present here community detection results for a number of social networks of political and economic interest, including (time permitting) Facebook, NCAA Division I-A college football matchups, connections in the NBA, and Supreme Court citations. We also identify the importance of such structures: for instance the underlying structure of the college football network strongly influences the computer rankings that contribute to the Bowl Championship Series standings. While many structural elements in each case are seemingly robust, we include attention to variations across identification algorithms as we investigate the roles of such structures.

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MS2

Community Structure in the United States House of Representatives

Network theory provides a powerful tool for the representation and analysis of complex systems of interacting agents. In this talk, we discuss the community structure in the United States Congress using both committee assignments and legislation cosponsorship. We focus on committee assignment networks in the House of Representatives (covering the years 1989–2004), in which a Representative is linked to the committees and subcommittees on which he/she sits. Using several community-detection algorithms, we reveal strong links between different committees as well as the intrinsic hierarchical structure within the House as a whole. We show that structural changes, including a tighter community structure, resulted from the 1994 elections, in which the Republican party earned majority status in the House for the first time in more than forty years. We confirm these findings using networks in the House and Senate defined according to legislation cosponsorship, indicating also that the increased polarization in Congress arose gradually rather than abruptly.

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MS2

Modularity: An Information-theoretic Approach

By representing a graph in terms of modules, we seek a simplified description which preserves information about the overall topology of the graph. This balance between simplicity and fidelity can be formalized in the language of coding theory, in which the task of revealing modules is re-expressed as minimizing an information-theoretic functional over all possible assignments of nodes into modules. A benefit of this approach is that it allows us define an order parameter — a dimensionless number between 0 and 1 — which quantifies a graph's modularity over all scales and over all possible numbers of modules. We apply this to quantify the modularity of a number of social, technological, and biological origin to quantify graph modularity without reference to a particular chosen partitioning or scale.

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MS3

Stochasticity-induced Switching Between Collective Motion States

We study a model of self-organizing group formation which exhibits noise induced transitions between two collective states. This demonstrates that changes to behavioral rules are not necessary for groups to transition between different collective states. We characterize the transitions with an effective potential which is a function of a single coarse observable. Short bursts of appropriately initialized simulations are used to efficiently estimate the necessary population-level quantities for this characterization.

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MS3

Eukaryotic Chemotaxis: How Cells Use Nonlinear PDEs to Decide Where to Go

Eukaryotic cells are often able to detect chemical gradients and move accordingly. Unlike the case for bacteria, these cells are large enough for the gradient detection to rely on differential receptor binding probabilities on the cell membrane. It is not yet understood how this input data is processed by the cell to make the motion decision; thus we cannot a priori predict the detection threshold, the response kinetics and the plasticity to changing stimuli. This talk will focus on some recent nonlinear models of this cellular information processing system and on experiments in progress on Dictyostelium to test some of the resulting expectations..

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MS3

Equilibrium Configurations for a Territorial Model

We show that distinct stable equilibrium configurations coexist for a territorial model based on Voronoi tessellations in a square domain, including equilibria not related by symmetry. The configuration that the population settles to, the cell in which each individual ends up, and the area that each individual controls is determined entirely by initial conditions. This suggests that an individual can obtain a competitive advantage or disadvantage despite having identical characteristics to other individuals.

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MS3

Optimal Foraging by the Zooplankton Daphnia and Natural Stochastic Resonance

Experiments with several species of Daphnia foraging for food are described. They move in repeated hop-pause-turn-hop sequences. With the experiment we observe exponential distributions of turning angles with a narrow range of noise widths across species including adults and juveniles. A stochastic theory and two simulations indicate that optimal noise widths maximize food gathering, a process called natural stochastic resonance. We hypothesize that the exponential distributions were selected for survival over evolutionary time scales.

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MS4

Inducing Chaos by Resonant Perturbations: Theory and Experiment

We propose a scheme to induce chaos in nonlinear oscillators that either are by themselves incapable of exhibiting chaos, or are far away from parameter regions of chaotic behaviors. Our idea is to make use of small, judiciously chosen perturbations in the form of weak periodic signals with time-varying frequency and phase, to drive the system into a hierarchy of nonlinear resonant states and eventually into chaos. We demonstrate this method by using numerical examples and laboratory experiment with a Duffing-type of electronic circuit driven by a phase-locked loop. The phase-locked loop can track the natural frequency of the Duffing circuit and deliver resonant perturbations to generate robust chaos. This is joint work with A. Kandangath, S. Krishnamoorthy, J. A. Gaudet, and A. P. S. de Moura.

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MS4

Efficient Chaotic Based Satellite Power Supply Subsystem

We investigate the use of the nonlinear dynamics theory to increase the efficiency of the power supply subsystems. The core of a satellite power subsystem relies on its DC/DC converter. This is a very nonlinear system that presents a multitude of phenomena ranging from bifurcations, quasi-periodicity, chaos, coexistence of attractors, among others. The traditional power subsystem design techniques try to avoid these nonlinear phenomena so that it is possible to use linear system theory in small regions about the equilibrium points. Here, we show that more efficiency can be drawn from a power supply subsystem if the DC/DC converter operates in regions of high nonlinearity. In special, if it operates in a chaotic regime, we have an intrinsic sensitivity that can be exploited to efficiently drive the power subsystem over high ranges of power requests by using control of chaos techniques.

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MS4

Fully Connected DPLL Networks: Modeling, Simulation and Optimization

Clock-distribution is an essential feature in many engineering applications as, for example, telecommunications networks and digital integrated circuits. In the last few decades this problem was predominantly addressed using master-slave strategies. In this type of strategy there are precise reference oscillators in the network called masters and their signals are distributed in the network, other oscillators called slaves (PLLs) extract the time basis from the line signals. Recently the development of wireless communication networks and the increasing size of digital integrated circuits and their rising operation frequencies indicate the need for the use of mutually-connected networks for the issue of clock-distribution. In this work mutually-connected networks of PLLs are studied in order to obtain conditions for the acquisition of a synchronous state for the network concerning the node parameters and the connection pattern of the network. Furthermore, numerical experiments were conducted to validate analytic results. Finally, a method is proposed, based on evolutionary algorithms, for the optimization of the network parameters considering the robustness and the ability to reject noise in the network as objectives.

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MS4

Recurrences to Characterise the Dynamics of Mechanical Systems from Short Time Series

Recurrences can be an efficient tool to characterise the dynamics of mechanical systems from short time series. Small changes can be detected and taken into consideration for the control of the dynamics. We will show how quantifications of a simple visual representation of recurrences in phase space give highly sentitive measures and can be very convenient for the analysis and construction of mechanical devices.

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MS5

Breakup of Non-symmetric Shearless Circles

We will describe the breakup of shearless circles of nontwist maps without symmetry. We will present the application of the renormalization group framework to this breakup scenario and discuss the differences and similarities between the breakup of symmetric and non-symmetric circles.

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MS5

Transport in Tokamaks with Reversed Magnetic Shear

The magnetic field line configuration in tokamaks with reversed magnetic shear is described by a nontwist map.The resonant perturbations are created by a chaotic magnetic limiter. The field line transport is much affected by the creation of invariant surfaces. Very strong perturbations are required to destroy these barriers, and even after breaking the transport turns out to be diffusive.

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MS5

Bifurcations and Twist in Volume-Preserving Mappings

Volume-preserving mappings are appropriate models for the study of mixing in incompressible fluids as well as the configurations of magnetic field lines. We study the normal forms for such maps near their codimension-one and -two bifurcations. The normal form near the triple-one multiplier is shown to be the quadratic diffeomorphism previously introduced by Lomelí and myself. The saddle-node-center bifurcation gives rise to families of invariant tori that undergo subsequent bifurcations at resonances. The frequency map of a one-action, volume-preserving map defines a curve $\Omega(J)$ in the two-dimensional frequency space. A version of KAM theory can be applied to this system providing the curvature of Ω is nonzero. Thus one analogue of twist in these systems in this curvature. We investigate the dynamical consequences of vanishing curvature, and explore the genericity of this phenomena in resonant bifurcations.

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MS5

Renormalization and Breakup of Shearless Invariant Tori - Recent Results

Area-preserving nontwist maps have been used as models for many physical systems. Of particular interest in these maps are the so-called shearless invariant tori. At the breakup point, shearless tori exhibit nontrivial scale invariance, which has led to the development of a renormalization group picture for nontwist maps. I will discuss recent results of breakup studies that investigate how the choice of winding number changes the details of the breakup.

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MS6

Transitions Between Irregular and Rhythmic Firing Patterns in a Model

Numerous experiments demonstrate increased correlations in activity within the subthalamic nucleus and globus pallidus in Parkinson's disease. We apply dynamical systems methods to understand transitions between irregular and rhythmic, correlated firing in a model for the subthalamopallidal network of the basal ganglia. Geometric singular perturbation theory and one-dimensional maps are used to understand how an excitatory-inhibitory network with fixed architecture can generate both activity patterns for possibly different values of the intrinsic and synaptic parameters.

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MS6

Phase Reduction Methods and Application to Feedback-controlled Deep Brain Stimulation

We present an overview of phase reduction methods as applied to populations of neurons modeled using the typical conductance-based formalism. We show, by numerical simulation, that the phase-reduced models compare well with the full-dimensional models at the population level for several types of stimulus. We also illustrate how the phase response curve can be used to design a feedback-based desynchronizing control system, a potential improvement over current open-loop EDBS technology.

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MS6

Breaking the Synchrony in an Ensemble of Bursting Neurons by Multisite Stimulation

We study a network of neurons including the subthalamic nucleus (STN) and the external segment of the globus pallidus (GPe). Each STN neuron excites a subset of GPe and receives inhibition from different GPe neurons. The inhibition for each GPe is from two nearby cells or half of the ensemble. STN neurons form synchronized bursting clusters. We apply various type of multi-site stimulation to break the synchrony within a cluster.

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MS6

Novel Techniques for Therapeutic Deep Brain Stimulation: Modeling and Experimental Approaches

We study possible anti-kindling effects of the standard high-frequency deep brain stimulation (HFDBS) and of desynchronizing stimulation techniques like the multisite coordinated reset stimulation (MCRS) theoretically in a mathematical model of the subthalamic nucleus (STN). The latter is an effective target for deep brain stimulation (DBS) in patients suffering from Parkinsons disease (PD). Depending on the structures being activated, electrical pulses may have excitatory and/or inhibitory impact. According to our simulation results MCRS may achieve robust long-term anti-kindling (i.e. curative) effects, irrespectively of the ratio between excitatory and inhibitory impact. This means, that during MCRS the STN unlearns its pathologic synaptic connections and reestablishes a physiological level of connectivity. In contrast, HFDBS has anti-kindling effects only if its impact is predominantly excitatory. Our results are relevant for selecting appropriate locations for DBS electrodes. In fact, even with HFDBS we may expect anti-kindling effects, provided the target is properly chosen. Our theoretical results are discussed in the context to a recent case report on an unusual clinical benefit in a patient with strong postural tremor due to spinocerebellar ataxia type 2 (SCA2) (Freund, Barnikol, Nolte, Treuer, Auburger, Tass, Samii, Sturm (2006) Subthalamic-thalamic DBS in a case with spinocerebellar ataxia type 2 (SCA2) and severe tremor - unusual clinical benefit, Movement Disorders, in press). Freund and coworkers were targeting on the excitatory cerebello-thalamic projection near the cerebellar peduncles. Their choice of the target made it possible that HFDBS activated an excitatory projection to the affected target area. This stimulation resulted in an unusual clinical benefit in terms of a pronounced restitution of function. According to our theoretical results, this unusual clinical benefit might be caused by an anti-kindling achieved by excitatory HFDBS Furthermore, we show that robust long-term changes of synaptic connectivity can be achieved even by short-term weak desynchronizing stimuli. Intriguingly, even short-term, weak desynchronizing stimuli, i.e. desynchronizing stimuli which are not able to cause a desynchronization during stimulation, may induce a robust unlearning of the mean synaptic weight, a so-called anti-kindling. Therapeutically rewiring stimuli of that kind shift the population into the basin of attraction of the stable desychronized state. At stimulus offset, we observe a transient rebound of synchrony. Our results might contribute to a novel therapeutic stimulation strategy for the therapy of neurological and psychiatric diseases characterized by abnormal synchrony and are discussed in the context of recent experimental results obtained with our desynchronizing deep brain stimulation techniques.

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MS7

Bifurcation Phenomena in the Flow Through a Sudden Expansion in a Pipe

Flows through a pipe with a sudden expansion are of both fundamental and practical interest. At low Reynolds numbers the flows are axisymmetric, but at higher Reynolds numbers the axisymmetry can be broken giving rise to non-axisymmtric flows. The talk will report progress in understanding this phenomena using methods from numerical bifurcation theory combined with a posteriori error esti-

mation and adaptive meshing techniques.

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MS7

General-Purpose Algorithms for Large-Scale Time-Periodic Flow Problems

A general-purpose periodic orbit tracking capability is being developed in Sandia's Trilinos framework. We use finite difference discretizations of the time domain and use a Newton's method to solve the entire space-time problem. Parallelism over the space and time domains is implemented, and different preconditioning strategies are investigated. For 3D Navier-Stokes applications, this formulation is for a "steady" problem in four dimensions, so existing continuation and stability analysis capabilities can be used.

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MS7

Newton-Krylov Continuation of Periodic Orbits in Large-scale Dissipative Systems

We present numerical algorithms for the continuation of periodic orbits of high-dimensional dissipative dynamical systems, and for analyzing their stability. They are based on shooting, Newton-Krylov and Arnoldi methods. Two non-trivial fluid dynamics problems, which after discretization give rise to systems of dimension $O(10^4)$, have been used as tests. The efficiency of the algorithms, which allow the unfolding of complex bifurcation diagrams of periodic orbits, makes them suitable for large-scale nonlinear dissipative partial differential equations. (With Marta Net, Bosco Garca-Archilla, Carles Sim)

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MS7

Matrix-free Bifurcation Analysis of the Navier-Stokes Equations

The spatially discretized 3D Navier-Stokes equation can have millions of degrees of freedom. The stumbling block for bifurcation analysis is linear algebra: algorithms require inversion and/or diagonalization of the Jacobian. The implicit inversion of the diffusive operators already in time-stepping codes provides a powerful preconditioner for iterative matrix-free methods. Thus, time-stepping codes can be easily modifed to calculate steady states via Newton's method and leading eigenvalues via Arnoldi's method.

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MS8

Variational Assimilation of Lagrangian Data in Oceanography

Within the framework of the Global Ocean Data Assimilation Experiment, an increasing amount of data is available. A crucial issue for oceanographers is to exploit at best these observations, in order to improve models, climatology, forecasts, etc. A new type of data is now available: positions of floats drifting at depth in the ocean. Unlike other data, mainly Eulerian, these ones are Lagrangian. I will present methods and results about variational assimilation of Lagrangian data.

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MS8

Sampling the Posterior for Partially Observed Dynamics

We study data assimilation from the Bayesian statistical perspective. The posterior distribution for the state of the system contains all the information that can be extracted from a given realization of observations and the model dynamics. We discuss the structure of the posterior for an application in Lagrangian data assimilation, and compare the performance of various methods designed to sample from it. This is a joint work with Amit Apte and Chris Jones.

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MS8

Assessing Predictability of the Atmospheric Global Circulation

Unlike for a low-dimensional system, the initial conditions for an atmospheric model cannot be determined by direct measurements. Instead, the initial conditions are obtained through combining a short term forecast and the latest observations. Thus model dynamics is (1) partly responsible for the uncertainties in the initial conditions and (2) fully responsible for determining the later evolution of the initial uncertainties. We investigate this dual role of the model dynamics in atmospheric predictability.

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MS8

Hierarchical Physical/Statistical Models for Retrospective

The Bayesian paradigm has long been recognized as a coherent probabilistic approach for combining information, and thus is an appropriate framework for data assimilation. Relatively recent computational advancements in Bayesian statistics have led to increased use of hierarchical models for complicated problems. Such models are ideal for retrospective analysis where there is significant uncertainty in the data, process and parameters that control the model. We illustrate this approach on ecological data related to the spread of an invasive species.

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MS9

Propagation and Quenching in Porous Media Combustion

Gaseous detonation is a phenomenon with very complicated dynamics which has been studied extensively by physicists, mathematicians and engineers for many years. Despite many efforts the problem is far from complete resolution. Recently Sivshinsky and his collaborators proposed the theory of subsonic detonation that occurs in hydraulically resistant porous media. This theory provides a model which is realistic, rich and suitable for a mathematical study. In particular, the model is capable of describing the transition from a slowly propagating deflagration wave to the fast detonation wave. This phenomena is known as a deflagration to detonation transition and is one of the most challenging issues in combustion theory. I will present some recent mathematical results concerning traveling front solutions arising in the context of the model. In particular, it will be shown that under very general assumptions the model admits traveling wave solutions. Moreover, these solutions unique in a presence of small but finite thermal diffusivity. This result strongly suggests that transition from deflagration to detonation is unavoidable unless quenching occurs. Some results on quenching, propagation limits of the combustion fronts and initiation of detonation in porous media will also be discussed. In particular, it will be shown that initiation of detonation can be formulated as a blow up problem.

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MS9

Traveling Waves in Boussinesq Systems of Reactive Flow

We consider the Navier-Stokes-Boussinesq system for a reactive flow, in a slanted (that is, not aligned with gravity's direction) cylinder of any dimension. We study the existence of a non-planar traveling wave solution, propagating with constant speed and satisfyinh the Dirichlet boundary condition in the velocity and the Neumann condition in the temperature.

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MS9

Collision Dynamics in Heterogeneous Dissipative Media

Particle-like (spatially localized) dissipative patterns arise in many fields such as chemical reaction, gas-discharge system, liquid crystal, binary convection, and morphogenesis. We discuss about the dynamics of moving particles in heterogeneous media, especially for the three types of heterogeneities: jump, bump, and periodic media respectively. Model systems include the Gray-Soctt model and a three-component reaction diffusion system of one-activator-two-inhibitor type. We focus on the following issues:(a) heterogeneity-induced defect-structure created around the jump point, (b) collision dynamics between particles and defects, (c) unstable objects called scattors which sort out the destinations of orbits after collision. When traveling objects like pulses or spots encounter defects created by heterogeneities, a variety of outputs are produced such as annihilation, rebound, splitting, and relaxing to an ordered pattern. It turns out that there is a class of unstable patterns called scattors which play a role of separator whose unstable manifolds guide the orbits to their destinations.

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MS9

Boundary Layers and KPP Fronts in a Cellular Flow

The objective of this talk is to describe how fluid cellular flows with large intensity affect front propagation. We consider propagation of premixed flames with unit Lewis number in incompressible flows with asymptotically large intensity. The speed-up of flame-fronts and their structure will be determined.

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MS10

Nonsmooth Systems: Challenges and Unsolved Problems

This talk will summarise the results of a Workshop on Nonsmooth Complex Systems held at the Centre de Recerca Matematica, Barcelona, Spain from January to March 2007. The Workshop brought together the key active workers to focus on quite specific challenges in a series of linked themes that cover the field. The 5 thematic areas were Theoretical Analysis, Bifurcations, Numerical Analysis, Control and Applications to Biology and Electronics

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MS10

Local and Global Issues in Continuous Piecewise Linear Systems

The stability of semi-homogeneous systems (the simplest structure formed by matching continuously two linear systems through a hyperplane containing the origin) is completely solved only for the planar case. Also, the problem of unfolding degeneracies is still a challenge for the analogue to the Bogdanov-Takens bifurcation: similar bi-parametric bifurcation sets are predicted but no explicit local information about the non-trivial emanating curves has been obtained yet.

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MS10

Co-dimension 2 and 3 Discontinuity Induced Bifurcations Revisited

We investigate scalar piecewise-linear maps with a discontinuous system function, originating from the field of power electronics. The parameter space of these systems is organized by a few discontinuity induced bifurcations of codimension two and three, where an infinite number of different periodic dynamics emerge (big bang bifurcations). Depending on the stability of these periodic orbits the big bang bifurcations generate different bifurcation structures in the areas of periodic and chaotic dynamics. Unfolding these bifurcations, several one- and two- parametric bifurcation phenomena, observed in experiments and simulations are explained.

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MS10

Structural Stability of Piecewise Smooth Systems

Filippov has developed a theory of dynamical systems that are governed by piecewise smooth vector fields. In this talk, I focus on some of its global and generic aspects. I will discuss a generic structural stability theorem for Filippov systems on surfaces, which is a natural generalization of the classical result of Peixoto. I will show that the generic Filippov system can be obtained from a smooth system by a process called pinching.

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MS11

Discovering Dominant Dynamical Structures in Hyperbolic Systems and Ocean Circulation

Eigenfunctions of the Perron-Frobenius operator corresponding to large subunit eigenvalues have been shown to describe “almost-invariant” dynamics for expanding maps. We extend these ideas to *hyperbolic* maps: a new procedure called “unwrapping” clearly reveals the geometric structures associated with almost-invariant and almost-periodic dynamics. We also describe recent work (with Kathrin Padberg) to locate coherent structures in the Southern Ocean via transfer operator methods. Experiments on state-of-the-art ocean model output demonstrate a significant improvement over existing methods.

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MS11

Meshfree Numerics for Transfer Operators

We propose a new approach to the discretization of transfer operators. In contrast to classical methods which are based on choosing a fixed finite dimensional subspace of the underlying function space, this approach uses ideas from meshfree methods for partial differential equations in order to approximate the action of the operator. We show how to compute eigenvalues and eigenfunctions of interest and compare our approach to the classical ”method of Ulam” on the basis of several numerical examples.

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MS11

Transfer Operator Methods in Control of Communication Networks

This talk is concerned with transfer operator based methods for analysis and control of non-equilibirum dynamics in communication networks such as Internet. Using finite-dimensional representation of transfer operators, we discuss identification, bifurcation analysis, optimal control synthesis and its implementation in a realistic network simulator environment ns2. The results provide first such theoretical justification for certain control algorithms used in communication networks. The network simulations exhibit satisfactory performance under controlled but persistently non-equilibrium and chaotic behavior.

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MS11

Approximation of Coherent Structures with Applications in Nonautonomous Dynamical Systems

Understanding transport processes plays an important role in the analysis of dynamical models of natural phenomena. We will introduce a transfer operator approach for the approximation of coherent structures in nonautonomous dynamical systems and illustrate our techniques by several relevant applications; in particular, we analyse transport in the Southern Ocean. In addition we compare our approach to other concepts such as finite-time Lyapunov exponents. This is joint work with Gary Froyland.

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MS12

Finite Time Characteristics of Organized Structures in Wall-bounded Turbulence: Robust Stability and Control

An overview of the ongoing work in our group to understand, predict and feedback control of wall-bounded turbulent flows will be presented. It will be shown that flow stability is more of a question of robust stability than that of nominal stability. A framework of robust flow stability theory will be formulated with a particular focus on time-varying disturbances and transient flow behavior. This new theory provides systematic answers to the ubiquity of organized structures in transition to turbulence, among others. Numerical computations done on Couette flow using spectral methods and global optical DPIV measurements in boundary layer transition will be presented. Illustrative examples, involving chaotic attractors and solitons, of active control of complex flows will be presented.

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MS12

Locating Periodic and Relative Periodic Orbits in High Dimensional Flows

In this talk I will present a comparative study of various methods for locating periodic and relative periodic orbits in high-dimensional systems representing discretised PDE's.

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MS12

An Experimental Study of the Dynamical Organization of Turbulence in Pipe Flow

We here present results of an experimental investigation into the role of travelling wave transients in turbulent pipe flow. Turbulent flows in the range of 2000¡Re¡4500 are investigated and different criteria are employed to identify travelling wave transients. We investigate azimuthal symmetries as well as axial periodicty and the dynamics of low speed streaks. Furhermore we provide evidence that turbulence has a finite lifetime and that the dynamics evolve around a chaotic saddle in phase space.

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MS12

Approach by Unstable Periodic Orbits to the Problem of Turbulence

In this talk, recently found unstable time-periodic solutions to the incompressible Navier-Stokes equation are reviewed to discuss their relevance to near-wall turbulence and isotropic turbulence. Spatio-temporal structures of the periodic solutions in plane Couette and high-symmetric flow are investigated to characterize the dynamics of coherent structures observed in the regeneration process of buffer-layer turbulence and in the energy cascade.

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MS12

Laminar, Turbulent and Coherent Flows

Almost everyone knows that fluid flows come in two kinds: laminar and turbulent. Turbulence is typically viewed as a disordered state of matter that requires a statistical description of the 'small scales' and their effect on the 'large scales'. But observations show that turbulent flows are full of multi-scale coherent structures. An effort to develop a mathematical theory of these structures in shear flows has led to the discovery of a multitude of exact coherent states – steady states, traveling waves, periodic and relative-periodic solutions of the Navier-Stokes equations– in addition to the laminar and turbulent states. All of these coherent states are three-dimensional and unstable. They come in pairs, upper and lower branches, through saddle-node bifurcations at relatively low Reynolds numbers. The upper branch states are directly connected with turbulent flows, indeed they appear to form the 'skeleton' of turbulent flows. The lower branch states are closer to the laminar flow but they never bifurcate from the laminar flow, not even at infinity. The lower branch states form the backbone of the phase space boundary between laminar and turbulent flows and are therefore directly connected with the question of transition to turbulence. The lower branch solutions have a relatively simple but non-trivial singular asymptotic structure and they may be ideal targets for the control of turbulence.

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MS13

Dynamics of Coupled Qualitatively Different Oscillators: Aging and Clustering

Any real coupled-oscillator system, whether organic or inorganic, cannot be free from deterioration due to various causes such as accidental events and aging, whereby some elements of the system should get inactivated to lose their self-oscillatory nature. Motivated by this, we discuss the effect of increasing the ratio of inactive elements for some mathematical models of coupled oscillators. This problem may be important, for example, in understanding the robustness of diverse rhythmic activities of biological systems.

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MS13

Sequential Desynchronization of Clusters in Neural Networks with Partial Post-Spike Response

The response of a biological neuron to incoming signals strongly depends on whether or not it has just emitted a spike. Here we propose an analytically tractable network model of coupled neurons with partial post-spike response, that bridges between total charge conservation and total charge loss considered in previous models. For convex rise functions we find a sequence of desynchronization transitions between sets of admissable cluster states that is controlled by the strength of the post-spike response.

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MS13
Chaos in Populations of Phase Oscillators

The dynamics of weakly interacting periodic self-sustained oscillators is successfully captured considering only the phases (and neglecting the amplitudes). The degrees of freedom associated to the phase coordinates may sustain (phase) chaos. In this contribution we study phase chaos in, both globally and locally coupled, phase oscillators. The disposition of the natural frequencies (say symmetry-related or random), determines the statistics of the Lyapunov exponents and the dissipation.

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MS13
An Exact Analysis of the Stability Properties of Pulse Coupled Oscillators

Stability of splay states is often analyzed through a mean field approach. We develop a method that allows analysing globally coupled rotators (including LIF neurons). The stability depends nontrivially on excitatory/inhibitory coupling properties. We also find that the thermodynamic and zero-pulsewith limits do not commute. This means that the ratio between pulsewidth and interspike interval is a crucial parameter. We can predict when and why the mean field approach fails.

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MS13
Self-organized Quasiperiodicity in Oscillator Ensembles with Global Nonlinear Coupling

We describe analytically and numerically a transition from fully synchronous periodic oscillations to partially synchronous quasiperiodic dynamics in ensembles of identical oscillators with all-to-all coupling that nonlinearly depends on generalized order parameters. We present a solvable model that predicts a regime where mean field does not entrain individual oscillators, but has a frequency incommensurate to theirs. The onset of quasiperiodicity arises in a self-organized manner and is illustrated with Landau-Stuart oscillators and a Josephson junctions.

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MS13
Synchronization Regimes in a Large-scale Model of Cortical Network

Genesis of oscillations and synchronization mechanisms leading to formation of complex patterns of spatio-temporal activity in cortical networks are studied using large scale network models implemented with map-based models of neurons. The network models consist of two layers of cells representing regular-spiking pyramidal neurons and fast spiking inhibitory interneurons. For different connectivity patterns among the neurons, we explore the behavior of the network as a function of synaptic coupling strength and intrinsic excitability.

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MS14
Inferring Effective Connectivity from Spiking Neurons Recorded from 512 Electrodes

The anatomy of the neocortex indicates that each pyramidal neuron makes and receives 1,000 to 10,000 synaptic connections. This suggests that information flows "democratically" in roughly equal proportions through each neuron. We use cortical slice cultures and a 512 electrode array to probe the effective connectivity of cortical networks. We show that information flow is distributed in a highly uneven manner, with some neurons acting as hubs, in contrast to the picture provided by anatomy.

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MS14
Cortical Dynamics in the Computation of Self-referenced Position in the Rat Vibrissa System

We recorded the spiking output of neurons in primary somatosensory cortex of rats as they performed an active touch task with their vibrissa. Our results demonstrate that spike rates are contingent on both vibrissa position and touch. These data reveal a cortical representation of object location in self-referenced coordinates. Mechanisms for this representation and the subsequent involvement of sensorimotor feedback will be discussed. Sponsored by HFSP, NINDS,& NSF/IGERT.

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MS14
Modulating Cortical Network Activity

Modulatory neurotransmitters activate second messenger signaling cascades which can operate on time scales orders of magnitude slower than traditional ionotropic neurostransmitters. Modulatory neurotransmitters may therefore play a role in allowing cortical neuronal ensembles to maintain patterns or transition between activity states. We show how we can combine network imaging with electrophysiology using the cortical brain slice preparation to probe how different neuromodulatory environments affect network and single cell behavior.

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MS14
Combining Stimulus and Spike-history Models to Estimate Neuronal Network Connectivity

We demonstrate that one can estimate the connectivity within neuronal networks using models that capture two classes of influences on a neuron's spiking probability: external stimuli and a neuron's own spiking history. By modeling one or both influences, one can detect the presence of causal connections among neurons by analyzing the spike time measurements of simultaneously recorded neurons. This analysis is designed specifically to control for effects from neurons that remain unmeasured (such as common input from unmeasured neurons). We contrast the advantages and limitations of both classes of models.

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MS14
Coding and Causality in Cortex

The locust olfactory cortex responds to different stimuli in different ways – namely, distinct odors generate reproducibly distinct activity profiles within the insect's olfactory bulb. I will present a new way to examine the coding properties of such a system. I will illustrate several features of this new method and their implications for synchrony, oscillation and ensemble coding.

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MS14
Low-dimensional Characterization of Neural Activity in Large Simulations

Obtaining dynamical information from simulations of thousands of coupled neurons is a challenging task. The huge amount of data generated by such simulations can easily overwhelm the investigator's ability to recognize consistent behavior in the network. In this talk, we present methods for the multivariate analysis of large simulated datasets that provide a low-dimensional characterization of network activity. We discuss results from the application of our methods to extract low-dimensional dynamics of orientation tuning in a large network model of mammalian visual cortex.

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MS15
Identifying a Transmitter by its Output

In many military applications, it is necessary to uniquely identify the origin of a signal (such as a radar signal) based only on the characteristics of the signal. Traditionally, linear signal analysis methods have been used. Considering the power amplifier in the radar transmitter as a driven nonlinear system, I am able to apply concepts from nonlinear dynamics to identify the transmitter. This emitter identification may be expanded to other types of signals, such as communications signals.

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MS15
Conventional and Unconventional Uses of Chaotic Signals in Radar and Sonar

The use of chaotic signals in radar and active as direct replacements for conventional types will be examined using standard models. Target, medium and hardware behaviour all play a part. Next the scope for performance improvement using the properties of non-linear dynamical systems will be assessed. Results on resonance detection will be referred to and the relevance of the positive findings in the use of chaotic excitation in structural health monitoring will be covered.

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MS15
Epileptic Seizure Analysis with Synchronization and Recurrence Statistics

Epileptic seizures often contain stereotypic electrical activity consisting of patterns that are repeated in a quasi-periodic manner. Common examples include spike trains, repetitive spike-slow-wave patterns, or intervals during which the signal appears to be filtered to a very narrow band. We introduce a simple model that displays this type of activity and suggest signal processing strategies based on synchronization and recurrence statistics in order to detect and quantify this type of behavior. To evaluate our methods, we develop a set of test segments that incorporate the identified rhythmicity features, and present results of applying our measures to these test segments. We then analyze segments of intercranial brain wave data containing seizures, and present typical examples. Finally, we discuss the relationship between our methods and existing techniques for analyzing deterministic signals, and discuss the limitations of extrapolating our results to the issue of whether chaos is present in brain signals.

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MS15

Application of Information Theory Methods to Food Web Reconstruction

In this work we use information theory and nonlinear signal processing techniques on time series of abundances to determine the topology of an unknown (at the time of the analysis) food web. We show the nonlinear techniques identify the food web interactions as well as or better than a conventional parametric analysis. The results using nonlinear techniques are robust to time series lengths of 300-400 points. This approaches time series lengths of ecological data available from real systems.

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MS15

Detecting Damage in a Composite Beam - Steel Lap Joint Structure using Chaotic Forcing and Time Series Attractor Statistics

We examined strain time series from a composite beam vibrated using broad-band chaotic signals. The system was damaged by de-torque the bolts in the beam's joint. Data was analyzed by reconstructing the attractor of the system using an "undamaged" baseline. We calculated various statistics between the baseline and the de-torqued attractors of the various damage levels. We show what functional relationships exist between the attractors and how those are related to damage levels.

