IP1

Tire Tracks, the Stationary Schrödinger's Equation and Forced Vibrations

I will describe a newly discovered equivalence between the first two objects mentioned in the title. The stationary Schrödinger's equation, a.k.a. Hills equation, is ubiquitous in mathematics, physics, engineering and chemistry. Just to mention one application, the main idea of the Paul trap (for which W. Paul earned the 1989 Nobel Prize in physics) amounts to a certain property of Hill's equation. Surprisingly, Hill's equation is equivalent to a seemingly completely unrelated problem of "tire tracks". As a further surprise, there is a yet another connection between the "tire tracks" problem and the high frequency forced vibrations.

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IP2

Linear and Nonlinear Problems of Mathematical Finance

We start with a general overview of financial markets as dynamical systems and introduce primary financial assets including bonds, equities, currencies, and commodities. Next, we give a broad outline of market microstructure, market impact, and algorithmic trading, with a particular emphasis of limit order books and their dynamics. We also discuss technical trading and time-series analysis. After that, we introduce financial derivatives and describe their risk-neutral and real-world valuation. We discuss possible choices of stochastic processes used for modeling primary assets; derive the corresponding pricing equations for derivatives, and demonstrate how these equations can be solved. We conclude our presentation by formulating some open problems of mathematical finance.

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IP3

Particle Trajectories Beneath Irrotational Travelling Water Waves

We describe the pattern of the particle trajectories beneath a travelling wave moving at the surface of water in irrotational flow and with a flat bed, with no underlying current, both in the setting of periodic waves and in the setting of solitary waves.

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IP4

Triggered Slip Processes in Earth

In 1992, a magnitude 7.3 Landers earthquake occurred in Southern California. As seismic waves were radiated, other earthquakes were dynamically triggered both nearby and far away, and elevated seismicity, termed delayed triggering, lasted for several months. Recent observations based on rapidly improving instrumentation show that a majority of earthquakes may be dynamically triggered. Our work indicates that the granular physics of the fault core, fault gouge, plays a key role in triggering. Because direct access to the fault is not possible, we are characterizing the granular physics of triggering at laboratory scales using physical experiments and numerical simulations.

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IP5

Pattern Recognition with Weakly Coupled Oscillatory Networks

Traditional neural networks consist of many interconnected units and are thus inherently difficult to construct. In the lecture, we focus on neural network models of weakly coupled oscillators with time-dependent coupling. In these models, each oscillator has only one connection to a common support, which makes them predestinated for hardware implementation. Two coupling strategies are considered. The first network was proposed by Hoppensteadt and Izhikevich [F.C: Hoppensteadt and E.M. Izhikevich, Phys. Rev. Lett. 82, 2983 (1999)] and possesses a global coupling function. The second one is a novel architecture with individual coupling functions. We present experimental realizations of both networks and demonstrate that the devices can reliably perform pattern recognition tasks. However, the scalability of the novel network architecture is much superior to the one of the globally coupled oscillators.

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IP6

The Topology of Fluid Mixing

Topological chaos is a type of chaotic behavior that is forced by the motion of obstacles in some domain. I will review two approaches to topological chaos, with applications in particular to stirring and mixing in fluid dynamics. The first approach involves constructing devices where the fluid motion is topologically complex, usually by imposing a specific motion of stirring rods. I will then discuss optimization strategies that can be implemented. The second approach is diagnostic, where flow characteristics are deduced from observations of periodic or random orbits and their topological properties. Many tools and concepts from topological surface dynamics have direct applications: mapping class groups, braids, the Thurston-Nielsen classification theorem, topological entropy, coordinates for equivalence classes of loops, and the Bestvina-Handel algorithm for train tracks.

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IP7

Modeling Reactive Events in Complex Systems

Reactive events such as conformation change of macromolecules, chemical reactions in solution, nucleation events during phase transitions, thermally induced magnetization reversal in micromagnets, etc. pose challenges both for computations and modeling. At the simplest level, these events can be characterized as the hopping over a free energy barrier associated with the motion of the system along some reaction coordinate. Indeed this is the picture underlying classical tools such as transition state theory or Kramers reaction rate theory, and it has been successful to explain reactive events in a wide variety of context. However this picture presupposes that we know or can guess beforehand what the reaction coordinate of the event is. In many systems of interest – protein folding, enzyme kinetics, protein-protein interactions, etc. – making such educated guesses is hard if not impossible. The question then arises whether we can develop a more general framework to describe reactive events, elucidate their pathway and mechanism, and give a precise meaning to a concept such as the reaction coordinate. In this talk I will discuss such a framework, termed transition path theory, and indicate how it can be used to develop efficient algorithms to accelerate the calculations and analysis of reactive events.