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MS15

Chaotic Signal Detection and Estimation Based on Attractor Sets: Applications to Secure Communications

We consider the problem of detection and estimation of chaotic signals in the presence of noise. We demonstrate a method for signal detection and estimation using a chaotic systems phase-space attractor, which, in the lack of closed form representations, can be approximated using sampled data. The method does not depend on knowledge of the systems initial conditions, nor on the synchronization of two separate systems. An application to physical layer secure digital communications is demonstrated.

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MS16

Invariant Manifolds of Spikes

Many singularly perturbed nonlinear elliptic equations have spike-like stationary solutions. These can be found through various methods, including Lyapunov-Schmidt schemes that, in the neighborhood of a proposed spike solution, decompose the operator equation into one that is restricted to a "normal subspace" and one in a "tangential subspace". Here, these subspaces correspond to eigenstates of the operator, linearized at an approximate spike solution, and where "tangential" means "corresponding to eigenvalues near zero", and "normal" means "complementary". In this talk I will describe a more global decomposition in which the "tangential subspace" is replaced by a finite-dimensional manifold of spike-like states and this manifold is invariant with respect to the corresponding nonlinear parabolic equation and also normally hyperbolic. The stationary spike-like states lie on this manifold.

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MS16

Front Propagation in Compressible Fluids

We discuss our most recent results in the stability of viscous compressible fronts in 1-D fluid dynamical models such as

those from gas dynamics, combustion, and phase propagation. We specifically examine the isentropic Navier-Stokes equations, Majda's model for a reactive gas, and Slemrod's model for gas dynamics with capillarity.

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MS16

Stability of Steady States in Multi-dimensions and the Maslov Index

For scalar reaction-diffusion equations in one space dimension, the stability of equilibria, and traveling waves can be determined by Sturm-Liouville theory. The Morse Index Theorem for geodesics on a Riemannian manifold can be viewed as a generalization of Sturm-Liouville theory to systems of equations, but still in one space dimension. This can also be applied to systems of PDEs that arise in applications if they have a certain gradient structure. The question addressed will concern how to extend these dynamical systems based ideas to multi-dimensional domains.

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MS16

Discussion

Discussion period.

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MS16

Strange Attractors for PDE's

In this talk, I will report a recent joint work with Don Wang and Lai-Sang Young on the existence of strange attractors for evolutionary partial differential equations under periodic. The general theory will be applied to the Brusselator equations.

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MS16

Pathwise Stationary Solutions of SPDEs and Weak Solutions of Infinite Horizon Backwards Doubly Stochastic Differential Equations

In this paper we study the existence of stationary solutions for stochastic partial differential equations. We establish a new connection between weak solutions of backward doubly stochastic differential equations (BDSDEs) on infinite horizon and the stationary solutions of the SPDEs. Moreover, we prove the existence and uniqueness of the weak solutions of BDSDEs on both finite and infinite horizons, so obtain the the solutions of initial value problems and the stationary solutions (independent of any initial value) of SPDEs. The connection of the weak solutions of SPDEs and BDSDEs has independent interests in both the areas of SPDEs and SPDEs.

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MS17

Dimension for Poincare Recurrences and its Applications

A new characteristic of fractal behavior of orbits in dynamical systems, the spectrum of fractal dimensions for Poincare recurrences, is supposed to be described. Possible application to the synchronization phenomenon will be discussed. Main results of the talk are published in the book: V.Afraimovich, E.Ugalde and J.Urias "Fractal Dimensions for Poincare Recurrences", Elsevier, 2006.

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MS17

Reconstructing a Recurrence Plot of Deterministic Driving Force from a Group of Driven Systems

In nature, many systems are driven by a common force. Since a driving force is sometimes not observed, recovering its information is important to understand the systems. We reproduce a recurrence plot for a driving force from observations of driven systems. Recurrence plots for driven systems, obtained using delay coordinates, are subsets of recurrence plot for a driving force. Thus if we take their union, we can approximate the recurrence plot for a driving force.

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MS17

Analysis of the Interaction of Systems by Means of Recurrences

We show how to detect and quantify the interaction between systems by means of recurrences. First, we present different measures based on recurrence to detect different types of synchronization and , second, measures to detect the direction of the coupling. We then compare the recurrence based measures with other existing techniques and discuss the advantages of our method. We apply the measures together with an hypothesis test to study the direction of coupling between heartbeats of mother and foetus.

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MS17
Spatial Recurrence Plots and Applications

We propose an extension of the recurrence plot concept to perform quantitative investigations of roughness and disorder of spatial patterns at a fixed time by means of spatial recurrence plots, or graphical representation of the pointwise correlation matrix for a two-dimensional spatial return plot. This technique is applied to the study of complex patterns generated by coupled map lattices, providing a systematic way of investigating the distribution of spatially coherent structures, such as synchronization domains. This approach has potential for many more applications, e.g., in surface roughness studies.

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MS17
Recurrence Plots of Quasiperiodic Systems

We propose a procedure to distinguish quasiperiodic from chaotic orbits in short time series, which is based on the recurrence properties in phase space. The histogram of the return times in a recurrence plot is introduced to disclose the recurrence property consisting of only three peaks imposed by Slater's theorem. An analytic description of noise effects on the statistics is carried out. Our approach demonstrates to be efficient recognizing regular and chaotic regions of a Hamiltonian system with mixed phase space.

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MS18
Invariant Manifolds and the Stability of Traveling Waves in Scalar, Viscous Conservation Laws

Invariant manifolds are constructed in the phase space of perturbations to the traveling wave solutions of scalar, viscous conservation laws and used to determine the asymptotic rate of convergence to these waves. This provides a geometric explanation of existing results demonstrating that the decay rate of perturbations can be increased by requiring that initial data lie in appropriate algebraically weighted spaces.

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MS18
A Variational Approach to Global Stability of Travelling Waves

We present a purely variational method which allows to prove global convergence to travelling waves in a class of semilinear partial differential equations, including reaction-diffusion systems and damped hyperbolic equations. Our approach does not use any form of the maximum principle, but it only applies to systems which have (at least formally) a gradient structure. This is a joint work with E. Risler (Nice).

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MS18
Asymptotic Behavior Near Planar Transition Fronts for the Cahn-Hilliard Equation

I will consider the asymptotic behavior of perturbations of planar wave solutions arising in evolutionary PDE of Cahn-Hilliard type in space dimensions $d \geq 2$. After briefly reviewing results for the case of one space dimension, I will focus on the spectrum of the operator that arises upon linearization of the Cahn-Hilliard equation about a planar wave solution, and also on the step from spectral to nonlinear stability. I will also briefly discuss several open problems involving the stability analysis of genuinely nonlinear structures such as saddle and doubly periodic solutions.

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MS18
Diffusive Mixing of Periodic Wave Trains in Reaction Diffusion Equations

We consider reaction diffusion systems on the infinite line which exhibit a continuous family of spectrally stable spatially periodic wave trains $u_0(kx - \omega t; k)$ parameterized with the wave number k. We prove a stable diffusive mixing of the asymptotic states $u_0(kx+\phi_\pm;k)$ as $x\to\pm\infty$ with different phases $\phi_-\neq\phi_+$ at infinity for solutions initially converging to these states as $x\to\pm\infty$. The proof is based on Bloch wave analysis, renormalization theory and on a rigorous decomposition of the perturbations of these wave solutions into a phase mode, showing diffusive behavior and into a remainder, which is linearly exponentially damped. Depending on the dispersion relation the asymptotic states mix linearly with a Gaussian profile in lowest order or with a non symmetric non Gaussian profile coming from Burgers equation which is the amplitude equation of the diffusive modes in case of a nontrivial dispersion relation.

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MS18

The Shooting Manifold for Strong Pulse Interaction in a FitzHugh-Nagumo Equation

We study multi-pulse solutions in excitable media. Under the assumption a single pulse is asymptotically stable, we show that there is a well-defined "shooting manifold", consisting of two pulses traveling towards each other. In the phase space, the two-dimensional manifold is a graph over the manifold of linear superposition of two pulses located at x_1 and x_2, with $x_1-x_2>>1$. It is locally invariant under the dynamics of the reaction-diffusion system and uniformly asymptotically attracting with asymptotic phase. The main difficulty in the proof is the fact that the linearization at the leading order approximation is strongly non-autonomous since pulses approach each other with speed of order one.

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MS18

Averaging Effects in Dispersion Managed NLS in "Quasilinear" Regime

The so-called quasilinear transmission regime in optical communication is described by the nonlinear Schroedinger equation with initial data consisting of a sequence of narrow Gaussian pulses. Unlike the dispersion managed soliton regime these pulses strongly overlap during the evolution. Nevertheless, the evolution turns out to be "nearly linear". We explain this phenomenon by using a model problem for NLS with periodic boundary conditions and highly localized initial pulse.

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MS19

How the Fractal Structure of Chaotic Invariant Sets Shows up in Scattering Cross Sections

The rainbow singularities in scattering cross sections for chaotic systems form a fractal pattern which reflects the fractal structure of the chaotic invariant set. Therefore the asymptotic observer who measures the cross section can follow the development scenario of the chaotic set under parameter changes of the system. In addition from the extraction of the scaling factors the measures of chaos are obtained. This possibility is an interesting contribution to the inverse scattering problem for chaotic systems.

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MS19

Topological Implications of Determinism: Non Intersection of Trajectories vs. Orientation Preservation

Because determinism precludes that unstable periodic orbits embedded in a three-dimensional chaotic attractor intersect, the knots and links they form are well-defined, and provide signatures of the geometrical mechanisms organizing the dynamics. Unfortunately, knots fall apart in higher dimensions. We have recently proposed that preservation of phase-space volume orientation is a more general criterion than non intersection of trajectories, and have found that a formalism based on it predicts correct topological entropies for horseshoe orbits.

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MS19

Topological Methods for Low Dimensional Chaotic Systems – An Overview

In the opening talk of the minisymposium, we give a brief introduction of topological methods for low dimensional chaotic systems. We first consider the computation of symbolic dynamics from periodic orbits of surface diffeomorphisms, giving brief descriptions of the Bestvina-Handel algorithm and a new algorithm of Moussafir. We then consider the problem for homoclinic tangles using methods developed by the authors. We finally outline some areas of physics where these techniques have been used.

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MS19
Estimating Topological Entropy on Surfaces

The topological entropy is a basic invariant measuring orbit complexity. We survey various methods for estimating the topological entropy of surface diffeomorphisms. Theorems of Gromov and Yomdin permit weak upper bounds, and theorems of Pieter Collins allow one to obtain lower bounds once one has accurate methods to calculate long pieces of stable and unstable manifolds. Summaring current joint work with M. Berz, K. Makino, and J. Grote, we consider various ways of computing stable and unstable manifolds, and use these to estimate the entropy of some Henon maps

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MS19
From Time Series to Knots and Braids: The Program in the Physical Sciences

In the first step, the relation between linking and knot properties of periodic orbits in $3D$-flows was proppused as a possible "fingerprint" for chaotic attractors. The second step added the idea that the flow (and its topology) could be reconstructed from experimental time series and imbeddings. After more than 20 years, we will discuss our present understanding of the relation among: template, orbits experimentally found, holes, imbeddings, braids and knots.

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MS20
Spectral Gap Results for Partially Dissipative Dynamics

We give a survey of several techniques allowing to obtain spectral gap results for infinite-dimensional evolution equations. The talk will focus on highlighting several spectral gap results obtained for a class of stochastic partial differential equations, as well as on applications of these results.

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MS20
Degenerately Forced SPDEs: The spread of Randomness

I will discuss how randomness spreads from scale to scale in degenerately forced stochastic partial differential equation. In particular, I will hive criteria guaranteeing the a specific class of SPDEs is ergodic and converging to equilibrium exponentially quickly. The specific examples of the stochastic Navier-Stokes and stochastic reaction difussion equations will be considered.

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MS20
Multiscale Analysis for SPDEs with Quadratic Nonlinearities

We derive rigorously amplitude equations for stochastic PDEs with quadratic nonlinearities, under the assumption that the noise acts only on the stable modes and for an appropriate scaling between the distance from bifurcation and the strength of the noise. We show that, due to the presence of two distinct timescales in our system, the noise (which acts only on the fast modes) gets transmitted to the slow modes and, as a result, the amplitude equation contains both additive and multiplicative noise. As an application we study the case of the one dimensional Burgers equation forced by additive noise in the orthogonal subspace to its dominant modes.

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MS20
Phase Transformation in Stochastic Reaction-diffusion Equations: Limits of Small Noise and Large System Size

We discuss stochastically-driven phase transformation in reaction-diffusion equations. Large deviation theory provides a way to analyze the probability of and most-likely pathway for transformation. We discuss issues related to the limit of vanishing noise and infinite system size. This includes joint work with R.V. Kohn, F. Otto, Y. Tonegawa, and E. Vanden-Eijnden.

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MS20

Rare Events in Spatially Extended Media

The dynamical behavior of many systems arising in physics, chemistry, biology, etc. is dominated by rare but important transition events between long lived states. Important examples include nucleation events during phase transition, conformational changes of macromolecules, and chemical reactions. Understanding the mechanism and computing the rate of these transitions is a topic that has attracted a lot of attention for many years. In this talk, I will discuss some recent theoretical developments for the description of rare events, as well as several computational techniques which allow to determine their pathways and rate. I will illustrate this concepts on the specific example of some reaction- diffusion equations driven by white-noise arising e.g. in the context of population dynamics, in micromagnetism, and in the description of the kinetics of phase transitions.

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MS21

Envelope Dynamics of Simulated and Experimental Nematic Electroconvection Patterns

A video displaying electroconvection of the nematic I52 is analyzed. Spatial Fourier transforms reveal that the dynamics is driven by four oblique modes corresponding to two pairs of travelling waves, consistent with a stability analysis of the underlying PDEs. Weakly nonlinear analysis predicts that the pattern is governed by four slowly varying envelopes. The envelopes are extracted using Fourier analysis, diagnosed with pattern analysis tools, and compared to simulations of globally coupled Ginzburg Landau equations.

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MS21

Experimental Studies of Spatio-Temporal Dynamics of Electroconvection

We present experimental results on the spatiotemporal structure of a nematic liquid crystal undergoing electrically induced convective flow. The observed patterns at the threshold indicate that the electroconvection is best described within the context of the weak electrolyte model for charge transport. We use Fourier analysis and demodulation of the convective structures to clasify spatiotemporal complex states and to verify the existence of low-order chaos at the onset.

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MS21

A Producer Grazer Model: Dynamics and Spatial Structure

The interaction between a forest pest and the tree cover is moderated by the availability and recycling of nutrients in the soil. A seasonal model presents the dynamics of this interaction as a function of the available nutrients and the nutrient uptake rate. The most interesting phenomena observed involve bistability between chaotic and stationary dynamics. Spatial models in the form of reaction-diffusion networks or integrodifferential equations are discussed. Front propagation and spatiotemporal chaos are studied.

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MS21

The Weak Electrolyte Model for Nematic Electroconvection: a Ginzburg Landau Approach

The electrohydrodynamic instability of certain nematic liquid crystals is a Hopf bifurcation with four critical wave numbers. To describe this instability in a weakly nonlinear analysis, a system of four globally coupled complex Ginzburg Landau equations is introduced, with coefficients

computed from the equations of motion. Some aspects of the complex spatiotemporal dynamics are discussed and related to recent experiments at Kent State University for the nematic I52.

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MS21

Modeling
Self-organized Behavior in Time-dependent Environments

We present numerical methods for multi-agent systems of autonomous vehicles, that accomplish common tasks in a time-dependent environment. The algorithms are based on simple, local interaction rules that create prescribed overall, complex patterns in which control, sensing, and communication are key elements. We address leader-follower interactions, obstacle avoidance, boundary tracking and the extention of the algorithms to 3D.

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MS22

Dynamics Near Robust Heteroclinic Phenomena

Consider a persistent heteroclinic network for a symmetric vector field on a three-dimensional manifold, with one-dimensional connections arising either through symmetry or through the transverse intersection of two-dimensional invariant manifolds. Under some general hypotheses, we prove switching and suspended horseshoes near the network. This dynamics is robust under symmetry-preserving perturbations. We also discuss switching for heteroclinic networks that arise naturally in the context of game theory.

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MS22

Discussion

Discussion.

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MS22

Heteroclinic Cycles in Coupled Cell Systems

We describe some of the variety of heteroclinic cycles that can occur robustly in asymmetric coupled cell systems with as few as three cells. We also indicate some of the associated dynamics and bifurcation. (Some of this work is joint with Peter Ashwin, Exeter, UK).

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MS22

An Overview of Robust Heteroclinic Cycling

Robust heteroclinic cycles arise in important classes of dynamical system, in particular, systems with symmetry. The simplest examples involve trajectories that repeatedly visit saddle-type equilibria. I will review developments that go beyond this simple case, for example, where the equilibria are replaced by periodic orbits or chaotic sets, and where the manifold between the components of the cycle is higher than one-dimensional. I will also review the effect of breaking the symmetry that guarantees the robustness of the cycle.

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MS22

Heteroclinic Cycles in N-person Game Dynamics

Game dynamics with cyclic interactions often exhibit rich dynamical behavior based on underlying heteroclinic cycles. In this talk, I will introduce spatial and Markovian extension of the standard game dynamics and its transitory behavior to complex heteroclinic cycles. Construction of heteroclinic cycles is also discussed based on game theoretic consideration.

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MS22

Frequency Locking and Complex Dynamics Near a Periodically Forced Robust Heteroclinic Cycle

We consider the Guckenheimer–Holmes robust heteroclinic cycle subjected to time-periodic forcing with frequency ω. Through analytic calculations and numerical simulation we explain the origin of the resulting complex dynamics. When the ratio of attracting and repelling eigenvalues of the heteroclinic cycle, c/e, is near 1, alternating intervals in ω of frequency-locking and chaotic dynamics are found, related to Arnol'd tongues for periodically-forced periodic orbits. When $c/e \gg 1$ the dynamics remains chaotic for all ω.

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MS23

A Multi-Scale Model of Tropical Intraseasonal Oscillations

We extend the multi-scale models of Majda/Klein for the tropical atmosphere and of Biello/Majda for the Madden-Julian Oscillation to include active moisture as in the work of Khouider/Majda. The Madden-Julian oscillation arises as an eastward propagating wave of precipitation on both the smaller, synoptic scale and the larger, planetary scales. The novel multi-scale organization of the forcing due to latent heat release (preciptation) makes for novel asymptotics and multi-scale non-linear waves.

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MS23

Gravity-wave Mean-flow Interactions in Simulations of the Quasi-biennial Oscillation

Interactions between atmospheric gravity waves and the background mean wind give rise to momentum deposition, mean-wind acceleration and descending shear zones, and hence play a role in driving the quasi-biennial oscillation (QBO) in the equatorial stratosphere. Gravity waves, because of their small scale, are generally unresolved in general circulation models, and their effects must be accounted for by means of parameterizations. I will discuss representations of gravity-wave effects in simple models of the QBO.

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MS23

A Hidden Markov Model Perspective on Regimes and Metastability in Atmospheric Flows

By using Hidden Markov Models, a new perspective is developed on the existence of atmospheric flow regimes. To identify regimes, we search for the presence of metastable states in model data, and we do so by fitting Hidden Markov Models to the data. If the resulting Markov chain possesses metastable states, we identify these as regimes. In this perspective, regimes can be present even though the observed data has a nearly Gaussian probability distribution.

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MS23

Spinning Down the Solar Core with Internal Gravity Waves

In this talk, I will briefly review the problem of the evolution of the Sun's angular momentum and explain how internal gravity waves generated at the base of the convection zone can lead to angular momentum extraction from the deep radiative interior through the effect of differential filtering. I will present results for the evolution of the internal rotation profile when waves are included and show that the concomitant surface lithium burning is also consistent with observations.

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MS24

Designing Threshold Networks with Given Structural and Dynamical Properties

Threshold networks contain a highly-compressible layered structure and allow fast computation of many network properties such as degree distribution, clustering, and degree correlation. We show how to construct arbitrarily large, sparse, threshold networks with (approximately) any prescribed degree distribution or Laplacian spectrum. Control of the spectrum allows careful study of synchronization properties of threshold networks including the relationship between heterogeneous degrees and resistance to synchrony.

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MS24

The Impact of Rate and Correlation Covariation on Network Information Transmission

There is strong evidence that the spike responses of distinct cortical neurons are correlated during sensory processing. I will address the question of how neurons transform correlations in their inputs into correlations between their outputs (spike trains). In particular, I will present experimental and numerical evidence that suggests that the susceptibility to a synchronizing input increases with the rate of the neurons' response. Analysis of leaky integrate and fire (LIF) neurons confirms this expectation. The mechanism underlying this covariation can be explained using a simple caricature of a threshold system. Finally, I will discuss the impact of this result on information processing in neuronal networks, and other threshold systems.

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MS24

Analyzing Network Models for the Spread of Epidemics

The spread of epidemics on networks has received considerable attention recently. Many of the analytical techniques developed implicitly assume that there is little clustering in the network. We will discuss extensions to incorporate clustering. We find that for some questions, the unclustered model provides a remarkably accurate estimate of simulated results, while for other questions the clustering significantly changes the answer.

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MS24

Characterizing the Dynamical Importance of Network Nodes and Links

The largest eigenvalue of the adjacency matrix of the networks is a key quantity determining several important dynamical processes on complex networks. Based on this fact, we present a quantitative, objective characterization of the dynamical importance of network nodes and links in terms of their effect on the largest eigenvalue. We show how our characterization of the dynamical importance of nodes can be affected by degree-degree correlations and network community structure. We discuss how our characterization can be used to optimize techniques for controlling certain network dynamical processes and apply our results to real networks.

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MS25

Structured Multiscale Models of *Proteus mirabilis* swarm-colony Development

We present continuous age- and space-structured models and numerical computations of *Proteus mirabilis* swarm-colony development. We base the mathematical representation of the cell-cycle dynamics of *Proteus* on those developed by Esipov and Shapiro, which are the best understood aspects of the system, and we make minimum assumptions about less-understood mechanisms, such as precise forms of the spatial diffusion. The models in this paper have explicit age-structure and, when solved numerically, display both the temporal and spatial regularity seen in experiments, whereas the Esipov and Shapiro model, when solved accurately, shows only the temporal regularity. The composite hyperbolic-parabolic partial differential equations used to model *Proteus mirabilis* swarm-colony development are relevant to other biological systems where the spatial dynamics depend on local physiological structure. We use computational methods designed for such systems, with known convergence properties, to obtain the numerical results.

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MS25

From Discrete to Continuum Swarms: The Irving-Kirkwood Approach

We derive a continuum model describing the collective motion of a group of self-propelled, interacting particles, by ensemble averaging of the corresponding discrete system. We build on the classical Irving-Kirkwood coarse graining method adapted for non-hamiltonian systems. We discuss limits of validity of the continuum model and compare behavioral trends with the corresponding discrete system for which morphologies of aggregation, stability and collapsing features are well established.

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MS25

A Hyperbolic Model for Animal Group Formation: The Role of Animal Communication in Modeling Different Group Structures

Signal reception is essential for the formation and movement of animal groups. I will present a one-dimensional hyperbolic model for group formation that incorporates different mechanisms for the reception of signals emitted by group members. Numerical simulations reveal a wide range of spatial patterns that can form. Some of these are classical patterns, such as traveling waves, or stationary pulses. There are also novel patterns, such as breathers and zigzag pulses.

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MS25

On the Swarming of Locusts: Discrete Models, Homogenization and Variational Minimization

We build an individual-based model for locust swarms incorporating social interactions, gravity, wind, and the boundary formed by the ground. For some parameters, the model produces a rolling "bubble" with grounded locusts, airborne locusts, and an unpopulated center, similar to actual locust swarms. To further understand this structure, we formulate a one-dimensional continuum problem describing a vertical slice. Using variational methods, we find exact solutions which agree closely with simulations of the discrete problem.

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MS26

Coexisting Solutions and Bifurcations in a Mechanical Oscillator - An Explanation for Gear Rattle?

Lightly damped backlash systems frequently suffer from noise and vibration problems. We present a nonlinear analysis of this behaviour. As a representative example, we derive a simple model for a pair of meshing spur gears as a single degree of freedom oscillator with backlash. We show analytically that the non-rattling solution can coexist with many other stable rattling solutions, and show the regions of existence and stability of such solutions on two-parameter bifurcation diagrams.

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MS26

An Analysis of Attractors in Mathematical Models of Vacuum Pumps

This talk is concerned with an analysis of attractors in models of gear-rattle in vacuum pumps. We use nonsmooth ODE models, proposed by Halse et al, where the nonlinearity arises from the backlash between the gear teeth. In order to understand the system's dependence on parameters, we present an analysis motivated by basin of attraction computations. This allows us to compare solutions for different models, and reveals the rich and delicate structure of the dynamics.

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MS26

Corner Collision of Impacting Systems: The Case of a Cam Follower

In this work we investigate the occurrence of corner-collision bifurcations in impacting systems and their application to the case of a representative cam-follower system. First, using the concept of discontinuity maps, we present the local analysis of a periodic solution undergoing a corner-collision. Then, we derive the local mapping associated to the bifurcating orbit and classify the observed bifurcation scenarios using the theory of bifurcations in piecewise smooth maps.

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MS26

Non-linear Behavior in a Discretely-Forced Oscillator

The simulated and experimental responses of a rigid-arm pendulum driven by an external impactor are considered. Here, impact occurs if the trajectory of a rotating impactor intersects that of the pendulum. Using the rotation rate of the impactor as the control parameter, experimental trials have demonstrated much of the dynamic behavior predicted by numerical simulations. The system exhibits chatter (i.e., multiple impacts within a single forcing period), sticking (i.e., contact between the pendulum and the impactor for non-negligible amounts of time), high-order periodicity, as well as behavior suggestive of chaos. A new convention for classifying periodic motions as well as insights regarding the nature of the coefficient of restitution (COR) in an experimental impacting system are also presented.

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MS27

Numerical Approximation of Homoclinic Trajectories for Non-autonomous Maps

For time-dependent dynamical systems of the form

$$x_{n+1} = f_n(x_n), \tag{1}$$

homoclinic trajectories are the non-autonomous analog of homoclinic orbits from the autonomous world. More precisely, two trajectories $(x_n)_{n\in\mathbf{Z}}$, $(y_n)_{n\in\mathbf{Z}}$ of (1) are called homoclinic to each other, if

$$\lim_{n\to\pm\infty} \|x_n - y_n\| = 0.$$

We introduce two boundary value problems, the solution of which yield finite approximations of these trajectories. Under certain dichotomy and transversality assumptions, we prove existence, uniqueness and error estimates. Finally, the method and the error estimates are illustrated by an example.

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MS27

Finding and Following Connecting Orbits Between Equilibria and Periodic Orbits

We introduce a numerical adaption of Lin's method to find and continue (in parameter space) connecting orbits between hyperbolic equilibria and hyperbolic periodic orbits. We demonstrate our method with an ODE in $\mathbf{R}^3$ with a heteroclinic cycle that consists of a codimension-zero connection from an equilibrium to a periodic orbit and a codimension-one connection from the periodic orbit back to the equilibrium.

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MS27

Revealing How Hyperbolicity Influences Transport in Aperiodic Fluid Flows

Hyperbolicity is fundamental in understanding transport in dynamical systems. The role of hyperbolic trajectories in steady and periodic systems has been well-studied. Recent observations show hyperbolic structures persist to govern the complicated flow structure of many aperiodic systems. However, the best way to quantify this phenomenon is unresolved. We focus on a criterion based on finite-time Lyapunov exponents. This method is applied to a variety of unsteady fluid systems, ranging from engineered to biological flows.

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MS27

Invariant Manifolds in Piecewise-smooth Systems

In smooth systems, invariant manifolds persist and stay smooth if they are normally hyperbolic. However, in non-smooth systems where the return map is non-Lipschitz no such notion exists. The talk will focus on defining normal hyperbolicity in the non-smooth context and giving conditions for an invariant manifold to persist under perturbation as a graph over the unperturbed manifold. Particular emphasis is placed on grazing manifolds, where the local discontinuity mapping is dominated by a square root term.

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MS28

The Spectrum of the Partially Locked State for the Kuramoto Model

The Kuramoto model consists of a large population of globally coupled phase oscillators with randomly distributed frequencies. A longstanding problem has been to analyze the stability of the model's "partially locked" state (in which oscillators near the center of the frequency distribution are phase-locked, while those in the tails are desynchronized). We construct the continuum limit of the model and prove that the partially locked state is neutrally stable, contrary to an earlier conjecture.

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MS28

Coherent Motion in Large Networks of Heterogeneous Dynamical Systems

We consider the onset of coherent motion in a large network of different dynamical systems, some of which could be chaotic and others, periodic. We find that the critical coupling strength at coherence onset is determined by the product of two factors: one depends only on the network topology; the other depends only on the dynamics of the uncoupled systems. This result is used to identify those nodes whose removal most efficiently decoheres the system.

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MS28

Chimera States for Two Interacting Populations of Oscillators

Biological oscillator networks often have a multiscale character: each oscillator is itself a network of smaller oscillators. We explore a solvable model in which two large groups of identical phase oscillators are globally but unequally coupled; oscillators pull more strongly on those in their own group. Along with a completely synchronous state, the system displays attracting chimera states (both static and breathing ones) where one group is synchronous and the other is not.

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MS28

Of Metronomes and Pendulum Clocks

In 1665 Christiaan Huygens observed that two pendulum clocks consistently synchronized their oscillations, with the pendulums locked in antiphase motion. The interaction was provided by the small motion of a common support on which the clocks were mounted. In contrast, a simple classroom demonstration using metronomes in place of pendulum clocks - with the same support-coupling mechanism - yields stable in-phase synchronization. We explore (and explain) the reasons behind this difference.

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MS29

Transient Turbulence

The laminar profile in pipe flow and plane Couette flow is linearly stable for all Reynolds numbers. In order to trigger turbulence, the Reynolds number has to be sufficiently high and the perturbation sufficiently large. Extensive experimental and numerical studies show that the turbulent state is not connected with an attractor, but rather with a strange saddle, with a lifetime that increases exponentially with Reynolds number.

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MS29

Transient Chaos in Spatiotemporal Dynamics: An Overview

We first summarize properties of transient chaos in low-dimensional systems, and discuss the relevance of nonattracting chaotic sets (most typically chaotic saddles), and the invariant measures on these sets. Lyapunov exponents, escape rates, and dimension formulae are reviewed. Next, we discuss how these concepts can be applied to high-dimensional problems, including crisis phenoma and the scaling of the escape rate with the system's size. A few early examples of transient chaos in continuous spatiotemporal systems are reconsidered.

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MS29

Coarsening and Relaxation in Phase Separation: A Pattern Formation Perspective

The decay of metastable mixtures commonly proceeds in three steps: (i) generation of microdomains; (ii) coarsening of microdomains; (iii) a sharp cut-off when new physical mechanisms become relevant. The early stages of (i) and (ii) can fairthfully be described by scaling approaches. To also gain insight into the crossovers we formulate phase separation as a problem of transient pattern formation. The crossover from (i) to (ii) corresponds to pattern selection, and in stage (iii) segregation stops.

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MS29

Transient Spatiotemporal Chaos in the Presence of Noise and Nonlocal Coupling

Spatiotemporal chaos on a regular ring network of excitable Gray-Scott dynamical elements collapses to a stable asymptotic state. We find that the addition of dynamical noise can advance and delay the transient lifetime of spatiotemporal chaos, depending on the noise amplitude and the degree of spatial inhomogeneity. We also find that the addition of few nonlocal network connections can prevent the collapse to yield asymptotic spatiotemporal chaos.

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MS30

MAXENT for Invariant Measure Approximation

Given a measurable, nonsingular transformation T on a probability space (X, m), invariant densities are solutions of the Perron-Frobenius equation:

$$P_T f = f.$$

Ulam's method constructs approximate solutions to this equation. We take a different approach, constructing solutions as the limit of a convergent sequence of convex optimization problems. One advantage: approximations converge to an exact solution without further dynamical conditions on T. We describe two calculations using energy and entropy objectives to illustrate both advantages and complications.

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MS30

Transfer Operator Approach for Coupled Cell Systems: Theory and Practice

Coupled cell systems describe dynamical systems composed out of a number of subsystems, with some further structure (symmetries). We ask how the structure and the symmetries of the system are reflected by its transfer operator. To find answers, we introduce a direct sum decomposition of its domain constructed in such a way that the block matrix representation of the transfer operator reflects the components of the system and takes advantage of its symmetries.

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MS30

Slow Decay of Correlations in the Generalized Baker's Map

The classical Baker's map exhibits prototype chaotic behaviour including Bernoullicity, uniform hyperbolicity and exponential decay of correlations. Generalized Baker's maps can be constructed which are just as chaotic (Bernoulli, up to a measurable isomorphism), but have arbitrarily slow decay of correlations. We report a family of these examples in which the range of behaviour is revealed transparently by building suitable Young towers. The important ideas are illustrated with numerical computations. (Joint work with C J Bose.)

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MS30

Detecting Phase Transitions and a Fast Way to Compute Topological Pressure and Entropy

It is well known that for different classes of transformations, including the class of piecewise C^2 expanding maps $T : [0, 1] \to [0, 1]$, Ulam's method is an efficient way to approximate the absolutely continuous invariant measure of T. We develop a new extension of Ulam's method and prove that this extension can be used for the numerical approximation of the topological pressure $P(\phi)$ associated with T and the potential $\phi = -\beta \log |T'|$, where $\beta > 0$. As a consequence, we demonstrate that our extended Ulam's method can be an efficient tool for detecting phase transitions: breaks in the analyticity of the topological pressure as a function of β. In particular, when $\beta = 0$, we obtain a simple, fast, and accurate way to approximate the topological entropy for T.

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MS31

Geometric Investigation of Low-dimensional Manifolds in Reaction-diffusion Equations

We study geometrically the approach to equilibrium for reaction-diffusion systems on bounded domains. For these dissipative systems, this approach occurs in the function space via low-dimensional manifolds. We identify fundamental aspects of this process for single species and two-species (with an explicit solution) models and demonstrate the dimensionality reduction from infinite to finite. To treat more complicated systems, these manifolds are generated numerically using ODE methods (modified to accomodate spectrum truncation).

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MS31

Multiscale Coupling of Macroscopic and Mesoscopic Models

Initialization (lifting) and hybrid spatial coupling of a mesoscopic lattice Boltzmann model (LBM) from/to macroscopic PDE variables leads to a one-to-many mapping problem. We use analytical relations or a numerical alternative: the constrained runs scheme. We show that this scheme is stable and convergent for reaction-difffusion LBMs. For the hybrid coupling, we show that the global spatial discretization error is one order less accurate than the local error made at the interface.

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MS31

An Introduction to the Design and Analysis of Reduction Methodologies

This talk will serve as an introduction to the ideas behind dimension reduction for nonlinear, multiscale dynamical systems. I will summarize key results concerning the accuracy and effectivity of reduction methods, focusing on the lessons that such analytical endeavors teach us. I will also examine in which sense (and cases) one may hope to include diffusion in a reduced model and possible frameworks/approaches for the development of accurate PDE reduction methods.

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MS32

Analyzing Economic Models with Ill-defined Forward Dynamics with Inverse Limits

There are models from economics, such as the cash-in-advance and overlapping generations models, that have the property of being well-defined backward in time but not forward in time. The analysis of these models has been ad hoc and incomplete. The solutions to these models form an inverse limit space. With this tool, the ill-defined map on the factor space is lifted to the inverse limit space, the space of solutions. The natural shift map on the inverse limit space is intimately associated with the original ill-defined map, and has the advantage that it not only is well defined forward in time, it is a homeomorphism. There is of course, a price: the new space is no longer an interval or a manifold, but in the interesting, chaotic cases is likely to be a complicated, fractal object. We have investigated the topology and dynamics of the inverse limit space and the induced shift homeomorphism. We have also constructed, for some chaotic cases, appropriate natural invariant measures of the factor space which we can lift to natural invariant measures on the inverse limit space. We are then able to integrate continuous real-valued functions defined on the inverse limit space (such as utility functions), and make conclusions about expected behavior of the systems and possibly, policy suggestions that would help, say, maximize utility.

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MS32

Estimating Model Error in a Weather Forecast System

Most models of physical processes are only approximations of the true dynamics. Errors in approximations are amplified by chaotic dynamics and can lead to serious problems in prediction. This talk will describe a general approach that combines empirical measurements with model forecasts to estimate the error in the model. Results from a specific application to the Global Forecast System of the U.S. Weather Service will be discussed. (Joint work with S. Baek, B. Hunt, E. Ott, and I. Szunyogh.)

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MS32

A Classification of Explosions

An explosion is a discontinuous change in the size of the recurrent set as a parameter is varied. Explosions can lead to crises of chaotic attractors in two dimensions, and unstable dimension variability in three dimensions. I discuss results relating to the one-dimensional version of a 1976 conjecture of Newhouse and Palis, which says that explosions always occur as a result of saddle-node bifurcations and tangencies of stable or unstable manifolds of periodic points.

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MS32
Time Series Reconstruction of Network Models

We discuss theory and techniques for the reconstruction of dynamics of networks from measured signals. For networks with simple topologies, the goal is to determine conjugacies or semiconjugacies with the system dynamics. For larger, sparsely-connected systems, computational methods are discussed for determining network topology.

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MS33
A Network Approach for the Study of Many-Particle Swarms: Achievements, Limitations and New Directions

Bird flocks and other similar assemblies of self-propelled particles exhibit the emergence of collective order states, where agents move in the same direction. The onset of such states occurs through a dynamical phase transition when the noise intensity descends to a critical level. This transition can be studied analytically using a novel network approach in which the self-propelled system is mapped into a dynamical network. We will present this approach, discussing its successes and limitations.

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MS33
An Eye on the Swarm: Linking Experiment and Theory

Animal groups are ideal subjects with which to develop and test mathematical models that link the behavior of individual components to the functioning of the dynamic group-level properties they create. Despite this, there is very limited quantitative information and most models remain untested. I will discuss recent attempts to understand how real groups behave and demonstrate where current models succeed (and where they fail) in providing an understanding of the underlying mechanisms of collective coordination.

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MS33
From the Microscopic to the Macroscopic Description of Swarms: Transport Theory of Active Brownian Particles

Active Brownian particles can take energy from the environment, put it into an internal storage, and convert it into kinetic energy. Because of this, they are in a stationary state of permanent motion where an over-damped description is not applicable. Using the moments of the Fokker-Planck equation, a macroscopic transport theory is derived. The analysis of its stationary states shows interesting results that can be applied to explain the stable motion modes of biological swarms.

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MS33
Current and Future Approaches to Swarming Systems Research: An Overview

The dynamics of swarms is a rich and relevant problem with biological and engineering applications. It can be described using universal concepts such as self-organization and phase transitions, but also has unique features: energy is continuously injected at the agent scale and interactions can be highly nonlinear. In this talk, we will overview current experiments and theoretical approaches for studying swarming systems (agent-based simulations, field equations, interaction-network analyses, etc.) and project possible future research directions.

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MS34
Continuous Symmetries and Relative Periodic Orbits Trace Formulas

Trace formulas relate short periodic orbits to long time invariant densities (natural measure). Higher dimensional dynamics requires inclusion of partially hyperbolic invariant tori into trace formulas. A trace formula for a partially hyperbolic $(N+1)$-dimensional compact manifold invariant under N-parameter global continuous symmetry is derived. In this extension of "periodic orbit" theory there are few periodic orbits - the relative periodic orbits that the trace formula has support on are almost never eventually periodic.

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MS34
Searching for Unstable Recurrent Patterns in Pipe Flow

We investigate numerically recurrent patterns in incompressible pipe flow, for values of the Reynolds number close to those at which turbulence looks sustained. We will show the finite-amplitude solutions found so far in an axially periodic (short) pipe, including new ones discovered recently by allowing for less symmetry constraints and also helicity. We will then introduce a method to seek generic time-periodic solutions, allowing for spatial shifts, and discuss their relevance to the turbulent dynamics.

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MS34
A Dynamical Systems Perspective on Turbulence

in Low-Reynolds Plane Couette Flow

We analyze low-Reynolds turbulence in plane Couette flow as a walk through a set of unstable invariant solutions to Navier-Stokes. Two cases are considered: the dynamics of an 'upper-branch' equilibrium for a small geometry and its decay to the laminar state, and self-sustained turbulence in a larger geometry. We discuss the role of symmetry, state space partitioning, construction of symbolic dynamics, and generation of new solutions from numerical simulation data.

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MS34

Unstable Periodic and Travelling Wave Solutions Corresponding to Large Scale Structures in Channel Flow Turbulence

We obtained unstable periodic solutions of streamwise-minimal channel flow with symmetries for upto Re=6000 by the shooting method. These solutions are on the basin-boundary of the turbulent attractor and have characteristics of large scale motions observed in fully-developed channel flow turbulence.

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MS34

Turbulent Fluids and Dynamical Chaos

The phenomenon of near-wall bursting has now been studied for more than 50 years. We will present five new three-dimensional solutions of turbulent plane Couette flow, one of which is periodic while four others are relative periodic. Each of these five solutions demonstrates the break-up and re-formation of near-wall coherent structures. We will discuss dynamical principles that suggest that turbulence can be understood in terms of periodic and relative periodic solutions of the Navier-Stokes equation.

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MS34

Cycles of Short, Long and Very Long Period in Isotropic Turbulence

We show that a single periodic orbit can capture many features of isotropic turbulence at moderate micro scale Reynolds numbers. This orbit has a period of two to three large-eddy turnover times. In this presentation I will look at orbits with shorter and much longer periods and a range of Reynolds numbers to try and extract a selection rule for periodic orbits with properties close to those of turbulence. Joint work with Shigeo Kida and Genta Kawahara.

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MS35

Generalized Connection Graph Method for Synchronization in Asymmetrical Networks

We present a general framework for studying global synchronization in networks of dynamical systems with asymmetrical connections. We extend the connection graph stability method, originally developed for symmetrically coupled networks, to the general asymmetrical case. The principal new component of the method is the transformation of the directed connection graph into an undirected graph. In our method for symmetrically coupled networks we have to choose a path between each pair of nodes and establish a bound on the total length of all paths passing through an edge on the network connection graph. The extension of the method to asymmetrical coupling consists in symmetrizing the graph and associating a weight to each path. This weight involves the node unbalance of 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. The synchronization condition for this symmetrized-and-weighted network then also guarantees synchronization in the original asymmetrical network (joint work with V. Belykh and M. Hasler).

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MS35

Synchronization, Modules and Motifs in Complex Networks

We show how dynamical processes (synchronization) among networking systems can offer a new understanding on the structural and topological features characterizing the underlying complex wiring of connections. In particular, we show how to efficiently detect and identify the hierarchical structure of modules, based on the cluster desynchronization properties of phase oscillators, and how to relate the abundance of specific patterns (motifs) observed in biological networks with their propensity to give rise to synchronous motion.

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MS35

New Results in Complex Networks' Efficiency and Vulnerability

Some of the main known results about efficiency and vulnerability for complex networks will be reviewed from a mathematical perspective. Also, several comparisons among these functions will be made following a pairwise strategy, and taking into account different efficiency and vulnerability functions. It will be shown in all cases that these magnitudes display strong correlations, which are typically piecewise linear in log-space as well as universal (i.e. independent of the number of nodes N) to a great extent. The analytical part of the presentation will develop explicit bounds linking all pairs of such parameters. Such presentation will be then completed by including new results that expand the domain of the theory to the realm of directed networks. This mathematical framework will be subsequently used to perform a comparative analysis of those performance measures over a significant sample of real networks.

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MS35

Partial Phase Synchronization for Multivariate Synchronizing Systems

Graphical models applying partial coherence to multivariate time series are a powerful tool to distinguish direct and indirect interdependencies in multivariate linear systems. We carry over the concept of graphical models and partialization analysis to phase signals of nonlinear synchronizing systems. This procedure leads to the partial phase synchronization index which generalizes a bivariate phase synchronization index to the multivariate case and reveals the coupling structure in multivariate synchronizing systems by differentiating direct and indirect interactions. This ensures that no false positive conclusions are drawn concerning the interaction structure in multivariate synchronizing systems. By application to the paradigmatic model of a coupled chaotic Roessler system, the power of the partial phase synchronization index is demonstrated.

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MS35

Synchronization in Networks of Neurons with Activatory and Inhibitory Connections

Through the last years, different strategies to enhance synchronization in complex networks have been proposed. In this work, we show that synchronization of non-identical neurons that are attractively coupled in a small-world network is strongly improved by just making phase-repulsive a tiny fraction of the couplings. By a purely topological analysis that does not depend on the neuron model, we link the emerging dynamical behavior with the structural properties of the sparsely coupled repulsive network.

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MS35

Spatiotemporal Dynamics of Networks of Excitable Nodes

A network of excitable nodes based on the photosensitive Belousov-Zhabotinsky reaction is studied in experiments and simulations. The addressable medium allows both local and nonlocal links between the nodes. The initial spread of excitation across the network as well as the asymptotic oscillatory behavior are described. Synchronization of the spatiotemporal dynamics occurs by entrainment to high-frequency network pacemakers formed by excitation loops. Analysis of the asymptotic behavior reveals that the dynamics of the network is governed by a subnetwork selected during the initial transient period. [M. Tinsley, J. Cui, F. V. Chirila, A. Taylor, S. Zhong, and K. Showalter, Phys. Rev. Lett. 95, 038306 (2005); A. J. Steele, M. Tinsley, and K. Showalter, Chaos 16, 015110 (2006).]

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MS36

Fluctuation-Driven Rhythmogenesis in an Excitatory Neuronal Network with Slow Adaptation

We study an excitatory all-to-all coupled neuronal network of N model neurons that possess random fluctuations in their firing rate and a slow activity-dependent synaptic depression. By exploiting a separation of time scales we analytically show how in the limit as N goes to infinity the system dynamics converges to a three-dimensional, nonlinear, deterministic ODE that exhibits regular oscillations if the strength of the single cell level noise sigma is sufficiently strong.

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MS36

Downregulation of Ia by Muscarinic Cholinergic Receptors

We show that activation of muscarinic receptors in vivo causes a large increase in burst firing in sensory pyramidal cells. Using an in vitro preparation and modeling, we show that activation of these same receptors also causes increased burst firing through downregulation of an Ia potassium current. Our results show a mechanism by which burst discharge can be regulated, thus controlling the response of sensory neurons to environmental stimuli.

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MS36

Dimension Reduction for Complex Neural Models

Many complex models of neural systems now exist, but their simulation and analysis remain challenging. I will discuss several examples for which low-dimensional models predict very well the dynamics of more complex models. These low-dimensional models cannot be derived analytically, but can be simulated and analysed through appropriately-initialised short simulations of the corresponding complex system.

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MS36

Phase-locking in Electrically Coupled Spiking Neurons: The Influence of Intrinsic Properties of Neurons

I will discuss how electrical coupling interacts with the intrinsic properties of neurons to generate phase-locked states. Using the theory of weakly coupled oscillators and phase-response curves from real and model interneurons, I will identify some of the characteristics of neuronal dynamics that are important for determining stability of phase-locked states. I will also examine how certain ionic conductances alter stability of phase-locked states.

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MS36

Analysis of Epileptiform Phenomena in Cortical Brain Slices

We and others have used integrodifferential equations to describe waves of epileptiform activity propagating through cortical tissue. Recent data, however, have revealed activity much more complex than smooth propagation. Here, we present data and extend our analysis to understand the complex activity that we have observed experimentally. We will also present preliminary analysis investigating epileptogenesis, the transition of activity from sparse and local to dense and propagating.

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MS36

Reliable and Unreliable Dynamics in Coupled Theta Neurons

We study the reliability of small networks of coupled oscillators in response to fluctuating inputs. Reliability means that an input elicits essentially identical responses upon repeated presentations, regardless of the system's initial condition. We initially focus on a 2-oscillator pulse-coupled network, adopting the standard 'theta neuron' model, and demonstrate that it exhibits both reliable and unreliable dynamics for broad ranges of coupling strengths. We further show that 1:1 phase locking in the zero-input system corresponds to high susceptibility for unreliable responses.

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MS37

Filter Induced Dynamics of a Semiconductor Laser with Optical Feedback

We consider a semiconductor laser subject to filtered optical feedback where a part of the laser emission re-enters the laser after it is spectrally filtered. This system can be modelled by a set of delay-differential equations and the dynamics supports two types of oscillations: internal relaxation oscillations and frequency oscillations, which are external roundtrip oscillations. We use numerical continuation to present a comprehensive bifurcation analysis with respect to physically relevant parameters.

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MS37

Transverse Mode Interaction in Semiconductor

Lasers Subject to Optical Feedback

We investigate a multi-transverse-mode vertical-cavity surface-emitting laser with optical feedback. Our model consists of partial differential equations, describing the spatial optical fields and carrier diffusion, and delay differential equations, modelling the external feedback. Continuation techniques are used to investigate the transition from self-feedback of the fields, through to a cross-coupling of the fields via the feedback. Moreover, our model is a test-case for the effectiveness of numerical tools in analysing large-scale systems with delay.

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MS37

Beyond-all-order Calculation of Pattern Formation and Localized Structures in Optical Cavities

We analyze a Turing instability in a model for nonlinear optical cavity. By carrying the calculation beyond all orders, we compute the exponentially small terms that couple the slow and fast spatial scales. This allows to construct analytically the snaking bifurcation diagram leading to multi-peaked solutions and to determine the exponentially small pinning range of parameters for which stationary localized structures exist.

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MS37

Excitability Mediated by Localized Structures in Nonlinear Optical Cavities

We analyze an excitability regime mediated by localized structures (LS) in a dissipative nonlinear optical cavity. The scenario is that stable LS exhibit a Hopf bifurcation that is followed by the destruction of the oscillation in a saddle-loop bifurcation. Beyond this point there is a regime of excitable LS under the application of suitable perturbations. The whole scenario is organized by a Takens-Bogdanov codimension-2 bifurcation in the limit where our model reduces to the NLSE.

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MS37

Nonlinear Dynamics of Lasers Without Population Inversion

Bifurcation continuation techniques are used to study instabilities resulting from a nonlinear interaction of two quantum-coherence-induced lasing solutions in a single-mode inversionless laser. We uncover codimension-two and -three double-pitchfork and double-Hopf bifurcations. The more interesting double-Hopf bifurcations are sources of instabilities of the type distinctively different from instabilities found in conventional lasers. In particular, we will discuss self-induced torus doubling cascade to chaos.

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MS37

Reduction of the San Miguel-Feng-Moloney Model for Vertical-cavity Surface-emitting Lasers

A four-level model for polarization switching of a quantum-well vertical-cavity surface-emitting laser is simplified by applying a multiple time scale method. The asymptotic theory is based on the natural values of the laser parameters and considers the case of fast spin-flip relaxation rate and large birefringence with respect to the relaxation oscillation frequency. The reduced problem consists of three rate equations for a two-mode semiconductor laser making an analytical analysis of the switching phenomenon possible.

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MS38

Return Maps of Folded Saddle-nodes

Folded nodes occur in generic slow-fast systems with two slow variables and one fast variable. Mixed mode oscilla-

tions appear in trajectories flowing past folded nodes. We present numerical computations of return maps for these flows. These maps yield insight into attractors and bifurcations associated with folded nodes. We also study the return maps of folded saddle-nodes that appear in generic one parameter families when a folded saddle and folded node are created.

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MS38

MMOs in Systems with More than Two Slow Variables

Canard explosion is a well known phenomenon of an exponentially fast transition from small to relaxation oscillations. Typically it does not occur in systems with more than one slow variable. Mixed mode oscillations are a generalization of canard explosion to systems with two slow variables. What happens when there are more than two slow variables? We show that under some general conditions mixed mode oscillations occur and the existing theory can be generalized.

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MS38

Mixed-mode Dynamics via Localization and Noise

The goal is to understand the effect of noise-induced mixed modes on coherence in oscillator networks. This behavior reduces phase coherence beyond simple stochasticity, due to competing in-phase/anti-phased and localized states. We demonstrate this generic behavior using Morris-Lecar oscillators with synaptic coupling and normal form models. Analytical and numerical results agree in predicting limited coherence and illustrate differences between excitatory and inhibitory coupling in the presence of noise.

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MS38

Mixed-Mode Oscillations in a Family of Three Time-Scale Systems

We discuss a model problem which, though analytically simple, exhibits a wide variety of mixed-mode patterns. One characteristic feature of this model is the presence of three time-scales. Using geometric singular perturbation theory and desingularization, we show that the mixed-mode dynamics is caused by a canard phenomenon. We derive asymptotic formulae for the corresponding return map, and we prove that the structure of the observed Farey sequences is determined by secondary canards.

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MS38

Discussion

Discussion - Session I

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MS38

Reduced System Computing and MMOs

Reduced System Computing (RSC) is a numerical approach to solving singularly perturbed differential equations in which approximate solutions are generated by concatenating solutions of the distinct fast and slow singular limits. I will show how RSC can be applied to the computation of mixed mode oscillations.

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MS39

Averaging in the Four Vortex Problem

We discuss the averaging approximation to the four-vortex problem on the plane with an initial configuration consisting of a *binary* plus two vortices; that is to say, a configuration in which the distance between two of the vortices is very small in comparison to the other distances.

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MS39

Geometric Phases in Under-actuated Mechanical Systems with Symmetry

In under-actuated mechanical systems with symmetry, geometric phases relate motion in the directly controlled shape space and induced motion in the uncontrolled group direction. A typical linear analysis yields suboptimal controllers that use low amplitude cyclic motions in the shape space. In contrast, a careful nonlinear analysis of the 3D pendulum provides global insight that yields a group-equivariant discrete optimal control algorithm based on Lie group variational integrators that addresses the limitations of existing techniques.

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MS39
An Example of Arnold Diffusion in Optics and Mechanics

In this joint work with Vadim Kaloshin we give a transparent example of Arnold diffusion in a mechanical system (a particle in a periodic potential in $\mathbf{R^3}$). This example, or rather a class of examples, can also be interpreted as bending of the light in a periodic optical medium which is arbitrarily close to being homogeneous. The geometry of Arnold diffusion is made very transparent in this example, and the proofs are quite intuitive.

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MS39
Nonholonomic Integrators on Lie Groupoids

During the last decade, much effort has been devoted to construction of geometric integrators for Lagrangian systems using a discrete variational principle. In particular, this effort has been concentrated for the case of discrete Lagrangian functions L on the cartesian product $Q \times Q$ of a differentiable manifold and on a Lie group G. The purpose of this talk is to describe Lagrangian and Hamiltonian Mechanics on a Lie groupoid when the system is subjected to nonholonomic constraints. We consider the general case of a lagrangians defined on a Lie groupoid Γ, this structure covers, as particular examples, the cases of cartesian products $Q \times Q$, quotients by Lie groups $(Q \times Q)/G$ as well as Lie groups G. The "nonholonomic data" are introduced fixing a constraint distribution (a vector subbundle of the Lie algebroid associated to the Lie groupoid Γ), and a constraint embedded submanifold of Γ. From a dicrete Holder's principle we derive the discrete Lagrange-D'Alembert, the discrete nonholonomic Legendre transformations and we geometrically characterize the regularity of the system. Also the discrete nonholonomic momentum map is defined. Finally, examples of nonholonomic integrators (also for reduced systems) are exhibited, from adequate discretizations of the continuous nonholonomic equations.

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MS39
Vortex Lattice Theory

We will describe a new method of finding N-vortex relative equilibria in the plane (i.e. vortex lattices in Bose-Einstein condensates). The problem is formulated as a linear algebra problem $A\vec{\Gamma} = 0$ where A is an MxN configuration matrix obtained by requiring that all intervortical distances remain constant, and $\vec{\Gamma} \in R^N$ is the vector of vortex strengths. We randomly deposit the N points in the plane, which with probability one will give us a configuration matrix of full-rank. Then we allow each of the points to execute a random walk, and we calculate the singular value decomposition of A at each step. Steps for which the smallest singular value is decreased are allowed, while those that don't are thrown out. In this way, the smallest singular value is used as a 'Brownian ratchet' device to hone in on new equilibrium configurations, i.e. matrices that are rank-deficient. Typically these equilibria are asymmetric, and the corresponding vortex strengths are obtained by requiring that they lie in the span of the right singular vectors corresponding to the zero singular values (i.e the nullspace of A). The method gives new insights into many issues, including the spacing of equilbria (as measured by the Frobenius norm) and their density.

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MS39
Geometry of Hamel Equations

Hamel Equations are Euler-Lagrange equations written relative to a frame in the tangent bundle of the configuration manifold Q that is not necessarily consistent with local coordinates on Q. In this talk we will obtain Hamel equations using a variational principle written in an arbitrary frame. We will also discuss how one can simplify the equations of motion of a mechanical system by selecting a suitable frame.

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MS40

Spatially Localized Oscillating States in Periodically Forced Dissipative Systems

Recent experiments on parametrically driven granular media have revealed the presence of spatially localized oscillating structures called oscillons. Additional experiments on spontaneously oscillating chemical systems forced near the 2:1 resonance have identified other types of spatially localized structures, including hole-like states in an oscillating background and fronts between domains which oscillate exactly out of phase. In this talk I will describe the origin and properties of these states in the context of a simplified model, the forced complex Ginzburg-Landau equation, that describes the dynamics near the 2:1 temporal resonance. In particular I will identify a single mechanism that may be simultaneously responsible for all three types of spatially localized structures.

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MS40

Localised Patterns: A Brief Survey

In this first talk of the minisymposium, I will summarise in simple terms the mathematical approaches to the existence of localised patterns in the canonical case of the 1D Swift–Hohenberg equation posed on the real line. Many aspects of the dynamics are well understood, through spatial dynamics and regular and 'beyond-all-orders' asymptotics. Extensions to large but finite domains, and the effects of a large-scale neutral mode, often found in pattern-forming systems, will be briefly described.

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MS40

Discussion

Discussion.

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MS40

Localised Hexagon Patches and Planar Fronts

Patches of stable, fully localized hexagons have been observed in a planar DC gas-discharge systems, see Ammelt, Astov and Purwins PRE 58(1998). Taking the Swift-Hohenberg equation as a model, we present numerical results showing how stationary patches of hexagons grow as the linear parameter is varied. We then show how the growth is governed by many different orientated hexagon planar fronts. We draw qualitative similarities between hexagons in the model and experiments.

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MS40

Localized Structures and their Control in Liquid Crystal Experiments

I will present experimental localized structures in a liquid crystal cell with optical feedback. Localized structures represent here the localized solutions of a pattern-forming system when bistability exists between different metastable states. I will show that different regions of existence and different types of localized structures can be selected depending on the nature of the metastable states. Then, I will present an experimental technique to control the dynamics of localized structures.

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MS40

Ferrosolitons or Switching Cells of Magnetic Liquid Patterns

We generate solitary spikes in the bistable regime of the Rosensweig instability in a layer of magnetic fluid (PRL 94,2005). Contrary to oscillons and other dissipative 2D-solitons these ferrosolitons are localized states in a lossless system. Their existence can be attributed to the inherent periodicity of the Rosensweig instability to which the wave front locks (Pomeau 1986). We measure the ferrosolitons profile and growth rate and compare it with numerics (O.Lavrova et al. J.Phys.Condens.Matter 18,2006).

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MS41

Effective Lagrangian and Hamiltonian Structures

for Nonlinear Lattices

Considering nonlinear lattices a major question of interest to mathematicians and physicists alike concerns the derivation of various macroscopic, continuous PDE models, depending on the underlying scaling. Within mathematics, in the framework of multiscale analysis, progress has been made in recent years concerning the rigorous mathematical justification of the derived equations, for instance by using a modulation theory approach. Moreover, since the macroscopic limits obtained often turn out to have Lagrangian and Hamiltonian structure, the question arises how these effective structures are related to their discrete counterparts. In this talk we present a recent result obtained in joint work with Michael Herrmann and Alexander Mielke, Berlin, and consisting in a general approach for the derivation of the reduced (effective) Lagrangian and Hamiltonian structures of the macroscopic limits directly from the discrete structures of the nonlinear lattice. After presenting the method, we aim to illustrate its several aspects on various examples of derived macroscopic equations, such us the nonlinear wave equation, the KdV and nlS equations, and the three-wave interaction equations.

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MS41

Nontrivial Effects of Dissipation in BEC and Optical Cavities with Periodic Potentials

The presence of dissipative terms in models of Bose-Einstein Condensates (BEC) in optical lattices and of nonlinear cavities with photonic crystals results in intriguing effects such as self-localisation, suppression of modulational instabilities and novel classes of breathers and spatial solitons. We compare these dissipative structures with their conservative counterparts and investigate the role of losses in their formation and stability.

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MS41

Nonlinear Waves in Two-dimensional Lattices

Discrete solitons and more specifically kink-like topological excitations are ubiquitous structures that arise in numerous physical applications ranging from dislocations or ferroelectric domain walls in solids, to bubbles in DNA, or magnetic chains and Josephson junctions, among others. Hence one of the most important problems in discrete systems is the existence of travelling waves and uniform sliding states. We study travelling waves on a two–dimensional lattice with linear and nonlinear coupling between nearest particles and a periodic nonlinear substrate potential. Such a discrete system can model molecules adsorbed on a substrate crystal surface. The purpose of this talk is to show the existence of both uniform sliding states and periodic travelling waves as well in a two-dimensional Frenkel–Kontorova (FK) lattice equation using topological and variational methods.

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MS41

Long-term Behavior of Discrete Schrodinger Equations

In the study of the dynamics of DNLS with initial data close to a soliton, one represents the evolution as a finite dimensional systems of ODE's coupled with a DNLS perturbed by a decaying potential. In this talk, I will present show some technical linear estimates, which allows one to control the dispersive nonlinear evolution in the 1 D setting. In particular, these techniques will be useful, in a rigorous proof of nonlinear stability (in appropriate orbital, asymptotic etc. sense) for such equations, if one has linear stability. More generally, one may be able to use these techniques to construct global stable manifolds in unstable problems, as it has been done recently for the continuous NLS.

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MS41

Moving Solitons in Optical Systems with Lattice Potential

We study solitons in a fibre Bragg grating model with a harmonic superlattice. For this model a variety of stationary solitons have been shown to exist in bandgaps created by the superlattice. However, a linear analysis reveals that moving solitons will only exist in the form of quasi-solitons with oscillatory tails. We present numerical results and discuss generalizations to other models.

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MS41

Gap Solitons in Harmonic Superlattices

Solitons are studied in a model of a fiber Bragg grating (BG) whose local reflectivity is subjected to periodic modulation. The superlattice opens an infinite number of new bandgaps in the model's spectrum. Averaging and numerical continuation methods show that each gap gives rise to gap solitons (GSs), including asymmetric and double-humped ones, which are not present without the superlattice.Computation of stability eigenvalues and direct simulation reveal the existence of stable families of fundamental GSs filling the new gaps – also at negative frequencies, where the ordinary GSs are unstable. This is joint work with Boris Malomed, Thomas Wagenknecht, Ilya Merhasin and Alan Champneys.

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MS42

Validated Continuation

I will present a rigorous numerical method which combines topological tools with continuation algorithms. Using this method, we obtain proofs about the structure of the set of stationary solutions at roughly the same cost as the traditional continuation approach. Furthermore, the constructive nature of these techniques may be used to detect when and where further computations are required to uncover the desired structure. The Swift-Hohenberg and Cahn-Hilliard equations are used to produce sample results.

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MS42

Recent Developments in MatCont

We discuss the software packages Cl_MatCont, its GUI version MatCont and its version for maps Cl_MatContM, which are Matlab toolboxes for the study of dynamical systems. They were and are being developed in collaboration with Yuri A. Kuznetsov (Utrecht) and several PhD students at Ghent and Utrecht, in particular Annick Dhooge, Bart Sautois, Hil Meier and Reza Khoshsiar Ghaziani. The current versions are available at: http://matcont.ugent.be.

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MS42

Macroscopic Dynamics of Conservative Maps Under Parameter Variation

We numerically analyze the change in the macroscopic dynamical behaviour of certain conservative maps on the plane as a system parameter is varied. The analysis is based on the computation of the leading eigenfunctions of the transfer operator for a randomly perturbed version of the underlying map. We show how the corresponding eigenvalues depend on the noise level and present associated numerical examples. This is joint work with Igor Mezic and Jerrold E. Marsden.

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MS42

Periodic Orbit Continuation in Multiple Time Scale Systems

Continuation methods utilizing boundary value solvers are an effective tool for computing unstable periodic orbits of dynamical systems. The standard implementation for these procedures is AUTO, which often requires very fine meshes on problems with multiple time scales. We will explore alternate strategies based on geometric singular perturbation theory for computing periodic orbits in these systems.

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MS42

Numerical Bifurcation Analysis, An Overview

This talk serves as an overview of the symposium. We will give a brief introduction to the subject of numerical bifurcation analysis, indicate active areas of research and put the topics covered by the symposium speakers into a historical context. The talk will also present some results of the author on the computation of invariant tori and the numerical analysis of Arnol'd tongue scenarios.

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MS42

Numerical Contination of Hamiltonian Relative Periodic Orbits

Recently there has been a lot of progress in the development of a general bifurcation theory of relative periodic orbits (RPOs) in Hamiltonian systems. In this talk we present numerical methods for the continuation of Hamiltonian RPOs. We apply our methods to continue the famous Figure Eight choreography of the three-body system to nonzero angular momentum, find a relative period-doubling bifurcation along the branch of rotating choreographies and compute the bifurcating branch.

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MS43

Measurable Dynamics, Partitions, Basin Information and Other Ergodic Quantification of Dynamical Systems, with Measures of Model Quality

Partitioning phase space of a dynamical systems with intricate basin structures is a critical step in understanding model behavior, such as basin hopping. We show a new graph theoretic approach to this problem capable of dealing with nondiagonalizable problems. Since issues of partitioning and modeling a dynamical system are intimately related to how two dynamical systems are considered either the same (topologically conjugate) or not, we will quantify our new “defect measure of almost conjugacy.

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MS43
Panel Discussion

Discussion.

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MS43
Optimal Control of Mixing in Stokes Fluid Flows

Motivated by the problem of microfluidic mixing, the problem of optimal control of advective mixing in Stokes fluid flows is considered. The velocity field is assumed to be induced by a finite set of spatially distributed force fields that can be modulated arbitrarily with time and a passive material is advected by the flow. To quantify the degree of mixedness of a density field, we use a Sobolev space norm of negative index. We pose a finite-time optimal control problem where we aim to achieve the best mixing for a fixed value of the action (time integral of the kinetic energy of the fluid body) per unit mass. We derive the first order necessary conditions for optimality that can be expressed as a two point boundary value problem and we discuss some elementary properties that the optimal controls need to satisfy. A conjugate gradient descent method is used to solve the optimal control problem and we present numerical results for two problems involving arrays of vortices. A comparison of the mixing performance shows that optimal aperiodic inputs can do better than periodic inputs.