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IP8
Predicting Epidemic Rare Events: A Dynamical Systems Perspective of Disease Extinction and Control

As seen by the many new vaccination campaigns across the world, disease control is of paramount importance in public health with eradication as the ultimate goal. Without intervention, disease extinction in a large well mixed population would be a rare event. In this talk, I will review some of the mathematical models and machinery used to describe the underlying dynamics of rare events in finite population disease models. I will show how to derive a new dynamical model that includes a dynamical systems description of the effective fluctuations of the noise that drives the disease to extinction. In analyzing the dynamic topology of the new expanded model, we can understand extinction from a dynamical systems perspective, thus discovering how to best use disease controlling resources.

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IP9
Engineered Gene Circuits: From Oscillators to Synchronized Clocks and Biopixels

This talk will focus on the development of synthetic gene oscillators and their synchronization. I will first describe an engineered intracellular oscillator that is fast, robust, and persistent, with tunable oscillatory periods as fast as 13 minutes. Experiments show remarkably robust and persistent oscillations in the designed circuit; almost every cell exhibits large-amplitude fluorescence oscilla- tions throughout each experiment. Theory reveals that the key design principles for constructing a robust oscillator are a small time delay in the negative feed- back loop and enzymatic protein decay that functions as an overloaded queue. I will then describe intercellular coupling that is used to generate synchronized oscillations in a growing population of cells. Microfluidic devices tailored for cel- lular populations are used to demonstrate collective synchronization properties along with spatiotemporal waves occurring on millimeter scales. While quorum sensing proves to be a promising design strategy for reducing variability through coordination across a cellular population, the length scales are limited by the diffusion time of the small molecule governing the intercellular communication. I will conclude with recent progress engineering the synchronization of thousands of oscillating colony biopixels over centimeter length scales.

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SP1
Juergen Moser Lecture: Title to Be Announced

To be posted when available.

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CP1
A New, Braid-Theoretic Approach to Uncovering Transport Barriers

In oceanic settings, it is desirable to identify key transport barriers that organize the material transport. In many cases the only velocity fields that are available for processing to find these barriers are geophysical models, which may not reliably represent the surface flow or the motion of particles on the ocean surface. In situations where the surface velocity field is not reliably known, however, there is the still the possibility of making direct measurements of trajectories through tracking floats. We look to develop a method that has the potential to harness this trajectory information to identify the existence of transport barriers by using tools from topology, in particular braid theory. We will present our braid theory based method and procedures for improving the accuracy of the resulting approximation for the transport barrier location.

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CP1
Development of An Efficient and Flexible Pipeline for Lagrangian Coherent Structure Computation

The utility of Lagrangian coherent structures for advective transport analysis is well-established. Broader adoption of this method is facilitated by development of robust and flexible software elements that accommodate wide-ranging application areas, and modularity that is easily extended or modified. We discuss use of Visualization Toolkit libraries and standards as a foundation for object-oriented LCS computation, and how this facilitates integration with flow visualization softwares. We discuss GPU kernels for efficient parallel computation, including optimization strategies for better utilization.

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CP1

New Developments in LCS Theory: Forward-Time Unstable Manifolds and Generalized Shearless Tori

The recent geodesic theory of Lagrangian coherent structures (LCS) [Haller & Beron-Vera, Physica D 241 (2012)] has enabled the accurate computation of transport barriers in temporally aperiodic flows, including generalized stable and unstable manifolds, generalized KAM tori, and generalized shear jets. For two-dimensional flows, the remaining challenges in LCS detection include the computation of generalized stable and unstable manifolds from a single numerical run, and the identification of generalized shearless (or twistless) KAM tori. In this talk, we present results on both of these problems, and show their application to unsteady fluid flows.

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CP1

Detecting Invariant Manifolds in Aperiodically Forced Mechanical Systems

We show how the recently developed theory of geodesic transport barriers for fluid flows can be used to uncover key invariant manifolds in externally forced, one-degree-of-freedom mechanical systems. Specifically, invariant sets in such systems turn out to be shadowed by least-stretching geodesics of the Cauchy-Green strain tensor computed from the flow map of the forced mechanical system. This approach enables the finite-time visualization of generalized stable and unstable manifolds, attractors and generalized KAM curves under arbitrary forcing, when Poincaré maps are not available. We illustrate these results by detailed visualizations of the key finite-time invariant sets of conservatively and dissipatively forced Duffing oscillators.

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CP1

Finite-time Scalar Reaction-diffusion with Lagrangian Coherent Structures

In recent years, the concept of Lagrangian coherent structures (LCS) has gained popularity in identifying finite-time invariant manifolds in aperiodic dynamical systems. They are relevant to quantifying the chaotic transport in non-diffusive fluid flows. In this talk, I will discuss some recent efforts on extending the use of LCS in systems with finite diffusion and reaction. It is found that in geophysically relevant regimes, LCS closely relate to the variability of scalar reaction-diffusion processes, suggesting its further use beyond a diagnostic tool for chaotic transport.