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MS43
On Inverse Problems in Measurable Dynamics: Inferring Infinitesimal and Frobenius Perron Operators from Observed Data Movies of Density Evolution

To construct the transfer operator from an image sequence we are required to have knowledge of a family of transformations. However, a sequence of images does not provide a direct access to the motion of a point in a phase space. Instead it only describes evolution in time of brightness patterns. Therefore, we present a technique to estimate a velocity field from an image sequence and its application to approximate the transfer operator.

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MS43
A Preliminary Look at Characterizing Flows using Deviation from Ergodicity

A new multiscale approach for characterizing flows is introduced. Scaling analysis is based on wavelets and the flows are distinguished according to deviation from ergodicity. Several well-known examples of dynamical systems are considered in a setting that builds intuition. The ideas are theoretically based in dynamical systems, ergodic theory and harmonic analysis and the motivation comes out of ocean science and engineering applications.

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MS43
Towards Practical Ergodic Theory for Hamiltonian Systems

Molecular dynamics refers to the computer simulation of material systems at the atomic level. In order to provide a rigorous foundation for the algorithms of molecular dynamics it is necessary to understand the ergodic properties of the relevant Hamiltonian flows. Unfortunately, much of the ergodic theory that has been developed for smooth systems does not apply to systems arising in Molecular Dynamics. I will explain the difficulties in this area and discuss some recent work on the problem.

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MS44
Fractional Diffusion Models of Anomalous Transport in Finite Size Domains

Fractional diffusion models of anomalous transport usually assume unbounded domains. This assumption simplifies the analysis but it is physically unrealistic and numerically problematic. Here we discuss how fractional models can be formulated and solved in finite size domains with boundary conditions. This requires the regularization of the Riemann-Liouville fractional derivative. Various applications are discussed including: non-local transport in fusion plasmas, anomalous diffusion in molecular clouds, and front propagation in the fractional Fisher-Kolmogorov

equation.

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MS44

From Diffusion to Anomalous Diffusion: Subdiffusion and Levy Walks

We review anomalous diffusion processes with emphasis on subdiffusion, which is widespread in many complex systems. We consider in particular the case of subdiffusion which corresponds to a continuous-time random walk process in which the waiting time for a step is given by a probability distribution with a diverging mean value. Relationships to the fractional diffusion or Fokker-Planck equations and their generalizations will be discussed. Special attention will be given to the problem of the initial conditions and the corresponding aging process. We will highlight recent results on linear response of a continuous-time random walk systems to a time-dependent field.

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MS44

Step-Flow Growth with Anomalous Diffusion

The growth of a stepped crystal surface by molecular beam epitaxy is investigated in the case when the adatom diffusion is a Levy walk. The analog of the Burton-Cabrera-Frank theory for the case of a Levy walk type surface diffusion is developed. The step-flow velocity is obtained as an eigenvalue of the corresponding boundary-value problem described by a fractional PDE. The resulting crystal surface growth rate is found as a function of the terrace length and the anomalous diffusion exponent.

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MS44

Reactions Among Subdiffusive Species

We present a number of analytic and simulation results for binary reactions among subdiffusive reactants that may be characterized by different anomalous diffusion exponents. The reaction kinetics in such systems are in general entirely different from those of diffusive systems and can often not be understood by simple subordination arguments.

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MS44

Instabilities in Anomalous Diffusion-Reaction Systems

Pattern formation in anomalous diffusion-reaction system is considered in two non-trivial cases: (i) Turing instability in sub-diffusive systems for 3 pertinent models; (ii) long-wave oscillatory instability in super-diffusive systems. In the case (i), stability characteristics of the 3 models are derived and compared. In the case (ii), super-diffusive modifications of the complex Ginzburg-Landau equation and the Kuramoto-Sivashinsky equation have been derived and investigated.

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MS44

A Hybrid Discrete-continuous Anomalous Diffusion Model of Angiogenesis

Angiogenesis, the formation of new blood vessels from existing vasculature, involves endothelial cell migration, which has a stochastic component and is also affected by chemotaxis. We propose and study a model of cell migration in which the cells are treated as discrete objects while the chemoattractant concentration is continuous. The waiting times between successive movements of a cell can be rather long resulting in anomalous diffusion. This is work in progress.

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MS45

Travelling Waves on Lattices Defined by Car-following Models

We consider the dynamics of microscopic car-following models on an infinite highway. Such models take the form of a lattice differential equation system, whose travelling wave solutions are defined by a delay differential equation boundary value problem. When reaction times are included, advanced-retarded FDE problems arise. We will use manifold dimension counting arguments to analyse the genericity of such solutions, and numerical continuation techniques to determine domains of existence and solution forms.

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MS45

Bifurcations of Rotation Solutions: An Accurate Way to Describe Car-following Circle-models with Road Works

Microscopic car-following models usually describe the movement of N cars on a circular road. It is very common to perform a stability and bifurcation analysis of those solutions that are constant in headways and velocities. By a generalization of these quasi-stationary solutions with *rotations* we are able to understand a wider range of traffic phenomena, e.g. a road works scenario. From the theoretical point of view we show the existence of Neimarck-Sacker bifurcations and so-called *tube solutions*, that bifurcate from the homogeneous traffic situation.

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MS45

Emergent Macroscopic Dynamics of Multi-Lane Traffic Models

We investigate altruism versus aggression in the microscopic behaviour of multi-lane traffic models. The emergent dynamics is quantified through macroscopic performance measures, such as mean velocity. We look for transitions in these measures to states where aggression impedes the individual or, in the extreme case, the system as a whole, and we bound these transitions in parameter space.

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MS45

Overview of Dynamical Systems Problems in the Modelling of Highway Traffic

In this talk I will describe the key spatiotemporal features of empirical highway traffic data and I will summarise their 50 year old modelling history. I will then focus on the nonlinear stability of microscopic car-following models in particular, and I will show how dynamical systems techniques may be used to understand the fundamental mechanisms behind traffic jam generation. Finally, I will illustrate connections to macroscopic PDE theory and outline possible future directions.

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MS46

Stochastic Synchronization Over Moving Neighborhood Networks

We examine synchronization for a group of dynamic agents that communicate via a moving neighborhood network. Each agent is a random walker in a finite lattice and carries an oscillator. Information sharing is possible only for neighboring agents. We introduce the concept of long-time expected communication network defined as the ergodic limit of the stochastic network. We show that the system synchronizes if the long-time expected network supports synchronization and the agents diffuse sufficiently fast.

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MS46

Designing Synchronizable Networks via the Laplacian Spectrum

Synchronization of oscillators coupled diffusively over complex networks requires stability of the synchronized state. This stability depends on the spectrum of the discrete (graph) laplacian for the network. Relationships between that spectrum and other measures of network structure are not well understood. We explore these relationships by examining network construction models which allow design of important features of the laplacian spectrum.

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MS46

Pinning-controllability of Complex Networks

We study the problem of controlling a general complex network towards an assigned reference evolution by means of a pinning control strategy. We define the pinning-controllability of the network in terms of the spectral properties of an extended network topology. The role of the control and coupling gains, as well as of the number of pinned nodes is further discussed.

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MS46

Fractal and Transfractal Scale-Free Nets

We explore self-similarity, dimensionality, and (multi)scaling in a new family of recursive scale-free nets that yield themselves to exact analysis through renormalization techniques. All nets in this family are self-similar and some are fractals — possessing a finite fractal dimension — while others are *small*

world and infinite-dimensional. We introduce a *transfinite* dimension that characterizes the peculiar scaling of small-world nets. In scale-free nets, first-passage time for diffusion and resistance between *hubs* (the most connected nodes) scale differently than for other nodes. Nevertheless, the Einstein relation for diffusion and conductivity holds separately for the two node subsets. The new nets let us distinguish between the effects of small-world diameter and scale-free degree-distribution for the first time.

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MS47

Coherent Dynamics in Stochastically-forced Excitable Systems

We analyze a family of motor protein models and show that there are generic organizing principles which lead to regular behavior in the motor dynamics. Further, we show that this analysis explains numerical observations made in certain models: specifically, those modelling myosin-V during vesicle transport and myosin-II during muscle contraction.

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MS47

Noise Enhanced Coding with Dynamic Subthreshold Negative Feedback

The increased awareness of fluctuations in biological systems has motivated the field of noise enhanced signal coding (i.e. stochastic resonance, SR) in excitable systems. We show that phasic systems (excitable systems which selectively respond to high frequency stimuli) show and extreme sensitivity to fluctuations allowing noise to effectively gate spike responses to slow inputs. This effect depends on a dynamic subthreshold feedback placing this result as both distinct from and complentary to classic SR.

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MS47

Optimal Time Scale for Spike-time Reliability and Stochastic Synchronization in Real Neurons

Constant stimuli result in spike times that are highly variable from trial to trial. By contrast, neurons fire spikes in response to repetitions of a rapidly fluctuating stimulus in a highly reproducible manner. Combining computer simulations, stochastic theory and whole cell recordings from olfactory bulb mitral cells and neocortical pyramidal cells we have shown that: 1) there is an optimal time scale of the stimulus fluctuations that maximizes reliability; 2) reliability increases with increasing amplitude of the input fluctuations. The optimal time scale turns out to be between 3 and 6 ms. As for the amplitude of the input, already 50% of the spikes are reliable as soon as the input fluctuations doubles the background input noise (ca. 10 pA). Our findings on reliability are immediately applicable to stochastic synchronization, where neurons receiving random but spatially correlated signals trigger synchronous spikes.

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MS47

Balancing at Stability's Edge

The neural control of balance involves processes that operate on multiple time scales. Parametric noise provides fast control, i.e. time scales short compared to the neural latency, whereas on longer time scales, time-delayed feedback and intentionally directed movements are involved (slow control). Mathematical descriptions lead to a novel class of stochastic delay control problems. Paradoxically, these models predict that the risk of falling becomes smallest when the system is tuned at the edge of stability and stochastic control predominates.

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MS48

Instabilities in Free-electron Lasers: Spatio-temporal Dislocations, and Hypersensitivity to Noise

We present a combined experimental/theoretical analysis of pulse evolutions in Free-Electron lasers. Nontrivial dynamics arises from the coexistence of convection and diffusion, leading to strong noise amplification. The transition to "turbulence" occurs through the occurrence of spectro-temporal defects. The present scenario appears in fact more general, as it can be reproduced by a real Ginzburg-Landau equation with nonuniformities and advection. Feedback control of the convective instabilities will be also addressed (numerically and experimentally).

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MS48

Complex Spatiotemporal Dynamics and Synchronization of Fiber Ring Lasers with Time Delayed Coupling

The dynamics of mutually delay-coupled erbium doped fiber ring lasers is studied by measuring the intensity fluctuations of the lasers. For comparison, we study a single ring laser with a second feedback loop. The delay time is varied over five orders of magnitude. The complexity of the dynamics increases with delay, yet excellent synchrony is maintained. Theoretical models and simulations provide insight into the dynamics of large numbers of interacting, coupled nonlinear oscillators.

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MS48

Polarization Dynamics of Semiconductor Lasers Subject to a Delayed Feedback

The response of edge emitting lasers subject to a delayed polarization-rotated optical feedback is studied both experimentally and theoretically. Square-wave self-modulated polarization intensities of a period close to twice the delay of the feedback gradually appear through a sequence of bifurcations. An asymptotic analysis of the laser equations in the limit of large delays leads to a condition for the square-wave oscillations. It explains why they are preferentially observed for sufficiently large feedback strength.

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MS48

Laser Electro-optical Delay Dynamics Generating Queued Mice and Elephants

Broadband electro-optical delay oscillator have been recently explored experimentally for chaos based communication purposes. Through their multiple, well controlled, and well separated characteristic time scales, they are intrinsically capable of producing on a wide temporal range, very different and complex dynamical behavior. We will report on their experimental analysis in the time and spectral domain, proposing dynamical mechanisms related to the physical structure of the nonlinear delay integro-differential equation modeling the experiment.

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MS49

Computing Global Decompositions of Dynamical Systems

Conley Theory has been an important tool for the topological analysis of dynamical systems. Recent results provide an algorithmic framework in which to develop computational tools for the study of the dynamics of continuous maps. Using software to compute the homology of maps, one can not only obtain coarse descriptions of global dynamics but also give rigorous proofs of the existence of certain localized dynamical structures such as periodic orbits, connecting orbits, and chaotic sets.

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MS49

Chaotic Braided Solutions Via Rigorous Numerics

In this talk, we will give a proof of existence of chaos in the sense of symbolics dynamics for the parameter dependent Swift-Hohenberg equation $(\nu - 1)u - 2u'' - u'''' - u^3 = 0$ for many different values of $\nu \in \mathbf{R}$. The first part of the proof relies on a rigorous continuation method to extract a skeleton of periodic orbits when the Hamiltonian is zero. The second part makes use of the skeleton to force the existence of infinitely many chaotic braided periodic orbits.

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MS49

Closed Characteristics on Non-compact Energy Surfaces

The study of periodic solutions of Hamiltonian equations has a long history, and a variety of results is known for compact energy levels (all motions are bounded a priori). In this talk we will consider Hamiltonians coming from classical mechanics and leading to non-compact energy manifolds. We use a variational formulation to prove that there must be at least one periodic motion on each energy level that satisfies certain topological and geometric conditions.

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MS49

Floer Homology for Braids on the Two-disc

Our goal is to prove forcing results for periodic solutions of Hamiltonian system on the two-disc. The main idea is to model such solutions as braids. For various types of braids we can define an invariant - Floer homology. The latter can be computed using Conley index theory for positive braids.

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MS50

Heterogeneity Stabilized Pattern Co-Existence in the Belousov-Zhabotinsky Reaction

We use the oscillatory Belousov-Zhabotinsky (BZ) chemical reaction as an experimental test bed to study resonant pattern formation in the presence of spatial inhomogeneity. We observe collisions of traveling waves with standing waves, stable spirals rotating at different frequencies, and phase wave pacemakers. These states are not observed in homogeneous conditions. We will discuss how heterogeneity stabilizes the co-existence of different patterns.

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MS50

Period-doubling of Coherent Structures

Motivated by experimental observations in the light-sensitive BelousovZhabotinsky reaction and subsequent numerical works, we discuss period-doubling bifurcations of spiral waves and other coherent structures. We report on explanations of the observed phenomena which involve a detailed analysis of spectra, and of the associated eigenfunctions, of defects on bounded and unbounded domains.

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MS50

Three-dimensional Wave Patterns in Excitable Media

We present results on the nucleation, the dynamics, the interaction and the annihilation of scroll rings in three-dimensional excitable systems. We investigate the influence of anomalous dispersion on these excitation vortices. Such anomalies can give rise to novel nucleation scenarios of scroll rings and also induce unexpected situations in which filaments terminate in the back of a moving excitation pulse. We will discuss the nucleation and interaction of closely stacked pairs of scroll rings.

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MS50

Spiral-wave Breakup in Excitable Media

Spiral waves in excitable reaction-diffusion systems can break up into a state of spatio-temporal chaos. The breakup may occur near the spiral tip (core breakup) or far from the tip (far-field breakup). Past analyses of these phenomena have been almost exclusively based on the study of 1D wave trains. This talk focuses on the computation of linear stability spectra and nonlinear simulations of spiral waves on large 2D disks.

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MS51

Gamma Oscillations and Attention

Gamma frequency (approximately 40 Hz) oscillations in electrical fields in the brain are known to be correlated with various forms of attention. I will talk about mechanisms underlying gamma oscillations, and about ways in which these oscillations may be functionally important in vigilance and selective attention. In particular, I will present numerical experiments and analysis suggesting that gamma oscillations promote competition among neuronal ensembles and help protect stimuli against distractors. This is work done in collaboration with Nancy Kopell and Steven Epstein.

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MS51

Travels in a Dynamic Entorhinal Cortex: An Experimental Walk

The entorhinal cortex (EC) is a critical interface between the neocortex and the hippocampus. *In vivo* studies show that the EC can adopt a number of dynamic states. Work in my laboratory has concentrated on the ability of the EC to generate different types of network oscillations (<1 Hz - >100 Hz) *in vitro*. I will demonstrate the experimental and computational approaches that have been adopted to understand the neuronal networks underlying this activity.

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MS51

Elucidation of Gamma Rhythm Switches in the Entorhinal Cortex as Observed in Vivo and In Vitro: A Modeling Study

Gamma rhythms are present in the entorhinal cortex during exploratory behavior in vivo and can be induced with kainate in vitro. In pharmacological and genetic models of schizophrenia gamma rhythms are disrupted. I will present a model of entorhinal cortex that reproduces data from these studies and elucidates the mechanism of gamma disruption. The model proposes novel gamma generating microcircuits and suggests that these alternate gamma generators are active during schizophrenia-like regimes.

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MS51

Binless Correlation Measures for Rhythmic Activity in Multiunit Neural Place Field Data

Measures of spike train correlation based on fixed width bins introduce quantization noise that obscures the rhythmic structure in multiunit spike train data. We show that an alternative binless correlation measure (Hunter et al, J. Neurophys 1998; Schreiber et al, Neurocomputing 2003; Fellous et al, J. Neurosci 2004) eliminates the quantization noise and significantly strengthens evidence for memory trace reactivation in rat hippocampal place cell ensemble recordings.

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MS52

Combustion Wavespeed Correction at High Lewis Numbers

The wavespeed of a one-dimensional adiabatic Arrhenius wavefront in the limit of high Lewis number (Le) is examined. A novel application of Melnikov's method leads to a perturbative theory for the wavespeed correction to Le $= \infty$ (no fuel diffusivity). Excellent agreement with numerics is obtained. This method is usable in coupled reaction-diffusion equations involving a parameter $\epsilon \ll 1$, which possess a conserved quantity when $\epsilon = 0$.

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MS52

Stability Analysis of Combustion Wavefronts at a High Lewis Number

The stabiliity of a one-dimensional adiabatic Arrhenius wavefront in the limit of large Lewis number is examined. Two cases are considered for the Lewis number: infinite value and large but finite values. The analysis is done with a numerical Evans function calculation based on the method introduced by Bridges and Derks in 1999. Our stability analysis is in agreement with results obtained previously.

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MS52

Oscillatory Dynamics in a Reaction-diffusion Sys-

tem Describing an Anchored Flame

A minimal model for a porous burner flame is a reaction-diffusion system involving the temperature and the mass fraction of the reactant, the first equation being posed on the half line and the second being posed on the real line. The physical situation is thus the following: a reactant is flown through an isothermal pipe into a region where it will react, thus creating a flame which stays bounded away from the aperture of the pipe. In the limit of large activation energies, a paper by G. Joulin derives, in the formal style, a differential-delay equation for the dynamics of the flame. The goal of this talk is to discuss a rigorous proof of that fact.

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MS52

Stability of Fronts in Gasless Combustion

For gasless combustion in one space dimension, we study convective stability of the combustion front with smallest wave speed. We prove that for all values of the exothermicity parameter, the stability index ($\operatorname{sgn} E'(0) \cdot E(\infty)$, where $E(\lambda)$ is the Evans function) is $+1$. A stability index of $+1$ is consistent with nonexistence of positive real eigenvalues. This result indicates that the front can only lose stability due to a Hopf bifurcation, which is consistent with numerical and other evidence.

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MS53

Effective Hamiltonian and Lagrangian Structures in Multiscale Systems

The derivation of macroscopic PDEs from microscopic ODEs is a fundamental problem in continuum physics. We present a general framework to derive effective macroscopic Hamiltonian structures directly from their microscopic counterparts. The approach employs an embedding of the discrete variables, exact two-scale transformations that take care of the scaling of time and space, and several reduction principles. For illustration we study various continuum limits of the atomic chain, with emphasis on modulations of oscillatory patterns.

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MS53

Longtime Validity of Boltzmann Equations for Hard-sphere Dynamics

The derivation of the continuum models from determistic atomistic descriptions is a longstanding and fundamental challenge in mathematical physics. In particular the emergence of irreversible macroscopic evolution from reversible deterministic microscopic evolution is still not fully understood. We study a classic system of N balls that interact with each other via a hard-core potential in the gainless case (particles anihilate each other upon collision). The asymptotic behavior as N tends to infinity is proved to be correctly described by the Boltzmann equation without gain-term for non-concentrated initial distribution. The mean-field description fails, when there are concentrations. These results pave the way towards a mathematical justification of the full Boltzmann equation.

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MS53

Justification of Coupled-mode Equations for Gap Solitons in Optical Lattices

Coupled-mode systems are used in physics literature to simplify the nonlinear Maxwell and Gross-Pitaevsky equations with a small periodic potential and to approximate stationary localized solutions called gap solitons by analytical expressions involving hyperbolic functions. We justify the use of the one-dimensional coupled-mode system by employing the method of Lyapunov–Schmidt reductions in exponentially weighted Sobolev spaces. In particular, convergence of iterations is proved and the error terms for exponentially decaying solutions are controlled. The coupled-mode system is also justified for multi-dimensional periodic solutions. We show however that the method of iterations fails for localized solutions in small multi-dimensional periodic potentials.

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MS53

Dispersive and Non-classical Shocks in Continuum Limits of FPU Chains

We consider the continuum limit of FPU chains under hyperbolic scaling of particle index and time for shock-type Riemann problems. The measure valued limit conserves mass momentum and energy, ruling out Lax shocks. For the Toda potential and zero dispersion limits of some PDEs it is known that shocks are dispersive. Recently, Whitham modulation equations of wave trains were formally deduced to describe the arising oscillations. We numerical confirm this and present evidence that for non-convex flux shocks can be undercompressive, i.e. non-classical.

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MS54

Modeling of Glial Cells in Neural-glial Networks

In the brain, glial cells are known to affect neuron firing patterns, however the mechanism(s) remain unknown. One experimental observation is that the glia near a neuron facilitate neuron communication while suppressing communication at more distant neurons via a reaction-diffusion process. We consider a proposed mechanism for this local facilitation and distant suppression using simple PDE and ODE models. We then examine the effect of model glial cells on a network of neurons.

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MS54

The Infinite Population Genetic Algorithm: A Dynamical System with Generic Properties

Genetic algorithms are a class of stochastic search algorithms based on natural selection. The infinite population model for the genetic algorithm, where the iteration of the genetic algorithm corresponds to an iteration of a map G, is a discrete dynamical system. The map G is a composition of a selection operator and a mixing operator, where the latter models the effects of both mutation and crossover. This presentation first offers a brief introduction to genetic algorithms and the corresponding dynamical systems model, it then examines the finiteness and hyperbolicity of the fixed points of this model. For a generic mixing operator, the fixed point set of G is finite and all fixed points are hyperbolic.

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MS54

Dynamical Properties of Biochemical Reaction Networks

Dynamics of interactions in biochemical reaction networks are an important problem in modern cellular biology. Mathematical models of biochemical reactions are usually large systems of coupled nonlinear differential equations with many unknown parameters, making direct numerical simulations practically impossible. Subnetworks of positive/negative cycles in a bipartite graph associated with a biochemical reaction can be used to predict multistability or oscillations. In more complicated models, the instabilities can be caused by diffusion or delays.

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MS54

On the Dynamics of Some Nonlinear Discrete Models

This talk deals with a brief presentation of some of the global asymptotic stability techniques employed in the study of nonlinear difference equations and systems of difference equations. These techniques are then applied to selected discrete models.

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MS55

Nonlinear Wave Combining in Two-Dimensional LC Lattices

In a nonlinear medium, constructive interference of two incoming waves with identical amplitude A can yield an outgoing wave with amplitude much greater than $2A$. A two-dimensional lattice of inductors and voltage-dependent capacitors features such phenomena. We discuss techniques for analyzing the high-dimensional, spatially extended dynamical system that governs lattice voltage and current. The wave combining we describe is of great potential use in high-speed analog electronics.

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MS55

Interaction of Discrete Breathers in Fermi-Pasta-Ulam Chain

Based on a regularized PDE model (Physica D 214 (2006) 33), we study the interaction of two moving discrete breathers in one-dimensional Fermi-Pasta-Ulam chain. We derive a reduced set of ordinary differential equations following a method of direct soliton perturbation by Jianke Yang, which in good agreement with a heuristic model given by Doi (Phys. Rev. E 68 (2003) 066608). Thus, a theoretical explanation is given for the energy exchange mechanism in the collision of discrete breathers of FPU chain.

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MS55

Chaotic Scattering in Solitary Wave Interactions

We demonstrate the reduction of the n-bounce resonance, a well known phenomenon in solitary wave collisions, to a discrete-time variant of the conservative Ikeda map. Above some critical velocity v_c, waves simply simply bounce off each other. Below v_c they may be captured and merge into a single localized mass, or they may interact n of times before escaping. Whether they are captured, and the value of n, depends fractally on their velocity. We explain this behavior showing how phase-space transport theory (turnstile lobes) interacts with the location of certain singularity regions in the phase-plane.

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MS55
Discussion

Discussion

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MS55
Solitary Waves in Discrete Media in the Presence of Four-Wave Mixing Products

In this talk, I will discuss solutions that arise in a vector discrete model of the Nonlinear Schrödinger equation where nonlinear inter-component coupling and four-wave mixing are taken into account. We show that the solutions to this model give rise to two single mode and two mixed mode branch solutions. These solutions are obtained explicitly and their stability is analyzed in the so-called anti-continuum limit.

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MS55
Nonlocal Traveling Waves in Heated Parametric Gain Devices

We consider the parametrically driven nonlinear Schroedinger equation coupled to a diffusion equation as a model for self-induced heating in the large-detuning mean field limit of an optical parametric oscillator. We show that the nonlocal detuning induced by the temperature gradient creates new travelling wave solutions. We analyze the existence and stability of these solutions using a collective coordinate reduction.

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MS56
Quotient Coupled Cell Networks

Quotient networks are associated with coupled cell systems restricted to flow-invariant subspaces defined by equality of certain cell coordinates. Given a (quotient) network, we describe a general method to construct coupled cell networks admitting it as a quotient; we investigate the impact of a codimension-one synchrony-breaking bifurcation from a synchronous equilibrium leading to branches of solutions (steady-state or periodic) of the quotient network, for the different networks admitting it as a quotient network.

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MS56
Coupled Cell Systems and Dynamics on a Spatial Domain

I will present a class of systems of ODEs – called "pod systems" – as a tool for analyzing certain aspects of dynamical systems defined on a spatial domain that are problematic for the standard PDE approach. These systems fit into the coupled cell framework in virtue of the fact that they are $\mathbf{S_N}$-equivariant; homogeneous coupled cell systems with all-to-all coupling. Most of the talk will focus on the dynamics of density distribuitions over a one-dimensional domain, but I will discuss some generalisations. An interesting feature of pod systems in this context is that fully symmetric equilibria correspond to unimodal distributions rather than the spatially homogeneous solutions typical of PDEs. It is thus possible to consider symmetry-breaking bifurcations from these equilibria, where we find that generically there exists a unique branch of bimodal distributions emanating from the bifurcation point. Pod systems grew out of the question of "sympatric speciation" in evolutionary biology, and I will briefly discuss the ramifications of pod systems in that field.

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MS56
Bifurcations in Coupled Cell Systems

Bifurcations in coupled systems consisting of identical units have many parallels with systems with symmetry including multiple eigenvalues, multiple solutions, and periodic solutions with spatio-temporal symmetries. In this lecture we present recent bifurcation theoretic results.

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MS56
Synchrony of Two Coupled Nerve Cells

Consider two nerve cells with Hodgkin-Huxley dynamics, where the state of each cell modifies the the other. Under what conditions will they synchronize? The answer

depends on the definition of synchrony. Taking synchrony to mean the two cells have the same behaviour at the same moment, it will always ocour for strong enough coupling and for most initial conditions if the coupling is symmetrical. For weak asymmetric coupling, other forms of synchrony appear.

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MS56

Robust Heteroclinic Networks of Cluster States in Coupled Phase Oscillator Systems

A highly connected network of coupled phase oscillators is considered. Partially synchronized states are found each containing three clusters of synchronized oscillators. An attracting heteroclinic network is detected which connects the cluster states resulting 'winnerless competition' dynamics between them. We investigate the effects of detuning, noise and external inputs as well as the effects of parameter changes in the system. The explored robust dynamics qualitatively explains the information processing in simple neural systems.

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MS56

Hopf Bifurcation in the Network of the Canals and Neck Muscles

The vestibular system in most vertebrates, humans included, controls balance by six semicircular canals to detect angular accelerations of the head motion. Signals from the canals are transmitted to eight groups of neck motoneurons thus the eight corresponding muscle groups. Through symmetry architecture and coupled cell network, we show that there are six possible spatiotemporal time-periodic states, arised by Hopf bifurcation from an equilibrium, are correspondent to natural head motions.

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MS57

Action Potential Propagation in Dendrites with Non-uniform Morphology and Voltage-gated Channel Properties: Predictions of Local Traveling Wave Attractors

Dendrites of many classes of neurons express voltage-gated sodium channels and are able to actively propagate action potentials generated in the axon. These backpropagating action potentials play an important role in synaptic plasticity and synaptic integration. Action potential propagation in dendrites is complicated by non-uniform morphology and voltage-gated channel distributions and properties, and as a result, action potential amplitude can vary with distance from the axon. In some cases, amplitude can suddenly begin to decline rapidly, a phenomenon called backpropagation failure. We show that local traveling wave attractors can be used to understand and predict changes in action potential amplitude due to the non-uniformities found along these dendrites. Attractor disappearance (bifurcation) can lead to rapid amplitude decline and may explain experimentally observed propagation failures. By computing these underlying attractors, and combining predictions with multicompartmental simulations, one is able to dissect effects on propagation due to morphology from those due to channel properties. Propagation failures are commonly due to changes in channel properties. Failures can also occur due to severe branch points, but only when channel properties leave the dendrite susceptible to this.

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MS57

The Dynamics Between Electrical Activity and Restructuring in Dendrites

The morphology of a dendrite influences patterns of electrical and chemical activity in the cell. Conversely, electrical and chemical activity can change the morphology of the dendrite. Two problems are presented to illustrate the dynamics. The first is an idealized model of a passive cable with an active soma capable of elliptic bursting. The second problem is a mathematical model for calcium-mediated spine restructuring in a dendritic cable with many spines.

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MS57

Modeling Calcium in Dendrites and Spines

Calcium is an essential messenger that can initiate many cascades of chemical reactions and regulate physiological basic functions, such as synaptic plasticity, A dendrite is a complex domain, containing a cytoplasmic fluid and many organelles, such as endoplasmic reticulum, actin filaments, microtubules and many others that may affect the diffusion process. Active processes such as calcium pumps, buffers, stores and the presence of dendritic spines control the propagation of the calcium signal. We would like to present a recent model in which we estimated the effect of these different parameters in calcium dynamics. When calcium concentration is raised in a part of a dendrite, it is not clear how far from the initial source, a detectable calcium concentration will spread. We present some results about calcium spread by taking into account the geometry of the dendrite and the effect of the organelles that reduce the free space available for calcium diffusion. In this approach,

the three dimensional diffusion in a crowded dendrite is approximated by a one domensional diffusion. Calcium imaging techniques are used to compare the theorectical predictions with the experimental data.

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MS57

Pyramidal Neurons as Multi-layer Networks

The question as to what is computed by an individual nerve cell remains a central open question of neuroscience. The traditional view that a neuron applies a single global threshold to its integrated excitatory and inhibitory inputssometimes called the point-neuron hypothesis (PNH)has been under steady attack since the 1980's. Given experimental and modeling studies indicating that the dendritic trees of CNS neurons are electrically compartmentalized, and are capable of generating localized spikes and plateau potentials, the PNH no longer seems tenable. What, then, is the proper simplifying abstraction of the single neuron? This talk will focus on the pyramidal neuron (the principal neuron of the hippocampus and neocortex), and will cover recent experimental and modeling studies suggesting that individual pyramidal cells function as subunitized multi-layered networks. We will then discuss variety of ways in which the computing properties of individual pyramidal cells could contribute to the sensory and memory-related functions of the embedding neural circuit.

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MS57

Conditions for the Initiation and Propagation of Spikes in Neuronal Dendrites

Excitable dendrites of many types of neurons can generate regenerative spikes during strong synaptic input. We map local conditions for dendritic spike initiation and propagation in compartmental models of neocortical pyramidal neurons and cerebellar Purkinje cells. We conclude that long, thin branches of pyramidal neurons and Purkinje cell spiny branchlets define functional units in which dendritic spikes are initiated preferentially while their spread is usually limited to the unit in which they were initiated.

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MS57

Trips and Resonant Membranes: On the Dynamics of Branched Dendrites

The dendrites of many nerve cells are complex branching structures that receive and process thousands of synaptic inputs from other neurons. By extending the 'sum-over-trips approach of Abbott et.al. (Biol. Cybern., 1991) we will describe a mathematical technique that allows one to determine the role of quasi-active membranes in dictating somatic response to injected current. To illustrate the power of this formalism we use it in conjunction with dual recording and cell reconstruction data.

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MS58

Numerical Continuation for Neutral Delay Systems: Application to an Electronic Oscillator

Complex delay-induced dynamics can be found in very simple practical applications. We illustrate this here by investigating the global dynamics of an electronic oscillator using newly developed bifurcation analysis tools for neutral delay systems. The oscillator is built from just a transmission line terminated by a diode and a negative resistor, and yet we are able to show the existence of complicated dynamics that is organised by a nearby homoclinic orbit.