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CP2

Steady Periodic Waves Bifurcating for Fixed-Depth Rotational Flows

We consider the existence of steady periodic water waves for rotational flows with a specified fixed-depth over a flat bed. We construct a modified height function which explicitly introduces the mean-depth into the rotational water wave problem, and use the Crandall-Rabinowitz local bifurcation theorem to establish the existence of solutions of the resulting problem. In the process we obtain explicit dispersion relations for the resulting flows.

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CP2

Revisiting the Two Wakes Interaction

this paper describes a model of two landau equations that captures the interaction between the wakes of the incompressible flow between two cylinders in side by side arrangement. From the calculation of the stability problem in the proximity of the first Hopf bifurcation for this particular type of flow, and an asymptotic approach appears this dynamic system of two coupled Landau equations, which in our view captures the nonlinear dynamics of this type of flow.

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CP2

Cross-Waves Driven by Extended Forcing

The nonlinear Schrodinger equation models successfully used to study cross-waves since Jones (JFM 138, 1984) rely on the assumption that modulations occur on a slow lengthscale compared to the subharmonic wavelength and to the spatial extent of the forcing. Neither assumption holds for high frequency (large aspect ratio) experiments. We extend the theory to include surface tension and a spatially extended forcing term and compare the resulting amplitude equations with recent experiments, finding good agreement.

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CP2

Rayleigh Surface Wave in An Incompressible Earths Crustal Layer Sandwiched Between a Rigid Boundary Plane and a Half Space

In the present paper, Rayleigh surface wave in an earths crustal layer has been studied. In the first case, the layer has been kept sandwiched between a rigid boundary plane and a sandy half space, while in the second case the sandy half space has been replaced by an elastic half space with void pores. The dispersion relation has been deduced and the effect of sandy parameter, rigid boundary, wave number, inhomogeneity parameter and void parameter has been illustrated and displayed by means of graphs.

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CP3

Measurement and Validation of Coupled-Patch Population Models Via Computational Topology

Coupled patch models of population dynamics combine local dynamics on patches with rules for dispersal of the population between patches. Thresholded population values give rise to spatial patterns and may evolve in a complicated manner in time. I will discuss joint work with Benjamin Holman in which we study coupled Ricker maps and the complicated patterns they produce. I will also present preliminary work on model construction and validation using field measurements of population distribution and density.

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CP3

Bifurcation Analysis of Reaction-Diffusion Vegetation Pattern Formation Models for Semi-Arid Ecosystems

We consider a class of reaction-diffusion models that seek to explain spatial vegetation patterns in semi-arid ecosystems. As a precipitation parameter is varied in these models, patterned states are created and destroyed in a pair of Turing bifurcations. The patterned states are characterized by up and down-hexagons on either side of a labyrinthine intermediate. We look at the transition between patterns using bifurcation theory to identify generic scenarios for transitions between these states.

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CP3

Highly Heteroclinically Connected Population Models

Modeling population dynamics using approximately conserved quantities facilitates analysis of phenomena driven by unpredictable time-dependent factors (e.g. annual rainfall). Level sets containing several saddle points linked by heteroclinic orbits can approximate complex behavior that is poorly modeled by single equilibrium conservative models such as Lotka-Volterra—small perturbations can trigger rapid, dramatic changes in qualitative dynamics. Highly heteroclinic models fit to the well-known Isle Royale wolf-moose and Hudson Bay Company lynx-hare harvest data successfully capture pivotal transitions.

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CP3

An Age-Structured Population Model with State-Dependent Delay: Derivation and Numerical Integration

We present an age-structured population model that accounts for the following aspects of complex life cycles: (i) There are juvenile and adult stages, (ii) only the adult stage is capable of reproducing, (iii) cohorts of juveniles can transition to the adult stage when they have consumed enough nutrition and (iv) the juvenile and adult populations consume different limited food sources. Taking all of these into account leads to a new mathematical model that cannot be directly analyzed using the established framework of functional differential equations or simulated by standard numerical schemes for age-structured populations. My talk will present the derivation of the model, its properties and numerical scheme to integrate the equations.

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CP4

Second Invariants for the Topological Characterization of the Iteration of Differentiable Functions

We consider dynamical systems defined by a particular class of differentiable functions, as fixed state space. The dynamics is given by the iteration of an operator induced by a polynomial map which belongs to an appropriate family of bimodal interval maps. We characterize topologically these dynamical systems, in particular using the second invariants defined for the iteration of the bimodal interval maps.

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CP4

Bifurcation of Safe Sets in 1-Dimensional Dynamical Systems

Partial-control in dynamical systems is a relatively new concept in which the trajectory is sought to be confined within a compact set rather than made to follow a prescribed trajectory. Safe sets arise naturally in partial-control and are typically compact sets with interior and depend on two parameters, the disturbance and control bounds. Here, the change in safe sets in 1-dimensional systems with changes in the parameters is studied and the singularities classified and explained.