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MS58

Neutral Delayed Dynamics in an Electronic Oscillator

We describe a chaotic transmission-line oscillator that appears particularly well suited for low-cost radar applications. The device consists of a linear transmission line terminated with a negative resistance and a diode. Despite its incredibly simple construction, the oscillator is modeled by a neutral delay differential equation due to the finite bandwidth of the negative resistor. We report experimental observations of complex dynamics in implementations using coaxial cable (¡100MHz) and micro-strip lines (200MHz).

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MS58

Chemical Oscillators Subject to a Delayed Feedback

Weiner et al (1989) and Beta et al (2003) investigated experimentally a chemical oscillator subject to a delayed feedback. They independently found that the period of the homogeneous oscillations as a function of the delay exhibits a sequence of bistable responses. We propose to explain this phenomenon by studying the Van der Pol oscillator. In the case of the relaxation oscillations, we derive a new delay differential equation for the phase of the oscillations.

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MS58

Of Random Time Delays, Rabbits, and the Visible Points of the Integer Lettuce

The analysis of digital control systems with random time delays gives rise to jump linear systems, where the transition jumps are modeled with an underlying finite-state Markov chain. One of the simplest such model is the so-called random Fibonacci sequence. We show some beautiful connections between the random Fibonacci recurrence, the visible points of the plane, the random walk on the induced self-similar graph, and the generalized Catalan numbers.

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MS58

Overcoming Delay-induced Essential Instabilities in Mechanical Stability Tests

Realistic tests in engineering often involve bidirectional real-time coupling between computer simulations and mechanical experiments. If this coupling occurs at a fixed joint then arbitrarily small delays in the coupling can result in essential instabilities, which are impossible to compensate. We present an approach that is able to overcome this difficulty. Our method has the additional advantage that it enables pseudo-arclength embedding and direct continuation of bifurcations in this type of hybrid experiments.

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MS58

Modeling Machining Instabilities and the Pupil Fight Reflex: DDEs with Non-smooth Parametric Forcing

Delay differential equations are ubiquitous in the modeling of physical phenomena, from such diverse areas as physiology and metal cutting. We have studied DDEs that arise in modeling chatter in drilling operations, and here we present work on a similar system with discontinuous parametric forcing (through episodic friction on the work piece) or impacts. This, it turns out, also describes the situation with the pupil light reflex (where the delay is the pupil latency time).

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MS59

Controlling Canards Using Ideas from the Theory of MMOs

We present a control mechanism for tuning a system to operate in the canard regime, the tiny parameter window between small and large orbits for fast-slow dynamical systems displaying periodic behavior. Our control strategy uses continuous feedback control, and is based on ideas from the theory of mixed-mode oscillations. We apply this to tune the FitzHugh-Nagumo model to produce maximal canard orbits. When the controller is improperly configured, periodic or chaotic mixed-mode oscillations are found.

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MS59

Analysis of Mixed-Mode Oscillations in a Cortical Pyramidal Neuron Model

We analyze a biophysical model of an entorhinal cortex layer V pyramidal cell and investigate the mechanism for the generation of mixed-mode oscillations in the model. Reduction of dimensions techniques are used to reduce the model to three dimensions, and the system is transformed into a canonical form with three timescales. The canonical form is used to elucidate the underlying dynamic structure responsible for the generation of small amplitude chaos and mixed-mode oscillations.

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MS59

Canards and MMOs in Mathematical Models of Intracellular Calcium Dynamics

Calcium is important for many cellular functions, regulating many aspects of cell physiology. Experiments show that calcium dynamics operates over multiple time-scales in the cell, and mathematical models of calcium dynamics are constructed to reflect this. While canards and MMOs are known to occur in some models of calcium dynamics, there has not been a systematic study of their role in producing complex dynamics across a range of models. This talk will

describe early results from such a systematic study.

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MS59

Rhythmic Mixed-mode Oscillatory Activity in Stellate Cells of the Entorhinal Cortex

The study of rhythmic activity in various areas of the brain has been the object of many experimental and theoretical investigations. This talk concerns the generation of rhythmic mixed-mode oscillations at theta frequencies (8-12 Hz) in a biophysical model of medial entorhinal cortex stellate cells (SCs). Mixed-mode oscillatory temporal patterns consist of a combination of subthreshold oscillations and spikes. The SC model consist of a multiscale, high-dimensional system of nonlinear ordinary differential equations describing the evolution of voltage and other biophysical variables. We show that during the interspike interval, where subthreshold oscillations are generated, the SC model can be reduced to a three-dimensional fast-slow system. Voltage is the fast variable and the two slow variables are the two components (fast and slow) of the hyperpolarization-activated (h-) current. Using dynamical systems arguments we provide a mechanism for the generation of subthreshold oscillations and the onset of spikes. This mechanism is based on the three-dimensional canard phenomenon. We show that, in this biophysical SC model, the subthreshold oscillatory phenomenon is intrinsically nonlinear and three dimensional, involving the participation of both components of the h-current. We discuss some consequences of this mechanism for the interaction between SCs and other cells and external inputs.

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MS59

Giant Squid, Hidden Canard: The 3D Geometry of the Hodgkin-Huxley Model

Changes in the timescales associated with the gating variables in the classical Hodgkin-Huxley model can lead to solutions featuring significantly slowed spikes and subthreshold oscillations. Using a geometric analysis, we thoroughly explore the transition from excitability to mixed-mode oscillations (MMO's) to relaxation oscillations that explains these findings. We also consider how MMO characteristics depend on the size of the singular perturbation parameter and other parameters in the system.

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MS59

Discussion

Discussion

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MS60

Understanding Oceanic Overflows Using Laboratory Experiments

Oceanic overflows are important elements of the earth's global thermohaline circulation but the mixing and entrainment that occur for such overflows is poorly understood. In particular, as the overflow water moves down the steep incline its stability is governed by the competition between stratification which stabilizes the flow and vertical shear which tends to destabilize the flow. We measure the properties of a laboratory experiment designed to mimic oceanic overflows to the degree possible on laboratory-accessible length scales. The flow exits a nozzle and flows along an inclined plane such that there is a gravitational forcing of the flowing gravity current. Further, we inject velocity fluctuations into the fluid prior to its exit from the nozzle, thereby generating a turbulent boundary layer condition at the plane boundary. The Taylor Reynolds number of the flow coming out of the nozzle is about 100. We simulataneously measure velocity fields using particle image velocimetry and density fields using planar laser induced fluorescence. We will present characterization of the gravity current including mean and fluctuating parts of the velocity and density fields as a function of distance from the inclined plate and the distance downstream. We compute the entrainment rate using several different approaches and directly measure the gradient Richardson Number for the flow as a function of spatial position. Finally, we compare our results with in-situ measurements of oceanic overflows.

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MS60

Experiments and Modeling of Deep-water Surface

Waves

We examine the evolution of waves in deep water that are generated in a physical laboratory using exact solutions to the scalar and coupled nonlinear Schroedinger equations. Solutions include envelope solitons, uniform wavetrains, and bi-periodic patterns of waves. We examine the properties of the waves and their stability.

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MS60

Falling Spheres in Stratified Fluids

We explore the motion of heavy spheres falling through a sharp salt stratified fluid layer in which an intriguing levitation phenomena is observed: the heavy sphere experiences a transient levitation in which the sphere descends through the sharp transition, stops, and rises back into the layer before ultimately returning to descent. Careful measurements will be presented showing the sphere residence time. The hydrodynamics, which involves a strong coupling between variable density fluid, and moving solid boundary, entrained, turbulently mixed fluid, and strong internal waves will be discussed. In turn, measurements performed in stratified karo will be presented, and the theory for this regime, which is low Reynolds number, will be discussed.

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MS60

The Hydrodynamics of Spinning Rods in Low Reynolds Flows

We present experimental measurements and mathematical predictions concerning the hydrodynamics induced by spinning rods in viscous fluids. Recent advances in nano-technology have enabled controlled manipulation of nanoscale objects immersed in fluids. Such advances allow for new biological measurements (such as physical properties of cell membranes) on length scales smaller than the wavelength of visible light, and direct observations are challenging. Moreover, on such scales, the hydrodynamics are thermally fluctuating, and observational tracers experience strong Brownian signals on top of coherent motion induced by nanoscale manipulation. As such, predictive mathematical theories are essential to interpret the observations. We discuss the hydrodynamic solutions we have developed for rods sweeping upright cones in viscous fluids. These quasi steady, three dimensional, exact and asymptotic solutions of the Stokes equations are used to study the motion of passive tracers. These predictions are shown to quantitatively match low Reynolds number experiments performed on a scaled up, table top version of the nanoscale measurements per- formed. In turn, the predictions on the nano-scale are considered where agreement is good, but not as good as on the macro scale. The uncertainty of the nanoscale measurements as regards missing observational information and stochastic dynamics will be discussed.

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MS60

Discussion

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MS60

On the Motion of an Annular Viscous Jet

We experimentally examine the motion of an annular jet of viscous fluid flowing down the outside of a thin, vertical fiber. As other authors have observed, perturbations develop along the free surface of the jet; our focus is on the instability that leads to the formation of these perturbations. We observe a striking transition in the perturbation dynamics at a critical flow rate, Q_c. Above Q_c, the distance from the orifice that perturbations form oscillates in time, and the spacing between perturbations varies, typ-

ically leading to the coalescence of neighboring perturbations. For fixed Q below Q_c, the distance from the orifice that perturbations form is constant, and the spacing between consecutive perturbations remains fixed as they travel down the length of the fiber (2 meters). We find the growth of the perturbations is initially rapid followed by a slower phase as they saturate in size. We compare the nascent perturbation growth to theoretical predictions developed from a long-wave model (Craster & Matar, J. Fluid Mech. 553, 85-105 (2006)).

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MS61

Characterizing the Edge of Turbulence for Shear Flows

We characterize the *edge of turbulence*, the boundary which separates the basins of attraction of the laminar and turbulent states, for a nine-dimensional model for sinusoidal shear flow in order to gain a greater understanding of the nature of and transition to turbulence. This includes a probabilistic analysis of the transition to turbulence by computing the probability that perturbations of a given energy will lead to turbulence for a large range of Reynolds numbers.

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MS61

Model Reduction Near Unstable Equilibria in Fluid Flows, Using Approximate Balanced Truncation

Reduced-order models are obtained for two different fluid flows using balanced proper orthogonal decomposition (BPOD), an approximation to balanced truncation that is numerically tractable for very large systems. The procedure is applied to flow in a plane channel, and separated flow past an airfoil, using models linearized about stable and unstable equilibria. The models are suitable for control design, and are better at capturing the input-output behavior of the system compared to standard POD/Galerkin models.

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MS61

Reduced-order Models for Fluid Dynamics, Combustion and Flow Control

The paper will present a set of reduced-order models for the global dynamics of various flow and combustion problems and its use for flow control. Examples include the flow dynamics in the vortex breakdown process, combustion with swirl and breakdown, the transition of viscous flows in an expanding channel to asymmetric states, the stall of airfoils, and the control of shear layers using upstream fluidic actuation at low and high frequencies.

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MS61

Appearance of Dissipative Dynamics in Hamiltonian Systems: A Dynamical Systems Viewpoint

An apparent paradox in classical statistical physics is the mechanism by which conservative, time–reversible microscopic dynamics, can give rise to seemingly dissipative behavior. In this paper we use dynamical systems theory tools to show that dissipation can arise as an artifact of incomplete observations over a finite horizon. In addition, this approach allows us to obtain finite–time, low order, approximations of systems with moderate size, and to establish how the approach to the thermodynamic limit depends on the different physical parameters. In addition, we also briefly discuss the implications of this approach in connection with the well known Fluctuations-Dissipation Lemma.

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MS61

Coherent Structures, Temporal Harmonics and Multi-resolution in Reduced Order Empirical Fluid Flow Models

POD modes often blend physically meaningful, vortical flow structures and temporal frequencies. Exacerbated by lack of spatial symmetries and varying periods, this phenomenon is detrimental in very low order design models, which are focused on the nearly periodic dynamics of few, dominant vortices. This issue is addressed by blending temporal, dynamic phasor analysis, to extract "pure harmonic" references, and an iterative POD procedure, to extract physically meaningful modes, associated with distinct periods.

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MS61

Lagrangian Coherent Structures and Clear Air Turbulence

We apply recent dynamical systems methods to three-dimensional atmospheric data to extract Lagrangian coherent structures (LCS) from the flow. These structures appear to play a crucial role in clear air turbulence, which we seek to detect and forecast for aviation safety. We compare LCS with commonly used diagnostics and show how dynamical systems methods can give new insight into the structure of clear air turbulence.

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MS62

Characterization and Control of Cavity-soliton Lasers Based on Vertical-cavity Semiconductor Devices

The spontaneous formation of small-area bistable lasing spots is observed at different positions within the aperture of a broad-area VCSEL with frequency-selective feedback. These spots can be switched on and off with an incoherent injected field. They are interpreted as spatial dissipative solitons. Approaches to model these devices are presented and first results on the occurrence of localization are reported.

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MS62

The Fermi-Pasta-Ulam Paradox, q-breathers and Beyond

I will introduce the essence of the Fermi-Pasta-Ulam paradox in a finite nonlinear chain. It consists of a nonequipartition of mode energies over large times, with exponentially localized energy distributions. I will then show that exact periodic orbits - q-breathers - exist in that chain, and can be obtained by continuation of the normal modes of the linear chain. q-breathers localize exponentially in normal mode space. Their properties (including the phase space flow nearby) account for the paradox aspects as nonequipartition, exponential localization, stochasticity thresholds, and recurrence, among others. Finally I will extend the concept of q-breathers to higher dimensional lattices and macroscopic systems.

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MS62

Spatial Instabilities and Pattern Formation in Periodic Media

The unusual optical properties of periodic materials allow for the control of light in ways that are not possible with conventional optics. Here we study the effects of a photonic crystal on the spatial instabilities and formation of spontaneous patterns in a nonlinear dissipative system driven out of equilibrium. In particular we show how the photonic band-gap affects the selection of a nonlinear spatial structure, allowing for the complete inhibition of modulation instabilities.

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MS62

Existence and Stability of Solutions of Discrete Nonlinear Schrödinger type equations in 1-, 2- and 3- dimensions

We will start this talk by presenting some motivating examples from optics and from atomic physics for the consideration of discrete nonlinear Schrödinger type equations. The existence and stability of discrete solitary wave and discrete vortex type solutions will then be considered in one, two and even three spatial dimensions, starting from the anti-continuum limit where the individual sites are uncoupled. The relevant methodology will quantify the number of real, imaginary with negative Krein and complex eigenvalues, in good agreement with numerical findings and with experimental results. Time-permitting, we will present some recent results on how to extend such approaches to defocusing nonlinearities, comparing with very recent experiments in photorefractive and photovoltaic crystal lattices in the

cases of gap solitons and dark solitons respectively.

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MS62

Phase Compactons in Oscillator Lattices

We study the phase dynamics of a chain of autonomous, self-sustained, dispersively coupled oscillators. In the quasicontinuum limit the basic discrete model reduces to a Korteveg de Vries like equation, but with a nonlinear dispersion. The system supports compactons (solitary waves with a compact support) and kovatons (compact formations of glued together kink antikink pairs) that propagate with a unique speed, but may assume an arbitrary width. They are robust and collide nearly elastically. Nondispersive effects are demonstrated with help of complex Ginzburg-Landau lattice.

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MS62

Cavity Solions in Discrete Media with Non-instantaneous Nonlinearity

Localised excitations are found in models of active media with a non-instantaneous nonlinearity. The question of existence reduces to that in a model with a saturable nonlinearity. Stability, however, is strongly affected by the by the response time of the noninearity. The solitons themselves are found via numerical continuation, whereas the stability is studied by a combination of spectral analysis and direct numerical simulations of the model.

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MS63

Stochastic Modulation Equations on Large Domains

We consider as an example the Swift-Hohenberg equation on a large (but still bounded) domain near its change of stability. This equation is a toy model for the convective instability in the Rayleigh-Benard model. Sufficiently close to the bifurcation, solutions are approximated by a periodic wave, which is slowly modulated by the solutions of a Ginzburg-Landau equation. Noise, for instance induced by thermal fluctuations, is natural for physical models like these. We discuss how noise in the equation affects the multi-scale approximation, and give rigorous error estimates in the stochastic case.

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MS63

Effective Dynamics for Stochastic Partial Differential Equations

The need to take stochastic effects into account for modeling complex systems has now become widely recognized. Stochastic partial differential equations arise naturally as mathematical models for multiscale systems under random influences. We consider macroscopic dynamics of microscopic systems described by stochastic partial differential equations. The microscopic systems are characterized by small scale heterogeneities (spatial domain with small holes or oscillating coefficients), fast scale boundary impact (random dynamic boundary condition), and, random fluctuations. An effective macroscopic model for such a stochastic microscopic system is derived. The homogenized effective model is still a stochastic partial differential equation, but defined on a unified spatial domain and the random impact is represented by an extra term in the effective model. The solutions of the microscopic model is shown to converge to those of the effective macroscopic model in probability distribution, as the size of holes diminishes to zero. Moreover, the long time effectivity of the macroscopic system in the sense of convergence in probability distribution, and in the sense of convergence in energy are also proved.

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MS63

Dynamics of Kinks in the ϕ^4 SPDE

Kinks are examples of coherent structures: localized features in a noisy, spatially-extended system. The ϕ^4 stochastic partial differential equation (SPDE) is studied with a combination of analytical and numerical techniques. After a suitable rescaling, it is equivalent to a stochastic Allen-Cahn problem. Kink creation and movement are driven by small-scale fluctuations. The short space and time scales, for the dynamics internal to one coherent structure and in localised events creating new ones, are linked to the large space and time scales of the system. A steady-state mean density of kinks (and antikinks) is dynamically maintained: they are nucleated in pairs, follow Brownian paths and annihilate on meeting. Accurate numerical algorithms have been developed, assisted by comparison of thermodynamic quantities with exact results obtained from the stationary density via the transfer-integral method. An effective model that treats kinks as point particles gives useful insight into the dynamics of the full SPDE.

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MS63

Model Subgrid Microscale Interactions to Form Macroscopic Discretisations of Stochastic Partial Differential Equations

Constructing discrete models of stochastic partial differential equations is very delicate. Stochastic centre manifold theory may derive and support spatial discretisations of SPDEs. I illustrate the technique on the nonlinear advection-diffusion dynamics of the stochastically forced Burgers' equation. The trick to the application of the theory is to divide the physical domain into finite sized elements by introducing insulating internal boundaries which are subsequently removed to fully couple the dynamical interactions between neighbouring elements. We see how a multitude of subgrid microscale noise processes interact via the nonlinear dynamics within and between neighbouring elements to affect a macroscale simulation. Noise processes with coarse structure across a finite element are the most significant noises for the discrete model. Their influence also diffuses away to weakly correlate the noise in the spatial discretisation. The nonlinear dynamics has two further consequences: the example additive forcing generates multiplicative noise effects in the discretisation; and effectively new noise sources are abstracted into the macroscale discretisation. The techniques and theory developed here may be applied to discretise many dissipative SPDEs.

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MS63

Determining the Topology of Complex Stochastic Patterns from Finite Discretizations

Applied models frequently generate complex random patterns whose geometry is hard to quantify. One recent approach has been to use computational homology for geometry quantification, based on discretizations of the patterns. In this talk, I present a probabilistic approach which discusses this method in the context of random fields. We obtain explicit probability estimates for the correctness of the homology computations, which in turn yield a-priori bounds for the suitability of certain discretization grid sizes.

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MS63

Large Deviation Asymptotics for Random-walk-type Perturbations

Symmetric random walks can be arranged to converge to a Wiener process in the area of normal deviations and is often used to replace Wiener process. However, random walks and Wiener processes have, in general, different large deviation principle. (Usually, a large deviation principle for processes can be described by an action functional.) It turns out that the action functional of certain random walks with specific chosen jump probabilities can approximate the action functional for Wiener processes in the best way. The action functionals for such random-walks and Wiener processes will be presented and compared during the talk. Consider dynamic systems with small random perturbations. If we replace the Wiener process in a perturbed system with random walks, it is expected that such a replacement will result in, in general, a different large deviation asymptotic behavior. There are many problems such as exit problem related to the large deviation asymptotic behavior of perturbed systems and they can be studied using the tool of large deviation principle. During the talk, results of exit problem for the random-walk-type perturbation will be presented and compared with those for the white-noise-type perturbation.

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MS64

Ecological Implications of Dynamic Variations in Microbial Stoichiometry: Approaches and Challenges

Changes in the stoichiometry of microorganisms have strong influences on steady-state properties of competitive fitness, predator-prey interactions, and nutrient cycling. Dynamic variation of stoichiometry in non-steady conditions contributes to competitive fitness, and likely alters predator-prey dynamics. Lagrangian approaches offer a potential solution to the challenges of modeling spatially heterogeneous habitats. When applied to competition for one nutrient in idealized spatially variable habitats, Lagrangian models suggest that findings from simple chemostat theory are unexpectedly robust.

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MS64

Nutrient Constraints on Cellular Level and the Evolution of Large Scale Patterns

The basic molecules of life - nucleotides and amino acids - have a fixed chemical composition that is immune to evolution. Can such fundamental molecular constraints manifest themselves on larger scales? Here, first we derive RNA:Protein ratio corresponding to maximal growth of phytoplankton cells. Second, by analyzing ODE model of phytoplankton competition we show that such biochemically optimal ratio can lead to one of largest patterns found on Earth - Redfield ratios of nitrogen to phosphorus in Deep Ocean.

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MS64

Models and Experiments Relating Stoichiometry of Individual Organisms to Population Dynamics

We investigate whether stoichiometry plays a role in regulating populations of the zooplankter Daphnia using: (a) population models based on tested representations of individual growth and reproduction; (b) population experiments; and (c) bioassays of individual performance of juveniles and adults in populations. We identify indirect mechanisms that resemble food quality effects, results that highlight the need for detailed empirical information on the response of individuals to dynamic environments.

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MS64

Mathematical Problems of Stoichiometric Ratios in Ecological Systems: Introduction to the Minisymposium

Most models of material fluxes through populations and ecosystems have heretofore focused on single elements, but additional problems arise when characteristic element ratios in various organisms must be maintained. Stoichiometric ratios link different element cycles at key points in food webs. Models that incorporate ratios often have different dynamics, such as different bifurcations and stabilities, compared with single element models. This introduction will survey new mathematical problems and model behaviors when stoichiometric ratios are considered.

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MS64

Some Producer-consumer Models with Stoichiometry

An improved understanding of the impact of nutrient and resource limitations on the behavior of model ecosystems relies on the study of systems that are process-based, yet mathematically tractable. This presentation will report on an examination of a family of elementary producer-consumer models that incorporate food quality and nutrient cycling effects. Combinations of analytic and numerical methods are used in the derivation of full-system dynamics, as well as that of various model subsystems.

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MS64

Dynamics of Stoichiometric Bacteria-Algae Interaction in Epilimnion

Bacteria-algae interaction in epilimnion is modeled with explicit consideration of carbon and phosphorus. Global qualitative analysis and bifurcation diagrams of this model are presented. It is shown that excessive sunlight will destroy bacterial communities. Competition of bacterial strains are modeled to examine Nishimura's hypothesis that in oligotrophic lakes, P limitation exerts more severe constraints on the growth of HNA bacteria, which allows LNA bacteria to be competitive.

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MS65

Rotational Stokes Waves of Finite Depth: Existence and Stability

Water waves are a prime example of applied mathematics describing wave motions of the kind which may be observed in the ocean, and they showcase diverse wave phenomena ranging in size from ripples to tsunamis or freak waves. Since their governing equations were proposed two centuries ago by George Gabriel Stokes, water waves have been a subject of intense research in mathematics as well as in physics and ocean engineering. The mathematical problem for free-surface water waves embodies the equation of hydrodynamics, the concept of wave propagation, and the critically important role of boundary dynamics. A precise account is given of its formulation as a free-boundary problem of a partial differential equation, and its distinct features are discussed. Particular emphasis is given to the effects of vorticity; the governing equations of water waves allow for rotational motions, and indeed, real flows typically carry vorticity. While the irrotational water-wave problem reduces to one of potential flows and its nonlinearity resides only at the boundary condition on the free surface, the rotational problem is intricate due to the additional nonlinearity in the field equation. Stokes waves refer to steady periodic waves under gravity whose profile rises and falls exactly once per wavelength. Presented in detail is for a general class of vorticities their existence of small amplitude an application of local bifurcation from a simple eigenvalue. Large-amplitude theories for rotational Stokes waves are reviewed. Results from numerical calculation of the extremal waves are discussed, in particular, new types of singular configurations attributed to vorticity. Linear instability is investigated for a certain class of free-surface shear flows, and then via a perturbative method and semigroup methods is established the linear instability of small-amplitude rotational Stokes waves near an unstable shear free-surface shear flow.

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MS65

Controlling Traveling Waves of the Complex Ginzburg-Landau Equation with Spatial Feedback

Previous work has shown that Benjamin-Feir unstable traveling waves of the complex Ginzburg-Landau equation (CGLE) in two spatial dimensions cannot be stabilized using a particular time-delayed feedback control mechanism known as 'time-delay autosynchronisation'. In this talk, we show that the addition of similar spatial feedback terms can be used to stabilize such waves. This type of feedback is a generalization of the time-delay method of Pyragus and has been previously used to stabilize waves in the one-dimensional CGLE by Montgomery and Silber. We consider two cases in which the feedback contains either one or two spatial terms. We give a numerical example to demonstrate our linear stability results.

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MS65

The Amplitude Equation for Rotating Rayleigh-Benard Convection

The amplitude equation for rotating Rayleigh-Benard convection is derived from the Boussinesq equations with the Coriolis force included. The vertical boundary conditions are no-slip, and the lateral boundary conditions are either periodic or rigid. In order to keep track of the mean flow, we look at the full system of equations, instead of a potential formulation. A multiple scales perturbation expansion in the control parameter epsilon is performed and appropriate solvability conditions are imposed. This leads to the usual amplitude equation at order 3/2 but a new rotation term enters at order 7/4. This rotation term will cause a change of phase with respect to time, whenever there is a gradient in the amplitude in the direction parallel to the rolls. As a result, rolls terminating perpendicularly to a wall will precess in the direction of rotation. The new rotation term will also cause stationary dislocations to glide perpendicular to the rolls. The amplitude equation results for a specific set of parameters are compared to numerical results from simulations of the full equations. There is good agreement for mean flow, wall induced precession and dislocation glide.

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MS65

Coherent States of Spatial Periodically Driven Hydrogen Atom

The classical and quantum dynamics of spatial hydrogen atom in a microwave field are studied. Wave packets constructed as superposition of suitable Floquet states are coherent states that show spreading, revivals and localization along the classical trajectory. The classical dynamics of this 3.5-dof Hamiltonian system is studied with time-frequency analysis based on wavelets. The coherent states are classically localized in a large phase space region showing resonance with the microwave field.

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MS66

Designing for Topological Chaos in Fluid Mixing

The Thurston-Nielsen theory gives a framework for understanding how individual periodic orbits of a surface diffeomorphism imply other chaotic dynamics. One approach to designing 2D fluid systems that mix well is to build in a unique top-level pA periodic orbit, either by motion of stirrers or boundary forcing. We discuss recent progress in such "designing for topological chaos" with a particular emphasis on doubly-periodic planar arrays of stirrers which yield transitive, ergodic maps on the entire plane.

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MS66

On Braids and Topological Entropies in Spatially Periodic Flows

Many archetypal two-dimensional mixing flows live in spatially periodic domains. As usual, underlying flow topology can be characterised by braids formed by periodic trajectories. The braids are elements of the torus braid group, capturing the usual 'crossings', and also how trajectories wrap around the periodic directions. A simple dynamical system is described that computes the action of torus braids on material loops. The dynamical system offers a fast and efficient method for computing the braid entropy, which serves as a lower bound for the flow entropy. The sine-flow is examined to illustrate the method.

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MS66

Realizing Topological Chaos with Simple Mechanisms

Topological nature of stirring fluid by using finitely many rods is closely related to braid theory. Based on this idea various stirring devices have been introduced by several authors. However, it seems that these are not efficient enough for mixing all body of fluids uniformly. In this talk we propose mixing devices, which are in fact a kind of batch stirring device, each consisting of a few gears that seems to be able to mix up given fluids uniformly, and show some results of experiments. We also observe the distribution of dilatations of pseudo-Anosov braids derived from the devices.

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MS66

Braid Theory and Microparticle Dynamics in Fer-

rofluids

We have studied an experimentally two-dimensional dynamical system of non-magnetic microparticles moving in a ferrofluid. Several phenomena have been studied using this so-called magnetic hole system, i.e. anomalous diffusion, aggregation, and order-disorder transition. In this talk I will concentrate on the motion of few interacting spheres, especially motion with an intermittent behavior. Magnetic holes can be made by dispersing non-magnetic plastic spheres on micrometer scale in ferrofluid. The spheres are set in motion by external, elliptically polarized, in-plane magnetic fields. In this magnetic field the plastic spheres get an apparent magnetic moment anti-parallel and proportional to this field. This motion can be analyzed using braid theory. By introducing the time axis as an extra dimension, each sphere trace out a world line in the spatiotemporal space, and all spheres together create a braided set of world lines in this space. On the resulting braid we can perform rank-ordering statistics, and showing power law according to the Zipf-Mandelbrot relation, or perform more standard analysis of variance, showing anomalous diffusion.

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MS67
Uncertainty Analysis and Design of Dynamics

We will present an approach that could be used to radically accelerate the numerical simulation, model reduction, and propagation of uncertainty in large nonlinear networks of interconnected dynamic components. In this approach a large network is decomposed into subcomponents using spectral graph theory. Operator theory and geometric dynamics methods are used to analyze propagation of uncertainty in subcomponents. We will how this approach would enable model-based design of robust aerospace and building systems.

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MS67
Variational Integrators and Computing what Counts

Long time trajectories of a comet moving in the solar system, are sensitive to model uncertainty. It makes little sense to compute individual trajectories accurately in such a situation. More appropriate is computing robust statistical quantities. This talk argues that computing almost invariant sets, transport rates, energy and momentum using variational integration techniques, and high ridges in LCS (Lagrangian Coherent Structures) are robust and that these are examples of quantities that make sense to compute.

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MS67
Discussion

Discussion.

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MS67
Operator Theory, Graph Theory and Networked Dynamical Systems

Complexity of systems can be roughly represented on 2 axes, one parametrizing complexity of structure, the other complexity of system dynamics. These two are not independent, and disentangling their interdependence is not trivial. We address complexity of the system in the context of its behaviours under parameter and initial condition uncertainty in the framework of ergodic theory and discuss how graph-theoretic decompositions on state variables allow an extension of that analysis to higher dimensional systems. The results depend on the use of operator-theoretic approach to dynamical systems, specificaly on properties of Perron-Frobenius and Koopman operators. Several examples of the approach for analysis of system with large number of degrees of freedom are presented.

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MS68
Multiscale Analysis of Ion Channels

Ion Channels are proteins with a hole that allow ions to cross impermeable membranes thereby controlling an enormous range of biological function. Ions are driven through channels only by electrodiffusion. Covalent bond changes are not involved. Mathematical analysis seems possible and important: mathematical methods of singular and geometrical perturbation theory have been applied with some success and the inverse problem of designing channels to specification has been solved in part.

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MS68
The Role of Molecular and Ionic Size in Determining the Properties of a Liquid: Application to Biology

Often mathematicians are tempted to neglect particle size to obtain equations for which simple solutions are possible. However, since the time of van der Waals it has been known that particle size plays a role that is often more important than the role of the attractive forces. The modern development of this idea will be discussed and illustrated by a theory of the selectivity of a calcium channel.

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MS68

Analysis and Computation for Some Models in Physiology

In this talk we consider some time and space dependent models of physiological processes in which the spatial component may be described by a discrete set of points as well as a continuum. We review some techniques for analysis and computation of such models and report on recent results.

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MS68

Reduction of the PNP System from Three-dimensional Domains to One-dimensional Intervals

The global dynamics of the Poisson-Nernst-Planck (PNP) system for flows of two types of ions through a narrow tubular-like membrane channel is studied. As the radius of the three-dimensional tubular-like membrane channel approaches zero, a one-dimensional limiting PNP system is derived. We justify this limiting process by showing that global attractors of the three-dimensional system are upper semicontinuous when the radius of the membrane channel goes to zero.

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MS69

Maximums of Random Processes and Non-uniform Phase Distributions

Numerical simulations (using the Fast Fourier Transform and Monte Carlo Methods) of short time series that include a large maximum indicate a non-uniform phase distribution is present when using a finite number of components. Exploration into the non-uniform distributions shows that the PDF appears to be dependent on the number of components used, the length of the record, the relative extremeness of the maximum, and the spectral energy of the process.

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MS69

Stability Analysis of Roll Motion of a Ship in Regular Seas

Roll motion of a ship, modeled as a SDOF nonlinear oscillator, is analyzed to investigate various instability phenomena like bifurcation, subharmonic and chaotic responses. The nonlinearity in the system arises respectively due to quadratic form of damping moment and nonlinear restoring moment in the form of signum function. The destabilizing wave moment appearing in the right hand side of the equation of motion is considered to vary harmonically due to regular sea. In order to trace different branches of the response curve and investigate different instability phenomena that may exist, the IHB method is modified by incorporating in it arc length continuation to make its incremental harmonic balance continuation (IHBC). A procedure for treating the nonlinear hydrodynamic damping moment and nonlinear restoring moment terms using distribution theory is also presented so that equation of motion is amenable to the application of IHBC. The stability of the solution is investigated by the Floquet theory using Hsus scheme. The stable solutions obtained by the IHBC method are compared with those obtained by the numerical integration of equation of motion wherever applicable.

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MS69

Nonlinear Dynamics of Moored Floating Systems in Random Waves

Nonlinear effects in the motion of moored floating bodies can result from kinematic nonlinearities in the coupling of multiple bodies, the hydrodynamics or restoring forces of the mooring system. This talk addresses the modeling and the analysis of a moored barge in narrow-banded random waves. Different techniques to characterize the motion by means of probability density functions are discussed. The results of different methods such as the Monte Carlo simulation, statistical linearization and perturbation techniques are compared.

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MS69

Capsize - Naval Interests and a Deterministic Approach

This first time slot will be split by the two minisymposium co-organizers. Patrick Purtell will first provide an overview of naval interests which extend from fundamental concepts to practical predictions and operator guidance. His presentation will be followed by Leigh McCue who will present a brief overview on the state of the art in analytical approaches to the analysis of capsize and other strongly nonlinear vessel behaviors.

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MS70

C1 Approximation of Vector Fields on the Renormalization Group Method

The renormalization group (RG) method for differential equations is one of the perturbation methods for obtaining solutions which are approximate to exact solutions for a long time interval. In this talk, it is shown that for a given vector field on a manifold and for the differential equation associated with it, a family of approximate solutions obtained on the RG method defines a vector field which is close to the original vector field in C1 topology un-

der appropriate assumptions. Furthermore, some topological properties of the original vector field such as the existence of an invariant manifold and its stability are inherited from those for the RG equation. This fact is used to show the presence of synchronization in coupled systems. The present RG method is also useful for detecting an approximate center manifold and a flow thereon. This method is viewed as strict mathematical formulation of the reductive perturbation method proposed by Kuramoto, and includes the geometric singular perturbation method proposed by Fenichel as a particular case.

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MS70

Interface Equations for Reaction-Diffusion Systems Near Critical Point

We consider the dynamics of interfaces in two space dimensions arising from front solutions for reaction-diffusion systems with bistable nonlinearity. As applications, we will derive the interfacial equations describing the motion of spiral waves.

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MS70

Analysis of RG and Normal Form Methods

We examine the mathematical basis of the Chen-Goldenfeld-Oono RG method and show that the crucial step is a near-identity change of coordinates equivalent to that of normal form theory. For systems with autonomous perturbations, we extend the RG method up to second (and higher) order in a small parameter epsilon and show it is equivalent to the classical Poincare-Birkhoff normal form. For systems with nonautonomous perturbations, we apply the RG method and show that it is equivalent to a time-asymptotic normal form theory.

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MS70

An Invariance Condition, the Renormalization Group, and the Dynamics of Large Power Networks

The combination of asymptotically valid local expansions and an invariance condition for weaving them into a global expansion has been successfully applied to singular perturbation problems involving ordinary and partial differential equations. We discuss this technique and its application to large systems of equations describing the dynamics of networks such as power grids, revealing in the process some obvious and not-so-obvious correspondences with renormalization-group analyses of stochastic and non-stochastic equations.

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MS71

Wild Arcs in Dynamics

A trajectory of a flow on a 3-manifold is wild if the closure of at least one of the semi-trajectories is a wild arc. A trajectory is 2-wild if the closure of each semi-trajectory is a wild arc. A flow is a continuous R-action on manifolds. We describe a method of embedding wild trajectories in flows on 3-manifolds. This methods yields interesting examples of dynamical systems. In particular: 1. Every closed and connected 3-manifold admits a flow with exactly one fixed point and whose every non-trivial trajectory is 2-wild. 2. Every boundaryless 3-manifold admits a flow with a discrete set of fixed points and every non-trivial trajectory 2-wild.

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MS71

Building a Data Base for the Global Dynamics of Multi-Parameter Systems

It is well accepted that nonlinear dynamical systems can exhibit a wide variety of complex dynamics that may be sensitive to changes in parameters. It is also quite common in applications that not all values of the parameters have been determined. We outline a proposed method for building a data base that can be queried to determine parameter values at which particular types of dynamical structures can be found or values at which specific types of bifurcations occur. The fundamental idea is to use topological methods that are computationally efficient to store essential features of the dynamics in terms of a directed graph with equivalence classes of homology maps at the nodes. The directed graph represents information about the existence of a global Lyapunov function and the homology maps at the nodes encode information about the recurrent dynamics.

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MS71

Multi-Valued Dynamical Systems in Economics

Many economic models have "equilibria" that are correspond to forward orbits from a dynamical system F :

$X \rightarrow X$. However, there are economic models where the equilibria correspond to the forward orbits of dynamical system generated by a relation $R \subset X \times X$, i.e. $R(x) := \{y \in X|(x, y) \in R\}$ may be multi-valued. In some models we have R multi-valued, but R^{-1} is single-valued. However, there are models where both R and R^{-1} are multi-valued. In this talk, we discuss these types of economic models and some progress that has been made in analyzing them.

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MS71
Infinite Horseshoes

Horseshoe maps are an essential part of chaos theory. Usually one assumes there is a map f of a rectangle S into the plane, and that f satisfies a number of hyperbolicity requirements that can be hard to check or in fact can fail to be true. In this talk we describe examples where it is important to have f not defined on part of the rectangle so that the image of the rectangle can stretch across itself infinitely many times. Examples come from mechanics. This work is joint with Miguel Sanjuan, Samuel Zambrano, and Judy Kennedy.

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MS72
A New Model for Myosin Motors Incorporating Brownian Ratchet and Powerstroke Mechanisms

A new mathematical model for myosin motor proteins is proposed. The traditional powerstroke model converts rotational drift caused by conformational change in its neck into translational motion. Similarly, rotational diffusion associated with the powerstroke can be also utilized to make translational motion in the same way as Brownian ratchets. The new model incorporates both powerstroke and Brownian motor mechanisims. Depending on parameter values, this motor works as a power stroker, a Brownian motor or a hybrid of the two. Various properties of single-head myosins are discusses, including speed, stall force, and efficiency. Coupled systems such as myosin V and muscle are also discussed.

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MS72
Burnt-Bridge Models of Molecular Motor Transport

Transport of molecular motors, stimulated by interactions with specific links between binding sites, called "bridges," is investigated by analyzing discrete-state stochastic models. In these models an unbiased diffusing particle can cross the bridge and burn it with some probability, creating a biased directed motion. We present several theoretical approaches that allow to calculate the dynamic properties of molecular motors in these systems. Theoretical predictions are supported by extensive Monte Carlo simulations. Theoretical results are applied for analysis of the experiments on collagenase motor proteins.

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MS72
Homogenization Theory for Molecular Motors

We investigate the transport properties of Brownian flashing ratchet motor models for molecular motors, in which the interactions with the thermal environment and external driving are modelled through additive and multiplicative stochastic noise terms, respectively. We use homogenization theory to develop rigorous computations for the long time drift, diffusivity, and efficiency (as characterized by a Peclét number) of the motor, and analyse their dependence with respect to the physical parameters of the system.

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MS72
Average Velocity and Effective Diffusion of Molecular Motors

In this study we start with the case where a particle is subject to a static periodic potential and a constant driving force. We derive analytic formulas for the average velocity and effective diffusion of the particle. When the driving force is small, the effective diffusion is exponentially small because the mobility of the particle is restricted by the periodic potential. When the driving force is in a certain range, the effective diffusion can become much larger than the Brownian diffusion. We will explain why this happens.

Then we will go on to derive the equation for the average velocity and effective diffusion of molecular motors in which the chemical reaction drives the motor forward by switching it among a set of periodic potentials.

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MS73

Numerical Aspects of Multidimensional Maximum-entropy Principle

The maximum entropy principle is a versatile tool for evaluating smooth approximations of probability density functions under specified constraints. We design a numerical algorithm for computing the maximum entropy problem, featuring orthogonal polynomial basis for Lagrange multipliers to achieve numerical stability and rapid convergence of Newton iterations. The new algorithm is found to be capable of solving the maximum entropy problem in the two-, three- and four-dimensional domain with low and moderate constraint order.

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MS73

Stochastic Integrable Dynamics of Polarized Light in Resonant Optical Media

In a resonant interaction, light of specific wavelengths excites electron transitions between atomic energy levels or energy bands in an active optical medium such as gas or crystal. In the lambda-configuration, light interacts with a medium via a pair of electron transitions between an energetically higher and two energetically lower atomic levels, which involve light of two different colors and/or opposite circular polarizations. We have identified a switching mechanism in this interaction: The color/polarization of the light will switch so that it will interact with the medium only through the transition between the higher level and the lower level less populated with electrons. If the initial occupation of the two lower levels varies randomly, an optical pulse passing through this material will switch randomly between two colors/polarizations. Mathematically, this phenomenon is described by exact, stochastically varying solutions of a completely integrable random partial differential equation, thus combining the opposing concepts of integrability and disorder.

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MS73

Numerical Techniques for Multi-Scale Systems

Fast variables are typically associated with high wavenumbers in spatially extended systems. We introduce a systematic procedure for "slowing down" the fast degrees of freedom by modifying the triad interactions coefficients in quadratically nonlinear systems. The goal of the methodology is to preserve the statistical properties of large scales while making the modified equations less stiff and allowing for direct numerical simulations with a larger time-step. This procedure can be carried out consistently with the conservation of energy in the original equations. Truncated Burgers-Hopf system is utilized to illustrate this approach.

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MS73

Mode-Reduction for Conservative Systems

A new stochastic mode-elimination procedure is introduced for a class of deterministic systems. Under assumptions of mixing and ergodicity, the procedure gives closed-form stochastic models for the slow variables in the limit of infinite separation of time-scales. We show that under these assumptions the ad-hoc modification of the nonlinear self-interactions of the fast degrees of freedom can be avoided. The procedure is applied to the truncated Burgers-Hopf (TBH) system as a test case where the separation of timescale is only approximate. It is shown that the stochastic models reproduce exactly the statistical behavior of the slow modes in TBH when the fast modes are artificially accelerated to enforce the separation of timescales. It is shown that this operation of acceleration only has a moderate impact on the bulk statistical properties of the slow modes in TBH. As a result, the stochastic models are sound for the original TBH system.

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MS74

A Mulitphase Flow Model of Calcium Induced

Morphology Changes in True Slime Mold

Cytoplasm of Physarum polycephalum shows periodic shuttle streaming through a network of tubular structures. The motion is driven by the periodic contraction of an actin-myosin gel that is regulated by a calcium oscillation. When the organism is small no streaming is observed, but steaming suddenly emerges as it gets larger. We present a mechanochemical multifluid model to explore how the sensitivity to changes in calcium concentration is related to the stability of the sol/gel mixture.

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MS74

Introduction to Protoplasmic Dynamics in Physarum

Although many models of amoeboid cell movement have been proposed, the physical mechanism remains open to question. The Physarum plasmodium has been widely used to model cell movement. Its rhythmic contractions and the resulting streaming of protoplasm have been well studied from a cytological point of view. Here we consider a physical mechanism for how the center of mass of a cell is displaced in a certain direction, based on spatiotemporal measurements of protoplasmic flow.

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MS74

Dynamic Patterns of Thickness Oscillation in Endoplasmic Droplet

Synchrony in the rhythmic contraction has long been regarded as a single characteristic of the plasmodium of the true slime mold, Physarum plasmodium. We found that plasmodia that develop from isolated endoplasmic drops actually exhibits various spatiotemporal patterns in the rhythmic contraction such as standing wave, many drifting spiral waves, a stationary rotating spiral wave, and synchronous pattern, and transitions between these patterns took place spontaneously.

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MS74

Modeling of the Adaptive Network of True Slime Mold

We describe here a mathematical model of the adaptive dynamics of a transport network of the true slime mold Physarum polycephalum, an amoeboid organism that exhibits path-finding behavior in a maze. When the organism is put in a maze, the network changes its shape to connect two exits by the shortest path. By reproducing this phenomenon we introduce new method to solve shortest path problem.

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MS75

On the Uniqueness of Traveling Waves in Porous Media Combustion

We study traveling wave solutions arising in Sivashinsky's model of subsonic detonation which describes combustion processes in inert porous media. Subsonic detonation waves tend to assume the form of reaction front propagating with a well defined speed. It is known that traveling waves exist for any value of thermal diffusivity. We investigate the question of uniqueness of the wave in the presence of non-zero thermal diffusivity through applying methods of geometric singular perturbation theory.

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MS75

Front Stability in a Non-smooth Ignition System

In this talk we consider a non-smooth system which models front motion in a noisy, excitable media. The model considered here arises from a consideration of membrane hydration in PEM fuel cells in which the protonic transport is approximated as a discontinuous function of membrane water content. Specifically the membrane is "ignited" if the water content crosses a specific threshold, while it is "extinguished" when water content is below the threshold. We constuct a family of smooth, monotone, composite solutions which describe the propagation of the ignited re-

gion across the fuel cell. In a noisy environment the fronts loose monotonicity and the front position is unresolved because of multiple ignition points. In linearizing about the global manifold of the slowly evolving fronts, we address the challenge of choosing an appropriate Sobolev space for which the nonlinearity is Frechet differentiable. We show that the pulse evolution fits naturally into the framework of the renormalization group methods developed to study the stability of slowly evolving patterns. The main result describes the exponential decay of the remainder and after the decay of the initial transient perturbations, we recover the formal pulse velocities at leading order.

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MS75
Pointwise Green Function Bounds and Stability of Combustion Waves

We establish sharp pointwise Green function bounds and linearized and nonlinear stability for traveling wave solutions of an abstract viscous combustion model which includes both the Majda model and the compressible Navier–Stokes equations for reacting fluids with artificial viscosity. The bounds are established under the necessary conditions of strong spectral stability; i.e., stable point spectrum of the linearized operator about the wave; transversality of the profile as a connection in the traveling–wave ODE; and hyperbolic stability of the associated Chapman–Jouguet (square-wave) approximation. This is joint work with M. Raoofi, B. Texier, and K. Zumbrun.

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MS75
Pore Formation in Solvated Polymer Electrolytes

Polymer electrolytes are comprised of long, hydrophobic polymer backbones with short, acidic side-chains which phase separate in the presence of a solvent, such as water, forming intricate nanoscale geometries filled with charged fluid. Such structures are the workhorses of ion transport, generating the selectivity of ion channels in cell membranes, the complex biochemical processes which occur within the pores of lipid membranes, and the protonic conductivity of polymer electrolyte membrane fuel cells. We present a novel model for the pore formation which balances bending energy of the hydrophobic backbone against the energy of solvation of the pendant acid side chains. The resulting energy is fourth order in space with a rich, surprizing structure, factoring into two second order operators: and Allen-Cahn composed with an offset of its own linearization. We investigate a class of gradient flows associated to this energy showing the existence of heteroclinc and homoclinic solutions which generate the pore structure and deriving a geometric flow for the sharp-interface limit.

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MS76
Homogenization for Mesoscale Oceanic Turbulence

We describe a mathematical approach based on homogenization theory toward representing the effects of mesoscale coherent structures, waves, and turbulence on large-scale transport in the ocean. We present results on some basic flow structures which will be used as part of a systematic parameterization strategy in which we couple numerical simulations of cell problems with asymptotic analysis with respect to key nondimensional physical parameters such as Peclét and Strouhal numbers.

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MS76
Evolution of Passive Scalar Distributions in Some Basic Deterministic Fluid Flows

Mixing and transport of passive scalars is an important physical problem. Observed distributions of scalars in convection, the stratosphere and the ocean have heavy tails large probabilities of large fluctuations. Mathe- matically, heavy tails have been found in random flows with and without chaos. Here we investigate distributions of scalars in deterministic flows. We see heavy tails for shear flows, cellular flows and chaotic flows in certain parameter regimes and take a first step towards explain- ing the appearance of such distributions by setting up an associated eigenvalue problem for simple shear flows. Time permitting, we will explore companion simulations for a scalar advected by a double gyre shallow water.

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MS76
Upscaling α-stable Levy Motions in Turbulence and Porous Media

Two problems are considered, super diffusion in turbulence and dispersion in fractal porous media. In the former case

weve shown that by modeling the convective velocity in a turbulent flow field as Brownian, one obtains Richardson super diffusion where the expected distance between pairs of particles scales with time cubed. By proving generalized central limit type theorems its possible to show that modeling the velocity or the acceleration as α-stable Levy gives rise to more general scaling laws that can easily explain most superdiffusive processes. A problem closely related to mixing in a turbulent flow field is dispersion in porous media when the conductivity field is a fractal. Here using arguments analogous to that of the turbulent case, we show how dispersion can be super diffusive and we further supple the generalized Fokker-Planck equations which are fractional with time dependent dispersion tensors. The latter model is applied to microbial transport in the subsurface.

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MS76
Discussion

Discussion.

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MS76
Dynamics of Probability Measures for Single Point Statistics of Random Passive Scalars

We explore the evolution of the Probability Density Functions (PDF) for the random Greens functions for a diffusing passive scalar, which is also advected by a veloc- ity field with stochastic components. These stochastic components are rapidly varying in time and they can be spatially dependent such as shears. Different analytical methods are presented to compute closed-form expres- sions for these PDFs or their asymptotic limits. Although computed for simple flows, these exact solutions retain mechanisms which are physically relevant. Moreover, these solutions can be effectively used as tests for more general situations where one has to resort to numerical studies of the PDF dynamics because only moment information is available. Interesting new phenomena in the random uniform shear layer will be presented using rigorous asymptotics methods

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MS76
Effective Diffusive Behaviour for Inertial Particles

We study various models for the motion of inertial particles in a velocity field, and subject to molecular diffusion. The enhancement or depletion of the effective diffusivity is studied as a function of a number of system parameters, including particle relaxation time, fluid relaxation time and molecular diffusivity. New and effective numerical techniques, based on operator splitting methods, are introduced and described. Joint work with Greg Pavliotis (Imperial) and Andrew Stuart (Warwick)

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MS77
Robust Actuation of Global Conformation Change

We consider a class of biomolecules modeled by a chain of coupled pendula moving in a local Morse potential. Although the conformations of the chain are stable and robust against noise, global conformation change of the chain can nevertheless be robustly induced by the action of a small, targeted control that excites resonances in the natural dynamics. A coarse 11/2 degree of freedom model effectively captures the conformation change event as a time-dependent control.

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MS77
Stability Properties of Coupled Pendula

A coupled pendula system on a periodic domain is investigated which contains locally bi-stable weak nonlinear dynamics with strong neighbor coupling. By using low order model representations we investigate the driving mechanisms for the exchange of global energy between different spatial modes. We find this energy exchange is key to the global stability of the oscillator chain.

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MS77
Wave's Travel by Instability of Mode in Coupled Pendulums

In one-dimensonally coupled nonlinear pendulums with external periodic force, there coexist stable and unstable wave modes. The instability of vibration shows the travel of wave from a stable mode to the other coexisting mode. In this paper, the traveling behavior of waves including standing mode, intrinsic localized mode, and impulsive mode will be discussed.

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MS77

Novel Vehicular Trajectories For Collective Motion From Coupled Oscillator Steering Control

Recent analysis of planar collective motion models using coupled oscillator steering control has focused primarily on states in which individuals move either in straight lines or in circles. We show that other, more exotic trajectories are possible when more general coupling functions are considered. These trajectories are associated with stable periodic orbits in the steering control subsystem, and can be understood in terms of the properties of those periodic orbits.

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MS77

Global Instabilities of Power Grid Coupled Pendula-like Models

Coupled pendula-like models are investigated which represent electro-mechanical dynamics of power grids. By numerical simulation it is shown that local disturbances induce global instabilities of the coupled models. It has a potential to explaining the mechanism of failure propagation of power grids.

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MS78

Effect of Feedforward Inhibition on Sparseness of Odor Representations

In a variety of brain areas feedforward inhibition provides an effective mechanism to control integration window of principal neurons. In the insect olfactory system this effect is achieved by the input from lateral horn interneurons to the mushroom body. Based on realistic model of the olfactory system, I will demonstrate the critical role of feedforward inhibition for maintaining the sparseness of olfactory responses across range of odor concentrations.

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MS78

The Construction of High-dimensional Olfactory Representations

Post-acquisition processing in sensory systems relies on an embedded metric of stimulus similarity to underlie essential operations such as contrast enhancement (edge-sharpening) and the regulation of stringency. The high-dimensionality of the olfactory modality, however, precludes the usual solution of mapping similarity relationships directly onto the neural substrate. I describe a neural algorithm for high-dimensional, non-topographical contrast enhancement embedded in olfactory bulb circuitry, and demonstrate how it can underlie the neuromodulatory regulation of olfactory receptive fields.

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MS78

Stochastic Synchronization in the Olfactory System

In this talk I will discuss some work on optimality and the ability of independent oscillators subjected to common noise to synchronize. I use Euler-Lagrange equation to compute the shapes of optimal phase-resetting curves in order to maximize a Lyapunov exponent. I also show that the color of the stochastic signal also has an optimum for maximizing the exponent. I apply this to some recording of olfactory mitral cells which recieve common noisy inputs from shared granule cells.

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MS78

Synchrony and Oscillations in the Mouse Olfactory Bulb

We analyzed responses of mitral/tufted cells in the olfactory bulb of the awake behaving mouse. Three prominent features of the extracellular potentials can be identified: neuronal action potentials, theta-, and beta-oscillations. We observed that timing of the action potentials tends to be aligned with certain phases of gamma-oscillations. The preferred phase of the action potential is not sensitive to odors but, rather, to the behavioral state of the animal.

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MS78

Rapid Plasticity Early in Olfactory Processing Underlies Nonstationary Neural Responses

We seek to understand how the olfactory system encodes natural odor plumes, which impinge repeatedly and chaotically upon odor receptors. We found that two interacting forms of plasticity, one peripheral, and one central, strongly influence neural responses to odorants throughout the olfactory system. We hypothesize that these timing-dependent forms of plasticity amplify odor signals at the onset and offset of (or entrance and exit from) odor plumes – information of great behavioral significance to animals.

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MS78

Multiple Attractors and Transient Synchrony in a Model for an Insect's Antennal Lobe

I will present a biologically motivated model of an insects antennal lobe. The model exhibits complex firing patterns such as transient synchrony, long transients, multiple attractors and a form of spatial decorrelation in which the temporal representations of similar odors evolve to distinct patterns. The model is analyzed by reducing it to a discrete dynamical system. Analysis of the discrete system demonstrates how the dynamics depends on parameters including the network architecture.

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MS79

Vorticity-Free Analyses of Animal Swimming Measurements

We present an approach to quantify the unsteady fluid forces, moments and mass transport generated by swimming animals, based on the identification of Lagrangian coherent structures (LCS) in the surrounding flow field. The LCS dynamics are shown to be well approximated by potential flow concepts, especially deformable body theory. Examples of the application of these methods are given for pectoral fin locomotion of the bluegill sunfish and undulatory swimming of jellyfish.

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MS79

Computations of Wake Dynamics in a Simple Model for Fish Schooling

We perform numerical simulations of the viscous flow produced by an array of three flapping hydrofoils. The system serves as a low-order dynamical model for cooperative locomotion in fish schooling. The interaction of the vortical wakes of the three flappers in several configurations is examined, and the overall thrust generated by the system is computed and compared with an isolated flapper. It is found that cooperative flapping can lead to large improvements in both thrust and efficiency. The thrust is shown to be qualitatively consistent with recent experimental measurements of forward swimming speed by Kelly and Xiong.

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MS79

Hydrodynamically-Coupled Solids

We consider the motion of systems of solid bodies in potential flow. The primary motivation is to study the effect of the hydrodynamic coupling on the motion of the submerged solids and gain insight into the role of this coupling in aquatic locomotion. To this end, a fish is modeled as a system of articulated links, and the net locomotion of the articulated body in potential flow is described in terms of geometric phases over closed curves in the shape space. We extend these models to study the interaction of multiple bodies and show, through examples, that the hydrodynamic coupling plays a role in motion coordination, which may be relevant to understanding the coordinated motion in fish schooling.

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MS79

Self-Propulsion of a Free Deformable Hydrofoil in an Ideal Fluid with Vortex Shedding

Models for aquatic locomotion that are rooted in ideal hydrodynamics are typically more accessible to analysis than viscous models are, but the price of this accessibility can be the faithful representation of essential physical phenomena. We present a model for the self-propulsion of a deformable hydrofoil in an ideal fluid subject to a time-periodic Kutta condition that provides for the shedding of a discretized propulsive vortex wake like the wakes of certain fish.

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MS79

A Hierarchy of Models for Control of Fish-like Locomotion

Various models are presented to study the self-propulsion and control of two-dimensional swimmers. The simplest models assume potential flow and Stokes flow. From the curvature of the connection relating shape changes to group

motion, certain gaits to effect a desired motion may be found by inspection. An improvement to the potential flow model includes the shedding of vorticity via a numerical Kutta condition. Swimming gaits are presented for forward and turning motions.

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MS79

Implementation of Shape Actuation Control for Underwater Swimming

Modeling and control for agile gait generation in robots built with fin propulsive and maneuvering surfaces are considered. Previous work has shown that simplified models with quasistatic lift and drag can be used to construct controls for forward and turning motions that strongly resemble biomimetic motions. The use of such models for agile maneuverability is evaluated here by comparing biomimetic fast start and snap turn data from experiment with simulation data from the model.

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MS80

Delay Coupled Systems: Scaling Laws and Resonances

We consider a model for two lasers that are mutually delay coupled. Signal propagation time causes a significant delay leading to the onset of oscillatory output. Multiscale perturbation methods are used to describe the amplitude and period of oscillations as a function of the coupling strength and delay time. Because we allow for independent control of the individual coupling constants, we show there is an atypical amplitude-resonance phenomena. Our theoretical results are consistent with recent experimental observations..

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MS80

Phase Synchronization in Time-delay Systems

In this paper we report identification of phase synchronization in coupled time-delay systems exhibiting hyperchaotic attractor. We show that there is a transition from non-synchronized behavior to phase and then to generalized synchronization as a function of coupling strength. These transitions are characterized by recurrence quantification analysis, by phase differences based on a transformation of the attractors, and also by the changes in the Lyapunov exponents. We have found these transitions in coupled piecewise linear and in Mackey-Glass time-delay systems.

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MS80

Synchronized Dynamics of Cortical Neurons with Time-delay Feedback

The dynamics of three mutually delay coupled cortical neurons in a line are explored. The middle neuron leads the outer ones by the delay time, while end neurons are synchronized with zero lag. Synchronization depends on the synaptic time constant, with faster synapses increasing both the degree of synchronization and the firing rate. Analysis shows pre-synaptic input during the inter-spike interval stabilizes the synchronous state for arbitrarily weak coupling, and independent of initial phase.

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MS80

Dynamics of Nonlocally Delay Coupled Stuart-Landau Oscillators

In large dynamical systems, time delayed mutual couplings have been found to produce dramatic changes in the dynamical behavior of the system, including creation of higher frequency states, frequency suppression and delay induced amplitude death among coupled identical oscillators. In this talk, we present new results of various types of non-locally coupled systems will be reported, including stability constraints on plane waves, spatial modulation of chimera states and novel modification of 'hole' solutions.

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MS80

On the Dynamics of Mutually Delay Coupled Spatio-temporal Systems

Small networks of mutually delay coupled fiber ring lasers are used to explore the in-phase (isochronal) dynamics of coupled spatio-temporal systems. We analyze a stochastic differential delay equation modeling a network of two mutually coupled fiber lasers. Delayed synchronization is observed between the two lasers, the isochronal state being unstable. Addition of self-feedback loops in the system stabilizes the isochronal solution. Analytical methods will derive isochronal stability parameter dependences for small networks of ring lasers.

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MS81

Numerical Integration of a Delay Equation of Electrodynamics

We report on a numerical search for periodic orbits of a delay equation of electrodynamics. The equation studied describes the motion of two interacting charged particles and has two state-dependent delays. Delay appears natu-

rally in electrodynamics because the speed of light is finite. We discuss a numerical method to search for periodic orbits.

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MS81

Multistability in Spiking Neuron Models of Delayed Recurrent Inhibitory Loops

Hodgkin-Huxley model of a recurrent inhibitory loop with a linear signal function can exhibit coexisting periodic solutions, but phenomenological spiking neuron models (such as the linear or quadratic integrate-and-fire model) without additional mechanisms fail to generate interesting coexisting attractive patterns. We show in this paper that incorporating more biological realities of firing and rebound as well as the absolute refractory period enables a simple looking scalar differential equation with delayed monotone feedback to generate large number of asymptotically stable periodic solutions with complicated binary patterns.

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MS81

Singularly Perturbed State-Dependent Delay Equations: Part II

We study delay-differential equations of the form

$$\varepsilon\dot{x}(t) = f(x(t), x(t-r)),$$

where the delay $r = r(x(t)) \geq 0$ is state-dependent. After determining the limiting shape of solutions for small ε, we study their detailed asymptotics, thereby obtaining stability and uniqueness results, including a new phenomenon of superstability. These techniques are also appropriate for problems with multiple delays. Degree theory, max-plus operators, and geometric singular perturbations are used in our analysis. Numerical results suggest a very rich structure, particularly for multiple-delay problems.

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MS81

Singularly Perturbed State-Dependent Delay Equations: Part I

We discuss recent results on differential-delay equations of the form $\varepsilon x'(t) = f(x(t), x(t-r))$. We focus on the case in which the delay $r \geq 0$ is of state-dependent type $r = r(x(t))$. After determining the limiting shape of solutions for small ε, we study the detailed asymptotics of these solutions. Such an analysis is important in obtaining uniqueness and stability results, as well as for studying problems with multiple delays. Intriguing numerical studies suggest a very rich structure, particularly in the case of multiple delay problems. Although the theory here is in its infancy, some new techniques seem very promising.

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MS81

Metastability (or long transients) in Delayed Differential Equations

We consider the scalar delayed differential equation $\epsilon\dot{x}(t) = -x(t) + f(x(t-1))$, where $\epsilon > 0$, and f verifies $df/dx > 0$ and some other conditions ensuring the convergence of almost all solutions to a set of equilibria. We show that there exists a large set of solutions of the above delayed equation that oscillate for a very long time T before approaching some equilibrium (T is of the order of magnitude of $e^{c/\epsilon}$, as $\epsilon \to 0$). Related results for the case where $df/dx < 0$ are also presented.

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MS81

Periodic Orbits of a Planar Differential Equation with Distributed Delays

We investigate a system of retarded differential equations

$$\begin{aligned} \dot{x}_1 &= \alpha x_1 +_{t-1}^{t} e^{k(t-s)} h_1(x_2(s))ds, \\ dotx_2 &= \alpha x_2 +_{t-1}^{t} e^{k(t-s)} h_2(x_1(s))ds \end{aligned}$$

There is not much room for periodic orbits in this dynamics. If α belongs to a small interval $(\alpha_o, 0)$, plus some conditions on the derivative of $h_i(y)$ at $y = 0$, we prove the existence of periodic orbits of small amplitude encircling the origin. For instance, taking α as a bifurcation parameter, the system undergoes a Hopf bifurcation at $\alpha = \alpha_o$.

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MS82

Spiking-bursting Transition in a Neuron Model: Ionic Mechanisms Using Low Dimensional Reductions

We study the dominant ionic mechanisms of a 16-dimensional, two-compartment model of a crustacean pyloric dilator neuron that exhibits distinct modes of oscillation – tonic spiking, intermediate bursting, and strong bursting. We systematically divide solution trajectories into regions dominated by a smaller number of variables, resulting in a reduced hybrid model having dimension as low as two in some temporal regimes. The reduced model exhibits the same modes of oscillation as the full model over a comparable parameter range. We investigate the low-dimensional organizing structure of the model dynamics and the dependence of the model oscillations on parameters such as the maximal conductances of calcium currents.

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MS82

Discussion

Discussion.

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MS82

Gamma Oscillations and Axo-axonic Cells

Gamma oscillations (30-90Hz) are thought to be important for synchronizing ensembles of neurons and moreover for sensory processing. How such gamma oscillations arise has been a prevalent topic of research of the dynamical systems of neural networks, often involving an interplay between excitatory and inhibitory cells. Recently it has been shown that axo-axonic cells, usually classified as inhibitory, can in fact be excitatory. We examine this effect on a network model of gamma oscillations.

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MS82

Manipulating Fast and Slow Neural Synchrony in Olfactory Processing

The rodent olfactory system produces prominent oscillations in the theta (4-12 Hz), beta (15-30 Hz) and gamma (35-100 Hz) bands. Gamma oscillations are significantly enhanced when pattern discrimination is difficult. Theta oscillations represent wide-scale coupling at the respiratory frequency and help transfer the system between resting and activated states. Beta oscillations indicate olfactory system processes involved in approach/avoid behavioral association learning. Rats modify all of these effects dynamically according to task demands and behavioral state.

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MS82

Coupled Rhythms and Transitions in Rat Auditory Cortex

We present a mathematical model to account for *in vitro* recordings from rat auditory cortex. The recordings reveal that two distinct frequencies, γ ($40-80$ Hz) and β_2 ($20-30$ Hz), initially occur in superficial and deep cortical layers, respectively. The rhythms synchronize at β_1 ($12-20$ Hz) frequencies after application of kainate. We present a simple biophysical model to account for the distinct frequencies and the transition to synchronous dynamics.