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CP4

Metric Entropy for Nonautonomous Dynamical Systems

In my talk, I introduce the notion of metric entropy for a nonautonomous dynamical system given by a sequence (X_n, μ_n) of probability spaces and a sequence of measurable maps $f_n : X_n \to X_{n+1}$ with $f_n \mu_n = \mu_{n+1}$. This notion generalizes the classical concept of metric entropy established by Kolmogorov and Sinai, and is related via a variational inequality to the topological entropy of nonautonomous systems as defined by Kolyada, Misiurewicz and Snoha.

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CP4

Graphical Krein Signature and Its Application to Hamiltonian-Hopf Bifurcations

We present a new type of criterion for Hamiltonian-Hopf bifurcation, particularly exact conditions allowing or preventing a collision of eigenvalues of opposite Krein signature. We give an exact condition contrary to the existing work that only covers 'generic' systems. The criterion arises from the geometrical theory of graphical Krein signature. This is a joint work with Peter Miller (U Michigan).

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CP4

Two Linear Foci Suffice to Get Three Nested Limit Cycles

By considering a specific family of discontinuous differential systems with two linear zones sharing the equilibrium position, strong numerical evidence about the existence of three nested limit cycles was obtained very recently in [Huan, S.-M. and X.-S. Yang, On the number of limit cycles in general planar piecewise linear systems, Discrete and Continuous Dynamical Systems-A, **32** (2012), 2147–2164]. We show, thanks to the canonical forms introduced in [Freire, E., Ponce, E., and F. Torres, Canonical Discontinuous Planar Piecewise Linear Systems, SIAM J. Applied Dynamical Systems, **11** (2012), 181–211] how to prove in an analytical way the existence of such three limit cycles in more general cases, by following a bifurcation approach.

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CP5

Spinodal Decomposition for the Cahn-Hilliard-Cook Equation

We study the Cahn-Hilliard-Cook equation, which is a model for a binary alloy. Spinodal decomposition in this model is described by different stages, based on the interplay of linear solution, nonlinearity and stochastic forcing. It can be shown that initially the additive white noise determines the exact position of the patterns arising. The characteristic features of the decomposed pattern are independent from the noise. After the initial stage the general dynamics behaves mostly deterministic until the pattern is fully developed.

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CP5

Localized Radial Solutions of the SwiftHohenberg Equation on the Poincaré Disk

In this talk, we present a result of existence of stationary localized radial solutions of the Swift-Hohenberg equation on the real hyperbolic space of dimension two, that we identify with the Poincaré disk. This type of solutions is of particular interest for some problems of orientation tuning in the visual cortex. The proof relies on spatial dynamics techniques. We also use numerical continuation to highlight our theoretical result.

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CP5

Fluctuations of Lyapunov Exponents in Space-Time Chaos: A Diffusion Process Linked to Surface Roughening

In a recent paper Kuptsov and A. Politi [Phys. Rev. Lett. 107, 114101 (2011)] reported on numerical simulations showing that the Lyapunov exponents fluctuations scale with system size according to a universal scaling law. Here we show that both the power law scaling and the universal exponent can be deduced analytically from the scaling behavior of the characteristic (or covariant) Lyapunov vectors. In particular, we define a surface associated with each Lyapunov vector such that the surface turns out to be a fractal whose roughening exponents (i.e. fractal dimensions) are directly linked to the Lyapunov exponent fluctuation exponent through a universal scaling relation. We, therefore, uncover a profound connection between the Lyapunov spectrum of (deterministic) chaotic spatially extended systems and the dynamics of non-equilibrium (stochastic) surfaces.

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CP5

Invariant Manifolds Describing the Dynamics of a Hyperbolic-Parabolic Equation from Nonlinear Viscoelasticity

The governing equations for a collection of dynamical problems for heavy rigid attachments carried by light, deformable, nonlinearly viscoelastic bodies are studied. These equations are a discretization of a nonlinear hyperbolic-parabolic partial differential equation coupled to a dynamical boundary condition. A small parameter measuring the ratio of the mass of the deformable body to the mass of the rigid attachment is introduced, and geometric singular perturbation theory is applied to reduce the dynamics to the dynamics of the slow system. Fenichel theory is then applied to the regular perturbation of the slow system to prove the existence of a low-dimensional invariant manifold within the dynamics of the high-dimensional discretization.

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CP5

A Continuous Generalization of the Ising Model

Traditionally, ferromagnetism is studied from the standpoint of statistical mechanics, using the Ising model. While retaining the Ising energy arguments, we use techniques previously applied to sociophysics to propose a continuum model. Our formulation results in an integro-differential equation that allows for asymptotic analysis of phase transitions, material properties, and the dynamics of the formation of magnetic domains.