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MS82

Half-center Bursting in a Two-cell Inhibitory Network Captured by a Burst Length Return Map

We derive the burst length return map which fully characterizes the anti-phase bursting in a mutually inhibitory network of two cells with T-currents. Although the map is constructed from the properties of a single isolated model neuron, it accurately captures the periodic and the chaotic activity of the full network. The parameter dependence of the map describes the regulation of the burst length, and elucidates conditions under which multistability of several bursting solutions is achieved.

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MS83

Physically Inspired Stochastic Partial Differential Equations

The focus of the talk is on the heat, Burgers' and Navier-Stokes partial differential equations (PDEs) and their stochastic counterparts. Questions related to existence and uniqueness of the solutions will be discussed. For the Navier-Stokes system, two potential stochastic evolution PDEs will be explored: randomly forced Navier-Stokes system in its velocity form and the stochastic vorticity equation. In connection with the stochastic vorticity equation, results pertaining to filtering and large deviations problems will be presented.

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MS83

Stochastic Attractor for the Shell-GOY Model

The shell-GOY model is a simplified Fourier system with respect to the Navier-Stokes one. We study its stochastic version which is a non autonomous system. We prove existence of the stochastic attractor using a pullback approach. We will also give some results on the determining modes.

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MS83

A Stochastic Lagrangian Representation of the 3-Dimensional Incompressible Navier-Stokes Equations

In this talk I will derive a stochastic representation of the Navier-Stokes equations based on 'noisy' particle paths. Roughly speaking the representation can be thought of as perturbing an inviscid flow with the Weiner process and averaging. This leads to the physical interpretation of viscous fluids as inviscid fluids plus Brownian motion of the fluid particles. I will use this representation to sketch an elementary proof of global existence for initial data which is small in $C^{2,\alpha}$.

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MS83

Dynamics, Local Times, and a Class of Linear Stochastic Partial Differential Equations

The main purpose of this talk is to describe two families of results on linear stochastic partial differential equations: First, we establish a dynamical construction of the Ornstein-Uhlenbeck process on Wiener space (Malliavin, 1987). This is based on joint work with David Levin and Pedro Mendez (2005), and verifies a conjecture of Benjamini, Häggström, Peres, and Steif (2003). Next we introduce a one-to-one correspondence between a family of linear stochastic partial differential equations and the theory of local times for symmetric Lévy processes. This is based on our on-going joint effort with Eulalia Nualart and Mohammud Foondun. The said correspondence "explains" why some of the exotic features of the stochastic heat equation (Walsh, 1986) hold.

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MS83

Stochastic 2-D Navier-Stokes Equation with Artificial Compressibility

In this talk we consider the 2-D stochastic Navier-Stokes equation with artificial compressibility in arbitrary unbounded domain and using the Minty-Browder monotonicity argument we prove certain new results on the existence and uniqueness for strong solutions and the limit to incompressible flow.

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MS83

Randomness and Geometry in Two Dimensional Turbulence

Incompressible ideal fluid flow can be understood as geodesic motion on the diffeomorphism group. We show how to include dissipation and fluctuation to give a geometric description of stochastic Navier-Stokes equations. An equilibrium probability distribution is shown to exist and the rate approach to it is estimated.

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MS84

Stability of Nonlinear Waves via the Krein Signature

Various problems in stability of nonlinear waves share the same underlying structure. They can be posed as eigenvalue problems in an appropriate indefinite metric space.

I will discuss particular cases when this approach guides numerical search for eigenvalues using the Evans function.

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MS84

Derivatives of the Evans Function and Fredholm Determinants

We will discuss further connections of the Evans function and Fredholm determimants of the Birman-Schwinger type operators. In particular, we will show how to evaluate derivatives of the Evans function and the related Fredholm determinant in terms of solutions of the nonhomogeneous Jost-type equation. This calculation is critical in stability analysis of traveling waves.

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MS84

Evans Function Calculations for a Two-dimensional System

All numerical computations of the Evans function up to now concerned essentially one-dimensional systems. We discuss the computation of the Evans function for a wrinkled front in a two-dimensional autocatalytic reaction-diffusion system. Fourier decomposition in the transversal direction brings the problem in the standard form, but the number of variables is so high that we cannot use the usual lift to the exterior product space.

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MS84

The Evans Function and Homogenization

We generalize the work of Oh and Zumbrun, and Serre on spectral stability of spatially periodic traveling waves of systems of viscous conservation laws from the one-dimensional to the multi-dimensional setting. Specifically, we extend to multi-dimensions the connection observed by Serre between the linearized dispersion relation near zero frequency of the linearized equations about the wave and the homogenized system obtained by slow modulation (WKB) approximation. This may be regarded as partial justification of the WKB expansion; an immediate consequence is that hyperbolicity of the multi-dimensional homogenized system is a necessary condition for stability of the waves. As pointed out by Oh and Zumbrun in one dimension, the description of the low-frequency dispersion relation is also a first step in the determination of time-asymptotic behavior.

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MS84

Shock Wave Stability in Viscous and Viscous-Dispersive Systems

We explore the stability problem for both viscous and viscous-dispersive traveling waves in one-dimension. The two main problems we consider are the p-system, also known as the isentropic Navier Stokes equations and Slemrod's model, which is the p-system with added capillarity. We compare numerical simulation methods with Evans function computation as a means of determining stability and observing the onset of instability.

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MS85

A Stochastic Immersed Boundary Method Incorporating Thermal Fluctuations: Toward Modeling Cellular Micromechanics

Many processes within the cell involve spatially organized and mechanically coupled events. In this talk we shall discuss a stochastic formulation of the Immersed Boundary Method which can be used to model spatial and mechanical aspects of cellular processes. In particular, we shall discuss an extension of the framework which incorporates thermal fluctuations through appropriate stochastic forcing terms in the fluid equations. This gives a system of stiff SPDE's for which standard numerical methods perform poorly. We shall also present stochastic numerical methods which handle the stiff features of the equations allowing for simulations over long time scales. Applications of the method in modeling the microscopic mechanics of polymers and membrane structures, osmotic swelling phenomena, and some basic models of molecular motor proteins will be discussed.

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MS85

Fusion Versus Endocytosis: A Stochastic Model for the Fate of Viruses

The simplest mechanism of virus entry into a host cell involves the binding of cell surface receptors to glycoproteins, or "spikes," on the virus membrane. Fusion peptides in the spikes may then be triggered by pH changes or binding of additional coreceptors. Thus, binding of virus envelope proteins to cell surface receptors not only initiates the viral adhesion and wrapping process necessary for internalization, but also starts the direct fusion process. We develop a stochastic model that incorporates both receptor mediated fusion and endocytosis. The relative fusion and endocyto-

sis probabilities of a virus particle initially nonspecifically interacting with the host cell membrane are computed as functions of receptor concentration, binding strength, and number of spikes. Using asymptotic analysis for large numbers of viral spikes, we find qualitative behaviors that are sensitive to only certain kinetic parameters.

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MS85

The Reaction-Diffusion Master Equation is an Asymptotic Approximation of Diffusion to a Small Target

We will present several mathematical models for studying reaction-diffusion processes wherein both noise in the chemical reaction process and diffusion of individual molecules may be important. In particular, we will examine the relation between the reaction-diffusion master equation model of spatially distributed stochastic chemical kinetics and models that track individual particles. Our analysis will demonstrate the importance of modeling point binding, equivalently binding to a small target, in understanding the reaction-diffusion master equation.

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MS85

Multiscale Analysis of Stochastic Reaction Networks

Stochastic models of cellular chemical reaction networks typically involve chemical species numbers and reaction rates varying over several orders of magnitude. A number of researchers have proposed exploiting the multiscale nature of these models to reduce the complexity of the model to be analyzed or simulated. Systematic approaches to model reduction will be discussed.

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MS85

A Numerical Scheme for Optimal Transition Paths of Stochastic Chemical Kinetic Systems

We present a new framework for finding the optimal transition paths of metastable stochastic chemical kinetic systems with large system size. The optimal transition paths are identified, in terms of the reaction advancement coordinate, to be the most probable paths according to Large Deviation Theory of stochastic processes. Dynamical equations for the optimal transition paths are derived using the variational principle. A modified Minimum Action Method (MAM) is proposed as a numerical scheme to solve the optimal transition paths. Compared with previous methods based on the limiting diffusion processes, the accuracy of the proposed scheme is guaranteed on the infinite time horizon. Applications to Gene Regulatory Networks such as the toggle switch model and the lactose operon model in E. coli are presented as numerical examples.

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MS85

Bifurcation Analysis of Stochastic Gene Networks

Through both observation and theory, it is now generally accepted that the dynamics of biological systems, especially gene networks, are a noisy process. It is also generally agreed that a good description of the dynamics is either a jump Markov process with a corresponding Master equation or a continuous Markov process with a corresponding Langevin or Fokker-Planck equation. But what sort of solutions do these Master, Fokker-Planck, or Langevin equations generate? How do parameters of the model affect the solution? How are solutions created or destroyed? What does stability of the solution mean in the context of a stochastic system? What does the noise do to the stability of each solution? How may we quantify these effects? How is the stability of a solution related to the escape rate from it? The answers to these questions will help us create synthetic gene networks that exhibit desired stochastic dynamical behaviors. The study of these questions is bifurcation analysis and its application to stochastic systems (called random dynamical systems in the mathematics literature) is a relatively new field. We aim at a conceptual presentation of how bifurcation analysis of random dynamical systems differs from deterministic ones (ODEs) and why it is important to know about these differences. We present our recent results on two new stochastic numerical methods that compute the stable and unstable random attractor of a chemical Master equation. We also discuss the existence of an invariant non-stationary distribution. We use these methods to compute the stochastic bifurcation diagram of the bistable Schlogl model, a type of chemical normal form for bistability in gene networks. We show how mesoscopic solutions to a chemical Master equation can emerge, grow in stability, lose stability, and collapse under small parameter changes. We also calculate the Lyapunov exponents of these solutions to quantify their relative stability. These results constitute a beginning to using stochastic bifurcation analysis to study realistic biological systems.

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MS86

Atmospheric Response of Means, Variances and Covariances using Fluctuation-Response Theory

Based on the fluctuation-dissipation theorem presented by Leith (1975) and broadened by Majda (2005) and Dymnikov and Gritsun (2005), we construct, test and apply three-dimensional operators that estimate response of the atmosphere to external forcing. Operators are considered that not only estimate the response of mean state variables but also variances and eddy fluxes of bandpass fields. These are then applied to problems including determining optimum excitation of the North Atlantic Oscillation and midlatitude stormtracks.

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MS86

A Generalized Fluctuation-Dissipation Relation in Nonequilibrium Hydrodynamics

Eyink et al. (1996) derived hydrodynamic equations applicable to systems not in local thermodynamic equilibrium, by a method of Zubarev. The internal fluctuations were shown to obey a generalized fluctuation-dissipation relation (FDR), whose validity is not restricted to thermal equilibrium or time-reversible systems or linear dynamics. A review of this theory and its precedents will be given, and a discussion of how the generalized FDR might be related to the climate system are presented.

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MS86

Application of the Fluctuation-Dissipation Theorem to Numerical Weather Prediction Forecasts

Recent advances in ensemble-based data assimilation applied to numerical weather prediction (NWP) models have facilitated the construction of state-dependent ensemble estimates of space-time correlation functions. Researchers in the field are beginning to exploit these correlations for improved understanding of the physical system, and it is expected that application of FDT ideas, a cornerstone of modern statistical mechanics, will accelerate advances in the field.

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MS86

The Influence of Tropical Convection on Mid-latitude Atmospheric Statistical Predictability - Part II

It is sometimes argued that the presence of the tropical Madden Julian Oscillation may improve mid-latitude weather prediction. Given that current atmospheric NWP models have trouble simulating the MJO well this is a potentially important area for improving weather predictions. We carefully analyze this question using simplified models of both the MJO and the global atmosphere. Our focus is on the influence of convection in shifting and transforming ensemble predictions.

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MS86

The Fluctuation Dissipation Theorem in Climate Theory

The Fluctuation Dissipation Theorem has found application in turbulence theory in the papers of Kraichnan, Herring and in atmospheric science in the 1975 paper of Leith. The theorem relates the relaxation or autocorrelation time of a system in thermal equilibrium with a reservoir to its sensitivity to external perturbations. The potential for its application to global climate theory is obvious: can we estimate climate sensitivity by studying the properties of the system in equilibrium?

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MS86

Using Fluctuation-dissipation Relationships to Assess Weather and Short-term Climate

Linear Inverse Models (LIMs) derived using Fluctuation-Dissipation relationships are competitive with nonlinear general circulation models (GCMs) at predicting short-term climate variations. The predictable signal may be identified with the LIM's deterministic linear dynamics and used to estimate a potential forecast correlation skill score at each geographical location. Maps of potential and actual forecast skill are constructed, and found to be very similar. This result places important constraints on further forecast skill improvements using GCMs

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MS87

Laplacian Eigenmaps and Manifold Learning

In this talk we will discuss some recent work on learning various invariants of a manifold given by point-cloud data. The object of particular interest will be the Laplace-Beltrami operator on the manifold and its eigenfunctions, which have recently found applications in a variety of problems of machine learning and other areas. We will discuss how these eigenfunctions can be computed, certain recent convergence results and mention some applications.

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MS87

Projected Dynamics from a Randomly Forced PDE

Please enter your abstract here. Seventy-five (75) word maximum. Do not include self defined TeX commands. The cable equation is a linear partial differential equation model of an imperfectly insulated uniform conductor which is coupled to its surroundings by capacitive effects. The resulting dynamical system when this is subjected to randomly selected discrete input pulses (representing a finite alphabet of possible input symbols) can be thought of as

iterated function system on a suitable Banach space. This can be shown to have a unique compact attractor which has a finite Hausdorff dimension. The context of this work is our development of an approach to signal processing which is not based on linear systems analysis. In this talk I will focus on projecting the IFS and its dynamics on the attractor to give the kind of simple time series model generally used by communications engineers.

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MS87

The Lagrange Inversion Theorem, IFT, and Nash-Moser

The relationships among the Lagrange inversion theorem, implicit function theorem, and the Nash–Moser theorem will be described. Since the Lagrange inversion theorem, while classical, is not part of every mathematician or scientist's vocabulary, a clear and clean version will be stated. The Lagrange inversion theorem applies to analytic functions. The extension to, and limitations on the extension to, the category of smooth functions will be described.

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MS87

Classical Multidimensional Scaling and Manifold Learning

Manifold learning (ML) techniques for nonlinear dimension reduction posit that data lie (approximately) on a manifold in an ambient space. Various ML techniques can be understood as applications of classical multidimensional scaling (CMDS), which embeds interpoint dissimilarities in Euclidean space. A prototypical example is Isomap, in which geodesic distance on the posited manifold is approximated by shortest path distance on a suitable graph, then embedded by CMDS. We survey several ML techniques from this perspective.

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MS88

Diffusion Geometry as a Tool for Encapsulating Complex Dynamics

We describe various applications of diffusion geometries as a descriptive tool for organizing complex configurations in high dimensions . In particular we describe the emergence of natural multiscale geometries, enabling dimensional reduction of data . Our examples cove massive computer network dynamics and control , as well as intrusion attacks and anomaly detection. Other applications cover effective descriptions of complex interactive particle systems.

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MS88

Challenges in Design of Cyber-Physical Systems

The design of future networked embedded systems for control of physical systems with spatially distributed dynamics will require the tight integration of IT systems (including algorithms, computational architecture, and communications) with control, and dynamics. The need is to develop research programs that include the elements of multiscale modeling and analysis tools that specifically include dynamics of the physical as well as embedded software systems and methodology to include uncertainty in the modeling and analysis.

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MS88

Uncertainty Quantification Methods in Modeling Heterogenous Interacting Populations

We use uncertainty quantification tools to study the dynamics of heterogeneous interacting populations in problems ranging from the Kuramoto model to coupled cellular and neuronal oscillators as well as agent-based models. Generalized polynomial chaos coefficients provide useful coarse-grained observables; short bursts of appropriately initialized detailed computations provide the information through which coarse-grained, equation-free numerics can be implemented. The agorithms demonstrated range from coarse projective integration to coarse bifurcation computations. We will also explore the use of data analysis algorithms to extract alternative coarse-grained observables.

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MS88

Accelerated Markov Chain Simulations for Aerosol Processing in Clouds

We present a new direct method for the forward-time simulation of the Markov Chain describing stochastic particle coagulation processes, applied to cloud droplet coagulation and mixing. These systems have a large range of scales, but no clear scale separation, preventing the use of existing accelerated methods. Our algorithm uses a hierarchical accept-reject procedure and particle clustering to achieve many orders of magnitude increases in efficiency.

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MS89

Density Functional Theory and Simulations of Spherical Ions in Biological Ion Channels

Biological ion channels can selectively conduct ions across cell membranes down the ions chemical potential gradients. Discrimination between ion species occurs in a small part of the channel where the ions are crowded into a very small volume. The correlations of spherical ions at high densities and how this leads to ion selectivity are discussed. The model is a drift-diffusion system that includes spherical ions via Density Functional Theory of fluids.

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MS89

Discussion

Discussion.

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MS89

Application of Dynamical System Theory to PNP Equations

The Poisson-Nernst-Planck (PNP) system serves as a basic model for electro-diffusion processes. In this talk, we will consider the dynamics of the PNP system taken as a model for ion flows through membrane channels. A general dynamical system framework will be set up for the steady-state PNP systems and special properties for this specific problem will be discussed. Recent results on the multiplicity and spatial types of steady-states will be reported.

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MS89

Experimental Studies of Nonlinearities and Fluctuations in Single Asymmetric Nanopores in Polymer Films

We examined ion current through single conically shaped nanopores at presence of sub-millimolar concentrations of calcium and cobalt ions. The pores have opening diameters of sereval nanometers and 1 micrometer, respectively. We will show that both divalent ions induce voltage-dependent ion current fluctuations and oscillations in time as well as negative incremental resistance in current-voltage curves. Application of this system for building a sensor will be discussed as well.

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MS90

Evaluation of Probability of Capsizing with Numerical Simulation

A random dynamical system with two stable equilibria is considered as a model of ship capsizing in irregular beam seas. To avoid numerical difficulties related with the extreme rarity of capsizing, it is computed as a combination of the upcrossing of a threshold roll and of transitioning to the "capsized" equilibrium after upcrossing. The probabilities of both random events are evaluated from numerical simulations made using the Large Amplitude Motion Program (LAMP) time-domain seakeeping code.

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MS90

Round Table Discussion

This concluding time slot will be open for round table discussion of the topics presented throughout the two-part minisymposium along with identification of directions for future research.

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MS90

Unstable Motions Resulting from Non-Linear Coupling of the Heave-Roll-Pitch Modes: Parametric Rolling of Ships in Head Seas

Parametric rolling of ships is a nonlinear phenomenon that has attracted much attention recently. A third order nonlinear mathematical model that couples heave, roll and pitch motions has been proposed by the Authors. This new model has succeeded in reproducing strong parametric resonance conditions in head seas. However, there are some important non-linear characteristics that have not been completely understood yet. This paper explores the influence of third order nonlinearities as well as the relevance of coupling between the vertical modes and the roll motion in the modelling of parametric resonance in head seas. Stability limits are derived and discussed using analytical based on Hill equation - and numerical approaches. Some relevant dynamical aspects are clarified. The influence of initial conditions on the development of roll amplifications is investigated and the effect of coupled or uncoupled modeling of the roll motion is addressed.

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MS90

Numerical Prediction of Surf-riding Threshold of a Ship in Stern Quartering Waves as Heteroclinic Bifurcation of Multi-dimensional System

A ship could suffer surf-riding, under which she runs with a wave. The condition of transition from periodic motions to surf-riding coincides with a heteroclinic bifurcation of ship motions in waves. The authors numerically identified the heteroclinic bifurcation points in a multi-dimensional control space by utilising a coupled motion model in stern quartering waves, which can be regarded as an autonomous system. Here the Newton method is applied to a two-point boundary value problem.

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MS91

Synthetic Chaos

Chaos is usually attributed only to nonlinear dynamical systems. Yet surprisingly, we find that a linear filter driven by a random binary waveform generates an output that, when viewed backward in time, exhibits the essential qualities of chaos, including determinism and a positive Lyapunov exponent. Using different encodings of the random symbols, the same filter can produce both Lorenz-like butterfly and Rossler-like folded band dynamics. Furthermore, the encodings can be viewed as grammar restrictions on a more general drive, which produces a chaotic superset containing both the Lorenz and Rossler dynamics. Thus, the language of chaos provides a useful description for signals not generated by a nonlinear dynamical system, suggesting chaos may be connected to physical theories whose underlying framework is not that of a traditional nonlinear dynamical system.

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MS91

A Topological Partition of the Hydrogen in Crossed Fields Phase Space

The hydrogen in crossed electric and magnetic fields is a well-studied atomic physics system whose phase space transport exhibits so-called bottlenecks, i.e. competition between phase space regions that inhibit transport and hyperbolic structures that mediate it. We develop an approximate topological partition of unstable periodic orbits belonging to the hyperbolic repelling set by labeling them with two sets of indices, accounting for rotational and the "stretch and fold" characters of the motion. This partition enables us to systematically explore the hierarchy of unstable periodic orbits, and compute a large number of orbits of increasing periods.

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MS91

Deconstructing Spatiotemporal Chaos using Local Symbolic Dynamics

We propose local symbolic models as a practical tool for understanding high-dimensional spatiotemporal chaos in diffusively coupled map lattices (CMLs). A local symbolic model is a truncation of the full symbolic dynamics to one that considers only a single element and a few neighbors. Local symbolic models can be applied element by element to a large lattice to build up an approximate picture of the global dynamics. Whereas the difficulty of finding the exact global symbolic dynamics increases exponentially with lattice size, the difficulty of the approximation presented here increases linearly at worst. The many uses of symbolic dynamics for one-dimensional maps, including control and targeting, are thus made practical for lattices. We explore the efficacy of the concatenated local model approach and give an example of controlling an arbitrary pattern in a CML using only small perturbations.

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MS91

Mostly Conjugate: Relating Dynamical Systems – Beyond Homeomorphism

A centerpiece of Dynamical Systems is comparison by an equivalence relationship called topological conjugacy. We present details of how a method to produce conjugacy functions based on a functional fixed point iteration scheme can be generalized to compare dynamical systems which are not conjugate. When applied to non-conjugate dynamical systems, we show that the fixed point is a function we now call a "commuter" a nonhomeomorphic change of coordinates translating between dissimilar systems. This translation is natural to the concepts of dynamical systems in that it matches the systems within the language of their orbit structures. We introduce methods to compare nonequivalent systems by quantifying how much the commuter functions fails to be a homeomorphism, an approach that gives more respect to the dynamics than the traditional comparisons based on normed linear spaces. Our discussion includes fundamental issues as a principled understanding of the degree to which a toy model might be representative of a more complicated system, an important concept to clarify since it is often used loosely throughout science.

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MS93

Schroedinger Flow and Landau-Lifshitz Dynamics

The Schroedinger flow into the 2-sphere is a geometric generalization of the linear Schroedinger equation, and a particular case of the Landau-Lifshitz equation for ferromagnets. In one space dimension, it is integrable, but in two dimensions it is not, and understanding the fate of local solutions (blow-up? asymptotics?) is a challenge. I will describe some recent work on these questions, part of a joint project with K. Kang and T.-P. Tsai.

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MS93

Symmetry Breaking of Ground States in Nonlinear Schroedinger Equation

The talk will focus on recent results regarding existence and stability of periodic solutions for NLS with double well potentials. It has been known that the equation admits periodic in time, symmetric in space, stable solutions (ground states) with small L^2 norms. In the case of attractive Hartree nonlinearity these solutions become unstable for large L^2 norms and are replaced by asymmetric ground states. The new results show that the same phenomena is present in the case of attractive, local, cubic nonlinearity. The results are valid even when the ground states are no longer minimizers of the energy functional (space dimensions two and three). Moreover, for both local and Hartree nonlinearity, we estimate the critical L^2 norm where the asymmetric ground states bifurcate and relate it to the separation between the wells of the potential. This is joint work with P. Kevrekidis (Univ. of Massachussetts), E. Shlizerman (Weizmann Institute), and M.I. Weinstein (Columbia Univ).

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MS93

Towards Classification of Chaotic Orbits in the Forced NLS

We propose that the hierarchy of bifurcations framework may be used to judiciously choose the initial profiles and parameter values which produce different types of chaotic solutions in near-integrable Hamiltonian systems. Here, depending on the forcing frequency of the perturbed NLS, for low amplitude solutions which are close to the plane wave solution, we show that three different chaotic scenarios (homoclinic chaos, hyperbolic resonance and parabolic resonance) emerge.

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MS93

Large Time Behavior of NLS : Soliton Dynamics, Numerics and Experiments

Abstract not available at time of publication.

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MS94

Epidemic Dynamics on an Adaptive Network

We study epidemic dynamics on an adaptive network, where the susceptibles are able to avoid contact with infected by rewiring their network connections. This gives rise to assortative degree correlation, oscillations, hysteresis and 1st order transitions. We propose a low-dimensional model to describe the system and present a full local bifurcation analysis. Our results indicate that the interplay between dynamics and topology can have important consequences for the spreading of infectious diseases and related applications.

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MS94

The Adaptive Dynamics of Coevolving Communities

The ecological and evolutionary dynamics of communities are linked inevitably and intricately, with frequency- and density-dependent selection pressures playing key roles. The theory of adaptive dynamics enables deriving fitness functions, selection pressures, and evolutionary dynamics from the underlying ecological interactions and population dynamics. I will explain how to analyze the fundamental feedback between a community and its fitness landscape(s) and how thus to understand the evolutionary gain and loss of biodiversity.

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MS94

Dynamics of Networking Social Agents: From Diplomacy to Friendship

We discuss two models of socially interacting agents. First, we consider a system of networking agents that seek to optimize their centrality in the network while keeping their degree low. Second, we model friendship networks by combining opinion spreading on the network with a preference for similar people to get acquainted. We study the macroscopic behavior of these models, including a phase transition in the latter case, and discuss the connection between these two models.

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MS94

Weighted Networks from Adaptive Synchronization

We consider adaptation of connection strength in degree heterogeneous network by local synchronization properties.

The connection strength increases with a rate proportional to the synchronization difference between a node and its neighbours. We find that the network becomes weighted and the connection weights are correlated with degree, so that nodes with large degrees have weaker input links. Synchronization can be enhanced significantly in this adaptive network.

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MS95

Hardy-Rellich Type Inequalities and Lyapunov Function Bounds

We consider the Lyapunov function method for producing bounds for the Kuramoto-Sivashinsky and similar equations. We discuss an inequality of Hardy-Rellich type, and its application to this problem. We give a physical interpretation of the method, and consider some possible extensions.

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MS95

Decomposing the Dynamics of Spatiotemporal Chaos in Rayleigh-Benard Convection

The spatiotemporal chaos of Rayleigh-Bénard convection (a fluid layer heated from below) is explored using large-scale numerical simulations for experimentally realistic conditions. Recent results show convection to yield extensive chaos and we discuss whether extensivity is found for arbitrarily small changes in system size (microextensivity). Using calculations of the Lyapunov spectra, fractal dimension, and Karhunen-Loève decomposition (proper orthogonal decomposition) we further quantify and discuss the underlying structure of the spatiotemporal chaos.

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MS95

Estimates for Kuramoto-Sivashinsky Type Equations

The recent work of Bronski and Gambill for obtaining bounds on the Kuramoto-Sivashinsky equation has provided a powerful real-space construction of the Lyapunov function, which can be generalized to numerous related systems. We discuss some of these extensions.

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MS95

Bounds on Rayleigh-Bénard Convection with Conductive Plates

We formulate a uniform variational bounding principle to obtain rigorous theoretical estimates for bulk heat transport in turbulent Rayleigh-Benard convection as a function of the temperature drop across the fluid. We treat a full range of thermal boundary conditions between the fixed temperature and fixed flux extremes, and show that the usual fixed temperature assumption is a singular limit of the full problem. We also obtain analytical bounds in the physically realistic case of a fluid bounded by conductive plates, and discuss some generalizations.

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MS96

Role of Gap Junctions in a Network of Globally Coupled Phase Oscillators

Globally coupled phase oscillators has been studied for a long time. Depending on the coupling function and heterogeneity, the network can exhibit synchrony, asynchrony or clustered solutions. We take such a network where equal sized two-cluster solutions are stable. After adding small amount of nearest neighbor gap junctions, the cluster solution becomes unstable. More interesting behavior is observed when gap junction coupling is as strong as synaptic coupling: traveling waves. Depending on the size of the network and strength of coupling, different varieties of traveling waves are found in the system. As gap junction coupling gets weaker, traveling waves bifurcate at a Hopf point giving rise to periodic solutions with a zig-zag pattern. In a small region for the bifurcation parameter, stable two-cluster state and periodic zig-zag solution coexist. We hereby present both analytical and numerical results.

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MS96

Normal Forms for Blue-Sky Catastrophe and Lukyanov-Shilnikov Bifurcation: Application to Bursting Neurons

Shilnikov and Cymbalyuk have shown the existence of many exotic bifurcations in detailed models of bursting neurons. I will show how the models can be reduced to normal forms near these bifurcations, so that they can be studied analytically.

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MS96

Phase Response and Spike Number Transitions in Bursting Neural Models

Phase response curves are often used to study the response of model neurons to synaptic inputs, but these typically assume biologically unrealistic (infinitesimal, instantaneous) perturbations. We show that bursting neural models exhibit a high degree of phase sensitivity to biologically realistic inputs, including changes in the number of spikes per burst. Using multiple time scale analysis and a reduction to discrete maps, we elucidate the mechanism of spike addition/deletion and its implications for burst phase response.

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MS96

Homoclinic Chaos on a Spike Adding Route into Bursting Neurons

Bursting is a manifestation of the complex, multiple time scale dynamics observed in diverse neuronal models. A description list of the nonlocal bifurcations leading to its onset is far from being complete and presents a dare need for interdisciplinary science of neurobiology. There was a recent breakthrough in this direction that explains a few novel mechanisms of transitions between tonic spiking and bursting activity, as well as their co-existence in models of leech interneurons through homoclinic saddle-node bifurcations of periodic orbits including a blue sky catastrophe. Here we report and describe another such mechanism in a model of a leech heart interneuron, the so-called a spike adding route: as a parameter shifting the membrane potential of half-inactivation slow potassium current is monotonically changed, a sequence of bifurcations occurs causing incremental change of the number of spikes in a burst. Of our special interest is the origin of the sequence, where each transition is accompanied by chaos within a narrow parameter window. To figure out the transition dynamics we construct a one-parameter family of the Poincare return mappings on the central manifolds of slow motions. We show that the transitions in question are due to the bifurcations of homoclinics of a repelling point of the map that is a threshold between tonic spiking and hyperpolarized states of the neuron model. A symbolic description applied to the trajectory behavior of the map allows us to systemize the order of interburst spike variations.

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PP0

Newtons Problem of Minimal Resistance in the Class of Solids of Revolution

As is well known, Newton found the solution of the problem of the body of minimal resistance in the class of convex solids of revolution. We consider this problem in the wider class of (generally nonconvex) solids of revolution. It appears that omitting the convexity assumption allows one to find bodies of smaller resistance than Newtons body of minimal resistance. We present the solution of the problem and construct the minimizing sequence of bodies.

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PP0

Cooperative Dynamics in Coupled Noisy Dynamical Systems Near a Critical Point: the dc-SQUID as a case study

Dynamical systems that operate near the onset of coupling-induced oscillations can exhibit enhanced sensitivity to external perturbations. We investigate this cooperative behavior and the attendant enhancement in the system response (quantified via signal-to-noise ratio analysis). As a prototype, we study arrays of dc SQUID and of Fluxgate magnetometers locally coupled in a ring configuration. We show that biasing the arrays near the bifurcation point of coupling-induced oscillations can lead to significant performance enhancements.

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PP0

Continuation of Defects in Reaction-Diffusion Systems

Reaction-diffusion systems posed on the real line can exhibit solutions formed by wave trains at $x = -\infty$ and $x = +\infty$ which are connected by an intermediate interface region: such solutions are referred to as defects. Continuation of defects involves solving a boundary-value problem in an appropriate frame of reference. We discuss various methods for the discretisation of such problems and present numerical continuation results of symmetric standing sources.

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PP0

AWM Poster: Modeling Migration: Simulating the Migration of the Capelin Around Iceland

In this poster, I will discuss a model of fish behavior which I am using to describe the annual migration of the Capelin around Iceland. I will describe the model which my research group is currently analyzing, how it evolved, the relevant biology behind it, and how we are working with the model in the context of the migration. I will also talk about the associated system of ODEs and the solutions which we have found.

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PP0

Turbulent-Laminar Patterns in Shear Flows

Plane Couette flow near transition displays steady periodic oblique bands of alternating turbulent and laminar flow. Numerical simulations of the Navier-Stokes equations in a tilted domain show a rich variety of such patterns, including spatio-temporal intermittency, branching and travelling states, and localized states analogous to spots. Quantitative analysis of the Reynolds-averaged equations reveals that both the mean flow and the turbulent force are centrosymmetric and can be described by only three trigonometric functions, leading to a model of six ODEs.

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PP0

The Dynamics of Interacting Kuramoto Systems

We study multiple interacting Kuramoto systems in which the connectivity is specified by a general matrix. Knowledge of this matrix is sufficient to determine the onset of collective synchronous behavior. We also discuss novel interaction dynamics and the effects of time-varying connectivity.