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CP6

Reduction Methods for a Family of Infinite-dimensional Nonsmooth Energy Balance Models

We study a family of energy balance models that numerically exhibit sustained oscillations of canard and relaxation-type. Although the full infinite-dimensional system can be reduced to a two-dimensional invariant manifold, one finds that within this manifold a slow-fast system governs the dynamics and that the associated vector field is nonsmooth. The lack of smoothness is due to physical assumptions on the system and results in a slow manifold which is only piecewise smooth. In this talk, we introduce techniques for proving the existence of periodic orbits in the full system in the presence of this difficulty.

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CP6

Effects of Noise on Grazing Bifurcations

In this talk I will describe the effects of incorporating noise into a canonical vibro-impacting model. An attractor of the deterministic model becomes an invariant density when noise is added. Under parameter change, the density transitions between approximately Gaussian and highly non-Gaussian forms. Impacts correspond to an extreme nonlinearity and as a consequence the size of the invariant density may be proportional to the square-root of the noise amplitude.

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CP6

On Quasi-Periodic Perturbations of Hyperbolic-

Type Degenerate Equilibrium Point of a Class of Planar Systems

This paper considers two-dimensional nonlinear quasi-periodic system with small perturbations. Assume that the unperturbed system has a hyperbolic-type degenerate equilibrium point and the frequency satisfies the Diophantine conditions. By KAM iteration we prove that for sufficiently small perturbations, the system can be reduced to a suitable normal form with an equilibrium point at the origin.

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CP6

Infinitely Many Homoclinic Orbits for Superlinear Hamiltonian Systems

In this paper we study the first order nonautonomous Hamiltonian System z? = JHz(t, z), where H(t, z) depends periodically on t. By using a generalized linking theorem for strongly indefinite functionals, we prove that the system has infinitely many homoclinic orbits for weak superlinear cases.

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CP7

Self-Organized Network Structure by Co-Evolving Dynamics Between Reaction-Diffusive Resources on Nodes and Weighted Connections

We investigated a simple model of a co-evolving weighted network exhibiting a dissipative diffusion process of a resource over a weighted network and resource-dependent evolution of the link weights. We demonstrate that this interplay between dynamics both on and of the network, yields an emergence of power-law distributions in both the quantities of the resource and the strengths of the links, accompanied with a microscopic continuous evolution of the network.

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CP7

Oscillatory Network Turing Instability

Diffusion-induced instabilities in network-organized systems are investigated. The oscillatory Turing instability is observed in three-component reaction-diffusion systems. In networks, the instability leads to spontaneous developments of oscillations in a subset of nodes, depending on the network architecture, while the other nodes continue to rest in the stationary steady state. Our results reveal that oscillations may occur even though individual nodes are not oscillators. This gives us a new scenario of oscillatory dynamics in network-organized systems.

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CP7

Interplay Between Network Topology and Stability of a Linear Time Invariant (lti) Control System with Homogeneous Delays

We focus on a class of LTI system with homogeneous inter-agent delays broadly studied in the literature, to present how the arising network structures (graphs) and delays are correlated from stability point of view, and how one can design the graphs such that the network can tolerate large delays without losing stability. We present these results based on our Responsible Eigenvalue concept, analytical study of rightmost eigenvalues and delay-adaptive inter-agent coupling design.

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CP7

The Joint Effect of Network Topology and Update Functions on the Stability of Boolean Networks

Boolean networks are dynamical systems commonly used to model gene regulation. We study the stability of attractors in a Boolean network with respect to small perturbations. While recent work has addressed the separate effects on stability of nontrivial network topology and update functions, only very crude information exists on how these effects interact. We present a general solution which includes both effects, and we show that our predictions agree with simulations of threshold Boolean networks.

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CP7

Large Systems of Interconnected Switches and Oscillators

While networks of interacting dynamical systems are of widespread interest, most research has been restricted to systems containing a single type of dynamical system (e.g., coupled phase oscillators). We analyze large systems of interconnected oscillators and switches and find several coexisting stable solutions. Transitions between these steady state solutions are explored, where we find that heterogeneity may play an essential role in stabilizing the macroscopic dynamics of large complex systems.

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CP8

On the Role of Intrinsic Neuronal Dynamics for Relay Synchronization

Recently, a new form of synchronous behaviour has been discovered in a general context where two oscillators synchronize without being directly coupled, and the information transmission is going only via a third, relaying oscillator which is not synchronizing with the other ones (relay synchronization). A thorough computational study of the effect of different intrinsic dynamical states of Huber-Braun model neurons exhibiting relay synchronization under gap-junction coupling is presented.

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CP8

Suppression of Bursting Synchronization in Clustered Scale-Free Neuronal Networks

Functional brain networks are composed of cortical areas that are anatomically and functionally connected. One of the cortical networks for which more information is available is the cat cerebral cortex. Statistical analyses of the latter suggest that its structure can be described as a clustered network, in which each cluster is a scale-free network possessing highly connected hubs. Those hubs are, on their hand, connected together in a strong fashion ('rich-club' network). We have built a clustered scale-free network inspired in the cat cortex structure so as to study their dynamical properties. We focus on the synchronization of bursting activity of the cortical areas and how it can be suppressed by means of neuron deactivation through suitably applied light pulses. It is possible to effectively suppress bursting synchronization by acting on a single, yet suitably chosen neuron, as long as it is higly connected, thanks to the 'rich-club' structure of the network.

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CP8

Optimal Chaotic Desynchronization and Its Application in Neural Populations

We develop a procedure which suggests a powerful alternative to the use of pulsatile stimuli for deep brain stimulation treatment of Parkinson's disease. The procedure finds an

energy-optimal stimulus which gives a positive Lyapunov exponent, and hence desynchronization, for a neural population, and only requires knowledge of a neuron's phase response curve, which can be measured experimentally. We illustrate the procedure for a model for thalamic neurons, which are believed to play an important role in Parkinson's disease.

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CP8

Mathematical Models of Bidirectional Signaling in the Neurovascular Unit

Neural network models can now simulate entire brain sections resolved to individual cells. The roles of neurovascular and neuroglial interactions are less well understood. We have developed the first bidirectional model of the neurovascular unit, comprising synaptic discharge, glia, and arterioles. It is a mechanical, electrical, and biochemical model with several interactional feedback loops. We will describe the biological system, model ODEs, and validation with experimental literature.

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CP8

Limb Coordination in Crayfish Swimming: The Neural Mechanisms and Mechanical Implications

During forward swimming, rhythmic movements of limbs on different segments of the crayfish abdomen progress from back to front with the same period, but neighboring limbs are phase-lagged by 25% of the period. This coordination of limb movements is maintained over a wide range of frequency. The exact mechanisms underlying this robustly stable phase-locking are not known. We use dynamical systems and fluid mechanics in conjunction with experimental results to obtain insight into these mechanisms.

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CP9

The Average Velocity of Planar Jordan Curves

We present a bound on the integral of the velocity of a planar Jordan curve in the interior of another Jordan curve. This bound is applied to verify a new Poincare-Bendixson type result for planar infinite-horizon optimal control. Namely, verifying the optimal value is attained by a periodic solution.

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CP9

Bio-Inspired Sensing and Control of An Underwater Vehicle in a Karman Vortex Street

By incorporating bio-inspired sensing modalities such as those based on a fish lateral line system, underwater vehicles may be able to navigate complex, unknown environments autonomously. This presentation describes results from using potential flow theory to model the flow around a fish-like body in a Karman vortex street. Assuming sensors collect noisy measurements of the flow, a nonlinear observer is incorporated to estimate the flow for use in a feedback controller designed for station-holding behavior.

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CP9

Amplitude Death Solutions for Stabilization of Dc Microgrids with Instantaneous Constant-Power Loads

Constant-power loads on dc microgrids create a destabilizing effect on the circuit that can lead to severe voltage and frequency oscillations. Amplitude death is a coupling induced stabilization of the fixed point of a dynamical system. We apply amplitude death methods to the stabilization problem in this constant-power setting. The amplitude death methods provide an open-loop control solution to stabilize the system.

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CP9

Controller
Space Categorization for Delay-Independent Stability of Linear Time-Invariant (LTI) Systems with Multiple Uncertain Delays

In many dynamical systems, delays can be *uncertain* making their control difficult. For such systems, it would be beneficial to design controllers that guarantee stability "independent of delays'. On a general LTI system with multiple uncertain delays, we present a non-conservative framework to achieve this *delay-independent stability* (DIS) control design even when the control matrices are structured. This framework is based on analysis of polynomials, although stability is associated with infinitely many eigenvalues.

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CP9

Branch and Bound Approach to the Optimal Control of System Dynamics Models

The System Dynamics (SD) methodology is a framework for modeling and simulating the dynamic behavior of socioeconomic systems. In order to optimally control such dynamic systems, we propose a branch-and-bound approach that is based on a) a bound propagation method, b) primal heuristics, and c) spatial branching on underlying nonlinear functions of the SD model. Our methods are implemented in the MINLP solver SCIP. Numerical results for test instances will be presented.

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CP10

Cell Cycle Clustering in a Nonlinear Mediated Feedback Model

The concept of an RS type feedback model for Yeast Autonomous Oscillation is extended to include a mediating chemical signaling agent. The dynamical properties of the resulting system include and extend previous results and may explain the onset of spontaneous density-dependent oscillations seen in experiments.