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PP0

Qualitative Study of the $(N+1)$-Body Ring Problem

We present a qualitative study of a simplified N-body problem: the $(N+1)$-ring Problem. We describe the evolution of the equilibrium points, their stability and their bifurcations. Besides, we use new numerical techniques: the OFLI2 to study the chaoticity of the orbits and the Crash test to classify the orbits as bounded, escape or collisions. Finally, we have performed a systematic search of symmetric periodic orbits of the system.

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PP0

Global Dynamics of a Non-Smooth Model of Metal Cutting

High-speed cutting processes often exhibit non-smooth behaviour due to a self-excited instability known as chattering, where the cutting tool repeatedly loses and re-establishes contact with the workpiece. We consider a cutting model that is formulated as a system of non-smooth delay differential equations (DDE). We show, via numerical continuation of the non-smooth problem, that stable chattering motion occurs after a grazing bifurcation where the cutting tool loses contact with the surface of the workpiece.

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PP0

Dynamically-Natural Spacecraft Formations

Spacecraft formation flying involves creating and maintaining a desired configuration or geometrical shape. In this investigation of the circular, restricted three-body problem, two controllers were designed: one to allow multiple spacecraft traveling in separate periodic orbits to be phase-locked and the other to establish the desired formation. Since the spacecraft are phase-locked on a single periodic orbit, the standard equations of motion (where neither controller is active) allows for the formation to be maintained over time.

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PP0

Voter Model on An Adaptive Disordered Network

We study voter dynamics on a network in which the connections evolve together with the dynamics of the agents. This dynamical model is exactly solvable. We obtain the final state of the sytem for arbitrary initial condition. On long time scales the network reaches one of its absorbing states (completely ordered), whereas on intermediate time scales a “neutral” state (with zero magnetization) or an active state (with finite magnetization) can persist for long

time.

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PP0

Analysis of Clustered Solutions in a Globally Inhibitory Network of Spiking Cells

A neuronal network of cells exhibits patterns of complex activity playing a major role in processing sensory information. We consider a globally inhibitory network containing an inhibitory neuron. This sends depressing synapses onto multiple uncoupled excitatory neurons, coupled reciprocally to the inhibitory neuron. We prove the existence and stability of 2 clustered solutions and generalize to n-clustered solutions showing how synaptic depression allows the network to display multi-stability of clustered solutions and determines interspike interval.

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PP0

An Integrative Approach to Modelling the Neuromuscular Control of the Finger

An ultimate goal of the biomechanical modelling of the hand is to determine a single integrated model that includes muscle activation, tendon and ligament coupling, and torque/force production. Presently there are several distinct models for each of these aspects. We use a data-driven approach to explore the appropriate coupling between existing state-of-the art model components in order to dynamically model a simple control task involving only the index finger.

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PP0

AWM Poster: Superlattice Patterns in Oscillatory Systems with Three-Frequency Forcing

Superlattice patterns, while well-studied in Faraday waves in viscous fluids, have found little attention in forced oscillatory systems. We find stable subharmonic supersquares in the near-resonantly forced complex Ginzburg-Landau equation. Using Floquet theory and weakly nonlinear analysis we obtain the amplitude equations for patterns comprised of 2, 3, or 4 modes of different orientation. Employing three forcing frequencies, we stabilize superlattices via spatiotemporal resonances. Numerical simulations in small and large systems confirm our analysis.

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PP0

Cardiac Excitation Propagation Without Gap Junctions

Cardiac cells are electrically coupled through gap junction channels. However, it has been suggested that propagation might be possible without gap junctions, via negative electric potentials in the narrow cleft space between abutting cells. By considering a simple two cell model of this mechanism, we find that there are two time scales involved in the dynamics of propagation. Phase portrait analysis of the slow subsystem reveals there are two distinct types of propagation failure.

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PP0

Exploration of Lattice Boltzmann Based Immersed Boundary Calculations

The Lattice Boltzmann Method is a relatively new computational approach for fluid flow problems that uses a mesoscopic particle-based technique. Its advantage over traditional CFD is that it bypasses the need to solve for the pressure gradient. This poster presents a LBM algorithm that incorporates the Immersed Boundary Method in order to simulate deformable particles, such as platelets in blood. The accuracy and speed of this method is compared to the Navier Stokes IBM.

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PP0

Periodic Bursting Through Resonance

We consider a pair of cells that inhibit one another. In the absence of input, each cell is bistable. The attractors are a rest state and a periodic solution, separated by an unstable periodic solution. Each cell is resonant and responds only to inputs that have frequency in a given range. We demonstrate periodic bursting without using excitatory connections or external stimuli. The bursting frequency is approximated using the resonance characteristics of the cells.

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PP0

Travelling Waves in a Radiation-Combustion Free-Boundary Model for Flame Propagation

We study a combustion-radiation model which models premixed flames propagating in a gaseous mixture with dust. This model combines diffusion of mass and temperature with reaction at the flame front, as well as radiation modelled by Eddington's equation. For the resulting free boundary problem we study the stability of the propagating flames.

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PP0

Instabilities at the Locking Boundary of Two Delay-Coupled Semiconductor Lasers

Two lasers are locked, when their optical fields oscillate with a common frequency, irrespective of a possible difference in their solitary frequencies. However, locking is lost when the parameter detuning between the two lasers becomes too large. We study the bifurcations and instabilities at the boundary of the locking region. Typical bifurcation scenarios are found, depending on parameters such as the coupling phase, the detuning, and the pump current.

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PP0

Mixed-Mode Dynamics in Coupled Oscillator Systems

M. Krupa et al examined the mixed-mode dynamics of the coupled oscillator model of the dopaminergic neuron in the mammalian brain stem. Analysis focused on the case of two oscillators and showed that observed mixed mode dynamics arose due to the generalized canard mechanism. They obtained detailed results on the existence and bifurcation structure of the mixed-mode periodic orbits. We generalize the results and analysis to a case of arbitrarily many oscillators.

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PP0

Stability of Flame Balls for a Free Boundary Combustion Model with Radiative Transfer

We study radial flame ball solutions of a three dimensional free boundary problem (FBP) which models combustion of a gaseous mixture with dust in a micro-gravity environment. The radiative flux is modelled by Eddington's radiative transfer equation. We first prove existence of spherical flame ball solutions for the stationary FBP. Stability properties are then discussed.

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PP0

A Simple Molecular Model of Mammalian Hibernation

A simple model of the dynamics of the body temperature of a hibernating mammal will be presented. Our model provides a good match to available experimental data, showing the interruption of low-temperature torpor bouts with periodic interbout arousals (IBAs). Because many of the biochemical mechanisms are unknown, this is a preliminary and largely phenomenological model that we hope will inspire further investigation.

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PP0

Comparison of Two Methods for Analyzing the Dynamics of a Hanging Chain

We compare the effectiveness of two numerical methods in analyzing the dynamics of a driven hanging chain. One includes the tension necessary to keep the length of the chain fixed, while the other employs a Lagrangian scheme which removes the necessity of calculating the forces of constraint. Advantages and disadvantages of the two methods are discussed, including such issues as computational efficiency, conceptual simplicity, and transparency of the dynamics.

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PP0

Models of Discrete and Continuous Rings of Hopf Oscillators with Time-Delayed Nonlocal Coupling

Models of discrete and continuous rings of uniformly spaced identical Hopf oscillators that interact through a time-delayed nonlocal coupling are considered. Plane-wave equilibria of the models, and the linear stability thereof, as well as oscillator death, are studied.

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PP0

AWM Poster: A Producer-Grazer Model: Dynamics and Spatial Structure

The interaction between a forest pest(gypsy moths) and the tree cover is moderated by the availability and recycling of nutrients in the soil. A seasonal model is developed that determines the dynamics of this interac- tion as a function of the total available nutrients and the nutrient uptake rate. The most interesting phenomena observed involve bistability be- tween chaotic and stationary dynamics. One and two dimensional spatial models in the form of reaction diffusion networks or integrodifferential equations are discussed. Front propagation as well as spatio-temporal chaos are studied. This is a joint work with Armbruster Dieter and Kuang Yang.

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PP0

AWM Poster: Multiscale Method in Heat Shock Model

A reaction network contains multiple reactions and chemical species. The number of molecules can be modeled stochastically using continuous time Markov processes. Since the abundance of the number of each molecule is different, we apply multiscale method. We scale the number of molecules and the reaction rates with the same parameter. By averaging and law of large number, fast and slow components are separated. We can reduce the dimensionality of complex models.

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PP0

Transition of Intrinsic Localized Modes in Coupled Cantilever Array Depending on Phase Structure

The intrinsic localized mode (ILM) is spatially localized and temporary periodic solution in nonlinear coupled oscillator arrays. Recently the modes have been experimentally observed in coupled cantilever array of MEMS devices. We investigate dynamical property of the modes which are spatially fixed in the array. Stability and phase structure depending on nonlinear coupling coefficient are numerically discussed. The possibility of the manipulation of ILM is proved by the control of coupling parameter.

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PP0

AWM Poster: Coarse Analysis of Stochasticity-Induced Switching in a Schooling Model

Many organisms display ordered collective motion, such as geese flying in formation, locusts swarming in sub-Saharan Africa, and fish schooling. Individual based models are often used when modeling aggregation since they can incorporate detailed descriptions of the interactions among agents. However, for realistic numbers of individuals, the models can become computationally and analytically intractable. I will highlight an individual-based stochastic model for fish schooling which exhibits noise induced transitions between two metastable collective states. I will then describe a coarse, "equation-free" computational framework that efficiently allows the construction of an effective potential, enabling coarse bifurcation analysis and the estimation of mean residence times in each state.

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PP0

Periodic Solutions of Fourth Order Differential

In this poster periodic solutions of the fourth order differential equation

$$u'''' + \alpha u'' + u^3 - u = 0, \tag{2}$$

for $\alpha \in \mathbf{R}$ are studied. We classify solutions according to their braid type and existence of the different types of periodic solutions is proven. For this we use a connection between the solutions of the equation and fixed points of the flow Ψ^t generated by a parabolic recurrence relation. Topological tools as Conley index theory are used to study invariant sets of Ψ^t.

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PP0
Nonlinear Time Series Analysis of Musical Compositions

We demonstrate the application of the methods of nonlinear time series analysis on serveral of Beethoven's compositions. In particular, we are interested in computing the transfer entropy between the time series generated by different instruments in Beethovens symphonies and between staffs of some of his piano music. This allows us to demonstrate certain relationships among instruments.

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PP0
AWM Poster: Analysis of a 2D Smoluchowski Equation for Magnetic Dispersions

We study a two-dimensional Smoluchowski equation for magnetic nano-rod dispersions. Steady state solutions under imposed magnetic fields and linear flow fields with zero vorticity tensor are of Boltzmann type, which is completely determined by the total potential. The total potential can be parameterized by order parameters and material parameters, and governed by two algebraic-integral equations representing an exact, finite-dimensional reduction of the infinite-dimensional PDE. We construct bifurcation diagrams by solving the algebraic-integral equations. We also obtain the exact steady state solution of the Smoluchowski equation under general linear flows in semi-implicit form.

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PP0
The Endothelial Glycocalyx: Flow, Stress and Vasoregulation

Endothelial cells are exposed to fluid mechanical forces such as shear stress. Variations in shear stress are known to affect many processes needed for proper vasoregulation. The endothelial glycocalyx, a dense matrix of membrane-bound macromolecules, plays a substantial role in the regulation of these processes. We use mathematical models to explore the effect of different matrix permeabilities and Reynolds number regimes on flow through a porous matrix to find the resulting exerted fluid stresses.

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PP0
AWM Poster: Self-Assembly of Quantum Dots in a Thin Epitaxial Film Wetting an Elastic Substrate

The self-assembly of quantum dots in thin solid films caused by epitaxial stress and wetting interaction with the substrate is studied. It is shown that wetting interactions change the instability spectrum from long wave to short wave which can lead to spatially regular arrays of quantum dots. A nonlocal, nonlinear evolution equation for the film shape is derived, and the stability of dot arrays with different symmetries is studied. Regions in the parameter space are determined where spatially regular surface structures can be observed in experiments.

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PP0
Control and Removing of Instabilities in Low Dispersion Photonic Crystal Fiber Resonators

We show that it is necessary to take into account up to the fourth order dispersion term to capture the full dynamics of a passive fiber resonator, especially when proceeding close to the zero dispersion wavelength. We demonstrate that a second frequency of instability can be observed at the primary threshold of instability and that this stationary state can be restabilized at large powers. Numerical simulations for a flattened dispersion fiber resonator confirm analytical predictions.

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PP0

The Role of the Bidomain Model of Cardiac Tissue in the Dynamics of Phase Singularities

The left ventricle of the heart consists of nested fiber surfaces in which the orientation of fibers in successive layers rotates through the thickness of the ventricle. Previous numerical and analytical works have shown this rotating anisotropy to be important in the generation of scroll wave instabilities in the context of the monodomain description of cardiac tissue. The bidomain model is widely recognized as providing a more accurate description of cardiac tissue than the monodomain model in describing macroscopic electrical wave phenomena in the heart, particularly in studies involving applied current. In this work, we present a systematic study of the comparison between the bidomain and monodomain descriptions of cardiac tissue in the generation of rotating-anisotropy-induced scroll wave instability. These results provide further insight into and complement existing work on the role of the bidomain on the dynamics of phase singularities.

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PP0

Dynamics of Symplectic Subvolumes

We analyze even-dimensional symplectic subvolumes in Hamiltonian systems, specifically differential ones that evolve along solution trajectories, and their constraints. We relate volume expansions to the local collapse of the tangent space in chaotic Hamiltonian systems. We also relate the general theory to probability maps in asteroid tracking. A practical computational approach is presented that utilizes the State Transition Matrix.

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PP0

Modelling Backlash Oscillations in Geared Systems

This poster describes models of gear-rattle in Roots blower vacuum pumps. We present nonsmooth ODE models for the dynamics of the pump, where the nonlinearity arises from the backlash in the gear mechanism. It is found that eccentric mounting causes the gears to lose and re-establish contact, generating noise and vibration. To minimise the machine's susceptibility to this phenomenon, we propose possible design solutions, and illustrate their implications for pump design.

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PP0

Travelling Solitary Waves in Saturable Schrödinger Lattices

A model of a photorefractive crystal described by a discrete Schrödinger lattice with a saturable nonlinearity is presented. In a one-dimensional system travelling solitary waves with zero tail amplitude are found. The stability of the waves with respect to amplitude perturbations is investigated numerically. Two-dimensional lattices are found to exhibits travelling wave like solutions obtained by 'kicking' stationary solutions, which can then travel in any direction on the lattice with little or no radiative loss.

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PP0

A Three-Dimensional Model of Cellular Electrical Activity

We present a model of cellular electrophysiology that takes into account the three-dimensional geometry of biological tissue as well as ionic concentration dynamics. The resulting PDE system is studied using both asymptotic and analytic methods. We find that the model possesses multiple temporal and spatial scales, which has important consequences for developing an efficient numerical scheme. Simulations with this model are used to explore the characteristics of cardiac action potential propagation without gap junctions.

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PP0

The Role of Synaptic Depression in Phase Maintenance

We address the issue of phase maintenance by constructing and analyzing a model network of a subgroup of neurons found in the Stomatogastric Nervous System. This network consists of an oscillator neuron that inhibits two follower neurons. We analyze how the phase of activity between this set of neurons is determined in the presence of depressing synapses between the neurons. We show that constant phase maintenance can be achieved solely through the interplay of the two follower neurons due to the depressive nature of their connectivity.

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PP0

Dynamics of Real and Simulated Computer Performance

Computer hardware is too expensive and time consuming to build during design, so computer architects build software simulation engines that model real hardware. Validation of these engines is paramount to their usability for design space exploration. We use standard nonlinear time-series analysis methods to compare program traces of a SPEC benchmark running on real hardware and various simulator configurations.

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PP0

Learning and Recalling the Periodic Environmental Changes in An Amoeba

We will present the evidence that the amoeboid organism of true slime mold, the plasmodium of *Physarum polycephalum*, had capacity of memorizing, anticipating and recalling the timing of periodic event. Possible mechanism is proposed from a dynamical system point of view.

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PP0

Numerical Techniques for the Onset of Thermal Convection in Spherical Geometry

Two new numerical methods are developed to compute the neutral stability curves and dominant eigenfunctions for the onset of thermal convection in rotating spherical fluid shells. The first computes the eigenvalues by evolving the linearized equations a time interval, and the second is based on a double complex shift. Both are applied to analyze the most difficult range of parameters, namely, low Prandtl number fluids and fast rotation rates with non-slip boundary conditions.

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PP0

Asynchronous activity in a non-weakly coupled two-cell inhibitory network with finite synaptic decay time

Synchronization between inhibitory neurons is of interest for the study of rhythmogenesis in biological networks. We analyze the dynamics of two type-I spiking model neurons coupled by reciprocal inhibition with non-negligible synaptic decay time. Relaxing the assumption of weak instantaneous pulse coupling destabilizes the synchronous firing and leads to a period-2 spike-order alternating state, as well as chaotic dynamics. These results can be understood geometrically based on the effective phase resetting curve of each cell.

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PP0

Wave Chaos in a New Class of Optical Microcavity

We introduce a new class of open optical microcavity whose confinement and directional emission properties can be engineered through modification of a space-dependent refractive index. Numerical results are provided for a microdisc with gaussian deformation of the refractive index. This leads to a new way of breaking integrability and inducing chaos in the classically equivalent system (*photonic billiard*) and to the potential fabrication of reconfigurable microlasers.

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PP0

Experimental Versus Theoretical Studies on Stochastic Evolution Models for Neurogenesis

In vitro studies use time-lapse microscopy of live neurons, to study the dynamics of axonal growth and the consequences of the disruption of their growth, by the use of ethanol. I propose stochastic techniques through mathematical modeling of neurogenesis with an emphasis on the axons spatial behaviors. From assumptions based on experimental observations we begin by describing our model as comparable to Langevin dynamics, we study and compare coupled stochastic differential systems to experimental data.

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PP0

Autonomous Coupled Oscillators with Hyperbolic Strange Attractors

We describe several models of coupled autonomous oscillators possesing hyperbolic strange attractors. One model is a fourth-order system of two coupled oscillators that has a strange attractor of Smale-Williams type. Other models are based on a construction of three coupled oscillators possesing a heteroclinic cycle. With different additional couplings this system demonstrates attractors of Smale-Williams type, Arnold cat map, and a hyperchaotic torus map.

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PP0

Hopf and Saddle-Node Bifurcation Points for Waves of Hodgkin-Huxley Type

For equations of Hodgkin-Huxley type under a traveling wave condition we describe the geometry of the subsets of parameter space were the stability of equilibria is lost through either saddle-node or Hopf bifurcation. These sets are singular submanifolds of the parameter space ruled by affine subspaces contained in the hyperplanes where the equilibrium is constant. In both cases, regular points and the geometry and codimension of singular points on these manifolds are described.

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PP0

Classical Chaos in a Novel Inhomogeneous Photonic Billiard

Dielectric microcavities / microlasers are becoming key components for novel opto-electronic devices. They represent a realization of a wave chaotic system (see companion contribution) where for instance the lack of symmetry in the resonator shape leads to non-integrable ray dynamics in the short-wavelength limit (*photonic billiard*). Contrary to usual procedure where a transition from a regular to a chaotic regime is induced by a geometric deformation of a circular cavity, we propose a scenario inducing rotational symmetry breaking by choosing an inhomogeneous dielectric material inside a circular cavity, i.e *chaos in an integrable billiard geometry* . We study the consequences of this choice, isolate the conditions for integrability in such systems, describe the transition to chaos and classify the effects of the symmetry of the inhomogeneous dielectric on the trajectories.

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PP0

One-Dimensional Spatiotemporal Chaos in the Nikolaevskii Equation

The Nikolaevskii equation is a sixth-order model partial differential equation for short-wave pattern formation coupled with a neutrally stable long-wave mode. Our extensive numerical investigations have shown that the amplitude equations obtained at leading order in multiple scale analysis do not fully capture the scaling on the spatiotemporally chaotic attractor. However, we find the addition of a single Burgers-like term at the next order appears to capture corrections to scaling, and discuss the implications.

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PP0

Resonance Crossing and the Breakdown of WKB

We review the phase space method of dealing with mode conversion in inhomogeneous wave problems by examining a resonance crossing in a pair of coupled oscillators. The Wigner tensor of the solution can be computed as a function on phase space. This function can give insight into the behavior of the system, and could be a useful tool for investigations into coherent interactions and the effects of noise in the system.

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PP0

Limit Cycles in a Macroscopic Neuronal Population Model: Local and Global Stability

We present rigorous results concerning the stability of limit cycles in a macroscopic neuronal population model. Limit cycles have been demonstrated to be important in the study of certain generalized epilepsies, notably absence seizures. In particular we focus on a specific reduction of Freeman's KII sets, denoted RKII sets. Developing a theoretical understanding of the stability of limit cycles in models of this type has important implications in clinical neuroscience.

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PP0

Feedback Suppression of Neural Synchrony by Vanishing Stimulation

We suggest a method for suppression of collective synchrony in an ensemble of all-to-all interacting units. The suppression is achieved by organizing an interaction between the ensemble and a passive oscillator. Technically, this can be easily implemented by a feedback scheme. The important feature of our approach is that the feedback signal vanishes as soon as the control is successful. The technique is illustrated by simulation of a model of an isolated neuronal population.

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PP0

Dynamical Systems Approach to Mixing in Hurricane Models

Distinguished hyperbolic trajectories and their stable and unstable manifolds can be used to quantify fluid transport through lobe dynamics for time aperiodic velocity fields. We apply these ideas to a 2-D axisymmetric hurricane model to describe mixing between the eye and eyewall. We also use these techniques to look at formation of polygonal structures within 2-D horizontal hurricane models. These ideas can be extended to three dimensions to describe mixing within more complicated models.

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PP0

Random Walk Simulation of the Q-Cycle Model of Electron Transport in Photosynthesis

Cytochrome b6f in an enzyme in the thylakoid membranes of chloroplasts which receives high free-energy electrons and uses this energy to pump protons across the membrane. The most popular hypothesis for the mechanism is the Q-cycle model. This poster presents a random walk simulation of the Q-cycle model, with the mechanism modified to explain experimental results when the electron-accepting sites of cyt b6f are initially reduced or oxidized. Simulation results will be compared with experiment.

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PP0

Dynamical Behaviour of Pool-Boiling Systems

Pool-boiling systems serve as model problem for boiling heat transfer in industry under natural-convection conditions. Such systems admit description by a mathematical model that involves only the temperature distribution within the heater and models the heat exchange with the fluid via a nonlinear boundary condition imposed on the fluid-heater interface. The dynamical behaviour of this nonlinear heat-transfer problem has been studied through bifurcation and stability analyses. Results thus attained are consistent with laboratory experiments.

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PP0

AWM Poster: Modeling Dna Self-Assembly with Graphs

Using weak hydrogen bonds DNA molecules nondeterministicly self- assemble into larger complexes. To study possible assembled complexes and the process of self-assmebly we developed a graph theoretical model. Given a pot of molecules, a labeled multigraph is assigned to the complexes that can arise, and a labeled multigraph to the pot itself. The model, besides giving information about the outcomes of the process, also gives raise to new mathematical facts and their applications.

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PP0

Statistical Comparison of Complex Networks

An important problem in complex network theory is to compare two different, but in some sense similar networks, no matter what their presentation or configuration, meaning regardless of permutations. We propose a useful statistic for comparison following a well chosen set of permutations to bring the network to a canonical presentation in which form we will show successful direct comparison by the simple statistic to another network also in its corresponding canonical form.

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PP0

Branching Dendrites with Resonant Membranes

Dendrites is the main site for synaptic input to neurons. An important feature in dendrites are intrinsic resonant properties. We model these resonances by linearising fully non-linear currents such as the Ih current. The resulting system of PDE's is solved in Laplace space with the aid of Green's solutions. To capture the diverse morphology of dendrites the solution is constructed by a generalised version of the "Sum-Over-Trips" approach that was derived by Abbot et al.

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PP0

Indecisive Behavior of Amoeba Encountering the Presence of An Environmental Barrier

We found that an amoeboid organism shows indecisive behavior which higher animals such as human frequently show. An amoeboid organism, the Physarum plasmodium, shows tree deferent behaviors after indecisive period when it encounters the presence of a chemical repellent. These behaviors are reproduced by a model based on reaction-

diffusion equations. The origin of long-time stopping and three different outputs may be reduced to the hidden instabilities of internal dynamics of the pulse.

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PP0

Stochastic Calcium Release in Ventricular Cardiac Myocytes

Calcium release in cardiac cells is inherently stochastic and detailed models of this are computationally expensive. Using a variety of asymptotic approximations, we have built a simplified yet reliable model of stochastic calcium flux through a release unit that incorporates the interactions of ryanodine receptors with cytoplasmic and sarcoplasmic reticulum calcium, and also calsequestrin. With this model, we calculate the probability of spontaneous sparks and the sparks to wave transition in a spatially extended system.

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PP0

AWM Poster: Dafermos Regularization of the Modified KdV Burgers Equation

This project involves Dafermos regularization of partial differential equations of order higher than 2. We show the existence of Riemann-Dafermos solutions near a given Riemann solution using geometric singular perturbation theory. Also we study the stability of Riemann-Dafermos solutions as stationary solutions by means of linearization.

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PP0

Biparametric Analysis of Stationary and Static Solutions of Two Beam Transport Systems

Bifurcations of the biparametric static solutions of the fluid description of the classical Pierce model are investigated and, by the first time, related with the existence of chaotic regions in the parameter space, with no occurrence of reflecting particles. Particularly, our investigation reveals that the system is not structural stable in relation to new considered parameter. Furthermore, the biparametric dependence of stationary states of two electrostatic systems are investigated by Particle-In-Cell simulations and results are related with static solutions of the one-dimensional fluid model.

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PP0

Multicomponent WKB and Path Integrals

By examining path integral methods for multicomponent wave equations in the presence of localized resonances, we are led to a new approach to multicomponent WKB. We are pursuing a new formalism, developed by N. Zobin, which should make it easier to identify uncoupled dispersion functions and polarizations, even in complicated geometry. As an example, a toroidally symmetric plasma is studied using a cold plasma model similar to that used in [1].
1] A. N. Kaufman, E. R. Tracy, and A. J. Brizard, "Helical rays in two-dimensional resonant wave conversion", Phys. Plasma 12 (2005) 022101.

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PP0

A Karhunen-Loeve Method of Characterizing Spatio-Temporal Chaos in a Ginzburg-Landau System

We present a method of characterizing spatio-temporal patterns. We exemplify our method on a system of four globally-coupled Ginzburg-Landau equations derived from the weak electrolyte model for electroconvection in nematic liquid crystals. Our method identifies complex solutions of this system as motion on a torus with chaotic excursions. This is done by reconstructing this behavior in lower dimensions, using the highest energy Karhunen-Loeve modes amplitudes.

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PP0

Using Guassian Expansions to Approximate Vorticity Solutions to the 2D Navier-Stokes Equations

By expanding solutions to the vorticity equation for 2D in-

compressible fluid flow in time dependent, Guassian derivatives we are able to study the vorticity dynamics on all of $\mathbf{R}^2$. The resulting tensor evolution equations are computed up to the hexadecpole moments and the convergence of such expansions are considered. Simulations will be demonstrated, including the classical coalescence of two rotating vortices.

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PP0

Pulse Dynamics in a Three-Component System

We investigate various types of pulse solutions in a certain singularly perturbed, bi-stable, three-component, reaction-diffusion system, that has a natural two-component limit. Using geometric singular perturbation theory and the Evans function approach, we study the existence, stability and bifurcations of standing pulses, traveling pulses and double-pulse solutions. Moreover, we consider the limit to the two-component system, that exhibits significantly less rich dynamics.

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PP0

Equation-Free Computing: a Lattice Boltzmann Case Study

The coarse-grained time-stepper is the basic tool in equation-free computing which allows us to extract the macroscopic dynamics from a microscopic model when a macroscopic description is not available. We present a detailed analytical and numerical study of the properties of the different components of this coarse-grained time-stepper when the microscopic model is a lattice Boltzmann model. The insights obtained here can guide further developments in this area.

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PP0

AWM Poster: Elastic Growth in Tissues

Growth plays a key role in many fundamental biological processes. In the theory of elastic growth, the growth process can be modeled as a sequence of incremental steps, where each step consists of a local addition of material followed by an elastic response to ensure integrity and compatibility of the body. I will present a general formulation of growth for a three-dimensional nonlinear elastic body and apply it to specific geometries relevant in many physiological and biological systems (such as the cylindrical growth of arteries and stems).

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PP0

Formal Asymptotics for Blowup in the Willmore Flow

The Willmore flow is a model in biophysics and has its origin in conformal geometry. It is an open question whether the Willmore flow can produce a singularity in finite time on a smooth surface. In our research we analyze the blowup, if any, on a particular axisymmetrical surface. If finite time blowup should occur, we investigate its asymptotics to give the blowup behaviour of this singularity.

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PP0

Dynamics of Neural Field Models

Neural fields are integro-differential equations used to model cortical dynamics. They are known to exhibit a wide variety of spatio-temporal behaviours with many parallels in neuroscience experiments. We are investigating a newly discovered type of dissipative soliton dynamics for localised solutions (bumps) in models with threshold accommodation, reported in [Coombes and Owen. Bumps, breathers and waves in a neural network with SFA. 2005]. We are most interested in the interactions between bumps, including particle-like scattering, deformation and anihilation, and describe mathematical techniques that can be used to probe such behaviour.

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PP0

AWM Poster: Lower Branch ECS - Backbone of the Separatrix

Exact Coherent Structures (ECS) come in pairs with an upper branch and a lower branch that bifurcate from a neutrally stable streaky flow. The lower branch ECS consist of O(1) streaks sustained by O(1/R) streamwise rolls and a streak instability eigenmode which develops a critical layer structure. They have a 1D unstable manifold and may be viewed as the backbone of the phase space boundary separating the basin of attraction of the laminar point from that of the turbulent state. The very low dimensionality of the lower branch unstable manifold suggests new turbulence control strategies.

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PP0

Optimal Strategy in E. Coli Chemotaxis

Biochemical signal transduction is the most basic level of biological information processing. Adaptation is important in signaling networks. Using a computational implementation of bacterial chemotaxis that includes a stochastic description of the signal transduction network coupled to an experimentally realistic motor response, we investigate the role of network adaptation in optimizing chemotactic response in terms of input/output information transmission. We make connection with existing and future experiments that probe information processing in biochemical signaling networks.

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PP0

Complex Dynamics in a Simple Multi-Lane Traffic Model

We demonstrate different families of periodic solutions in a simple microscopic multi-lane traffic model, posed on a ring road, where vehicles are nonlinearly coupled and lane changes are deterministic. We examine how model parameters change the system output and illustrate qualitatively different solution regimes. Finally, we investigate how these results may be used to aid the design of macroscopic traffic models.

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PP0

Exploration of Phase Space Reconstruction of Nonlinear Differential Equations Using Perona's Method

Perona et al.'s nonlinear differential equations reconstruction algorithm using only time series data has yielded a useful method for reconstructing first-principle-like models via a user defined set of nonlinear basis functions. Results of our ongoing exploration of these methods into diffeomorphic attractor space reconstructions of sufficiently connected and observable systems will be presented, e.g. applications of Taken's Embedding Theorem and Sauer's Spike Train Embedding Conjecture are explored.

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PP0

Processing of Odor Information in Simple Network Models of the Olfactory Bulb: Concentration Dependence

We study the processing of odor information in the olfactory bulb, which is the first structure in the brain to receive the output from the olfactory sensory neurons. Using a class of simple, experimentally supported firing-rate models we address the question of how the output patterns from the bulb, which are essential determinants for the perception of the corresponding odor, change with odor concentration and how this change depends on the network connectivity.

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PP0

Bifurcations and Control of Flocks under LJ-Potential Rules

We will investigate the flocking of automata which interact via Lennard-Jones type potentials (long range attraction, short range repulsion) together with viscous terms which tend to align the velocities of nearby agents. When Euclidean symmetry is broken via a global central force field with elliptical equipotential surfaces, a rich bifurcation structure of competing equilibrium patterns is revealed — giving new insights into the minimum-bandwidth control of the flock.

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PP0

Neural Population Dynamics and Cannabinoids Signaling

We consider an excitatory-inhibitory spiking neural network, introducing a phenomenological model of Cannabinoids dynamics underlying DSI (depolarization-induced suppression of inhibition). Cannabinoids are retrograde messengers which are released postsynaptically and bind to presynaptic receptors, allowing fine-tuning of neuronal response. Moreover we develop a Wilson-Cowan style firing rate model incorporating the Cannabinoids dynamics. Importantly we consider an application of sensory gating in hippocampus and demonstrate its abolishment by cannabinoids agonists, in a manner consistent with our experimental findings.

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PP0

Wave Propagation in Spike Response Models of Neuronal Networks Connected by Electrical and Inhibitory Coupling

We study wave propagation in models of a sub-network of layer 4 neocortex that consist of fast-spiking inhibitory neurons connected by both electrical synapses and chemical synapses. We explore two types of spike response models: one with a voltage-based description of spikes and another with a current-based description of spikes. We determine conditions for the existence of waves, as well as the velocity of the waves as a function of model parameters.

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PP0

AWM Poster: Minimizing Action Integrals in the Comet 3-Body Problem

Using variational techniques, I examine the family of comet orbits for the 3-body problem. First I find the minimizing orbit of the curves which start collinear and end isosceles and then I consider how moving the initial condition on the shape sphere leads to a family of orbits.

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