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CP10

Period-Adding Cascades in Models of the Eukaryotic Cell Cycle

Low-dimensional models of the eukaryotic cell cycle represent cell division by discontinuous jumps in the model state, in response to the crossing of a protein concentration below a critical level. This work documents period-adding cascades in such models, associated with convergent sequences of grazing bifurcations, and induced by this jump discontinuity. It establishes the universal nature and scaling characteristics of such cascades in the unfolding of suitably constrained border-collisions and saddle-node bifurcations of period-two orbits.

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CP10

Dispersion and Breakup of Clusters in Cell Cycle Dynamics by Various Mechanisms

Random perturbations of the cell-cycle dynamics with feedback model tend to disperse clusters. We consider and contrast the effects of mechanisms of stochastic perturbations, variable division time and generational differences on dispersion and eventual breakup of the clusters in the feedback model. Beginning with numerical simulations, we study the differences in the effects of these three types of perturbations in the system in the setting of both small and large perturbations.

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CP10

Universality of Stable Periodic Solutions in a Cell Cycle Mode

We study a model of cell cycle ensemble dynamics from the perspective of parameter space - a two dimensional triangle T. For the type of system consider and any positive integer k there exists a special periodic solution that we call k-cyclic. We show under very general nonlinear feedback

that for a given k the stability of the k cyclic periodic solutions can be characterized completely in parameter space. For a given k we prove that T is partitioned into k^2 subtriangles on which k cyclic solutions all have the same stability. We observe that for negative feedback parameter space is nearly fully covered by regions of stability of k clustered solutions with k small, e.g. $k \leq 7$. For many parameter values we observe bi-stability or multi-stability. We also observe that as k grows large, the parameter region for which the k cyclic solution is stable becomes small in area and tends to the boundaries of parameter space.

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CP10

On Cyclin/cdk Oscillations in the Cell Cycle

Abstract: The cell cycle is driven by complexes formed from cyclin dependent kinases (CDKs) and their cyclin subunits (Clb2). Exiting mitosis requires a shift of balance between Clb2:CDK1 and the phosphatase Cdc14. Experiments show that Cdc14 can be locked in an oscillatory regime by stabilising Clb2. Using a model we propose that Cdc14 being part of a biochemical oscillator increases its tunability, and Clb2 acting as a feedback controller leads to increased robustness of Cdc14 activation.

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CP11

Calculating Early Treatment Gains

The setting is a patient infected with a proliferating pathogen. We consider the problem of calculating the difference in time to resolution for the same intervention/adjuvant applied at two different times. Our goal is to develop a framework with which it is possible to regress the early treatment gain from a minimal set of data.

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CP11

On Spread of Phage Infection of Bacteria in a Petri Dish

A reaction diffusion system with time delay is proposed for virus spread on bacteria immobilized on an agar-coated plate. The delay explicitly accounts for a virus latent period. The focus is on the speed of spread of infection resulting from a localized inoculum of virus and of the existence of traveling waves of infection.

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CP11

A Perspective on Multiple Waves of Influenza Pandemics

The past four influenza pandemic outbreaks in the United States has had multiple waves of infections, although the underlying mechanisms are uncertain. We use mathematical models to exhibit four mechanisms each of which can quantitatively reproduce the two waves of the 2009 H1N1 pandemic. All models indicate that significantly reducing or delaying the initial numbers of infected individuals would have little impact on the attack rate. This reduction or delay results in only one wave.

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CP11

The Significance of Hiv Modelling on Public Health Strategies

It has been widely reported that new public health strategies have had a significant impact on decreasing new infection rates for HIV - in regions where the approach has been implemented. In 2011 the journal *Science* declared that the biggest scientific breakthrough of the year was the new approach to HIV. I will explain how mathematical modelling of HIV transmission dynamics has played a significant role (possibly negative) in controlling the spread of HIV. My work on HIV is joint with Brandy Rapatski and Fred Suppe.

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CP11

The Heterogeneous Dynamics of the Transcription Factor NF-kB

NF-kB is a transcription factor that controls hundreds of genes. Single-cell imaging has shown that when certain stimuli hit the cell, NF-kB nuclear concentration oscillates. Our experiments show that NF-kB dynamics in cells is more heterogeneous than previously reported: in particular, for some cells oscillations are not observed. We attempt to unveil the origin of this heterogeneity using a mathematical model involving the main components of the system.

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CP12

An Approach to Secure Communication in Chaotic Systems Without Synchronization

The secure communication is important for several purposes, for example, to keep safe: banking sites, government secrecy, ... A traditional way to build a secure communication system is through the synchronization, instead of it we present a novel feature without use synchronization as the coding mechanism. In this work we will show how the transfer entropy can be use to determine the coupling directions in coupled map lattices and then transmit secure information.

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CP12

The Approximation of Coherent Structures in Non-Autonomous Dynamical Systems

Coherent structures in the context of non-autonomous dynamical systems can be analyzed using transfer operator methods based on long-term simulations of trajectories on the whole state-space. In principal these methods are also applicable to a part of the state-space. In this talk we present an algorithm that automatically selects a subset of the state-space probably containing coherent structures. This preselection is based on the approximation of almost invariant sets and reduces the numerical effort significantly.

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CP12

Autosynchronization Methods for Pde Model Fitting and Nonlinear Data Assimilation for Ocean Ecology Informed by Partially-Observed Hyperspectral Satellite Imagery

Applications of synchronization to modeling ocean ecology by partially observed cloud-covered satellite imagery are discussed. When modeling spatiotemporal systems for which not all variables are observable, often the observable contains still hidden regions. Given multiple images of a dynamic scene and assumed model describing chaotic reaction diffusion dynamics, parameters and model states are adaptively observed by synchronization of the model to observed data, a specialized autosynchronization. Autosynchronization is effective despite hidden spatial information.

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CP12

Monitoring the State of in-Land and Coastal Waters from Space

I'll describe current multi- and hyper-spectral imagers currently used to examine water quality of coastal and in-land sites such as the Columbia River Mouth or Lake Erie. Besides showing many beautiful images, I'll also provide an overview of the current 'product' algorithms used to estimate geo-chemical-bio water parameters such as chlorophyll concentration. I'll further describe some new product algorithms based on insights from nonlinear dynamics designed to capture the 'shape' of ocean and lake color.

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CP13

Multiple Snaking Scenarios in Three-Dimensional Doubly Diffusive Convection

Doubly diffusive convection is a classic example of a pattern-forming system. Among the variety of solutions exhibited by systems of this type are the interesting time-independent spatially localized states called convectons. Here, we focus on a three-dimensional binary fluid in a vertically extended cavity with no-slip boundary conditions whose motion is driven by temperature and concentration differences between a pair of opposite vertical walls. No-flux boundary conditions are imposed on the remaining walls. When the temperature and concentration contributions to buoyancy balance the system admits a conduction state whose instability leads to quasi two-dimensional spatially localized rolls with D_2 symmetry located on a pair of primary snaking branches. Secondary symmetry breaking instabilities occur during every nucleation process along the primary snaking branches and lead to fully three-dimensional twisted convectons with Z_2 symmetry which also snake.

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CP13

Localized Pattern Formation in Reaction Diffusion Equations with a Source Term

In this talk we will show how the theory of localized pat-

tern formation, via so-called homoclinic snaking arises naturally in systems of reaction diffusion equations in parameter regimes where Turing instabilities occur. The key criterion is that the Turing instability should be sub-critical. We shall show how this situation arises naturally in a Schnakenberg system with a constant source term. This leads to an interplay between quadratic and cubic nonlinear terms when the problem is re-centered on the nontrivial equilibrium. For an appropriate set of parameter values, of relevance to a problem in plant biology, the restabilization of the bifurcating branches leads to a snaking-like structure whose dynamics can also be described using the theory of semi-strong interaction. This provides a link between asymptotic theories of non-local spike interaction and underlying local Turing bifurcations.

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CP13

Spatial Localization in Two-Dimensional Convection with a Large Scale Mode

Localized states (LS) are of considerable interest in both rotating convection [C. Beaume et al., J. Fluid Mech., in press (2012)] and magnetoconvection [D. Lo Jacono, A. Bergeon and E. Knobloch, J. Fluid Mech. 687, 595 (2011)]. In 2d convection with stress-free boundary conditions (BCs), the formation of LS is due to the interaction between convective rolls and a large scale mode. We develop a fifth order nonlocal Ginzburg-Landau theory [H.-C. Kao and E. Knobloch], in preparation to describe the effects of spatial modulation near a cod-2 point where the leading order theory breaks down [C. Beaume et al., J. Fluid Mech., in press (2012)]. With mixed velocity BCs the large scale mode becomes (weakly) damped and a new length scale appears in the problem. This permits the interpolation between global and local coupling and sheds light on numerical continuation results for 2d rotating convection with stress-free and no-slip BCs.

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CP13

Phase Reduction Analysis of Oscillatory Patterns in Reaction-Diffusion Systems

Phase reduction method for oscillatory spatiotemporal dynamics of reaction-diffusion systems, such as localized spots, spiral waves, and target patterns, is developed. Phase sensitivity function of the system, which quantifies linear phase response of the system to weak spatial perturbations, is obtained as the solution of an appropriate adjoint equation. Layers of coupled reaction-diffusion systems exhibiting oscillatory dynamics are analyzed using the developed method, and interesting synchronization phenomena, such as multi-modal phase locking, are found.

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CP13

Eisenman2012 Arctic Sea Ice Model: Analysis in Discontinuous Albedo Limit

We analyze the Eisenman (2012) version of a low-dimensional Arctic sea ice model, developed to investigate Arctic sea ice retreat under increasing greenhouse gases. It includes sea-ice thermodynamics, albedo feedback, and periodic solar forcing, and is piecewise smooth. In the limit of a discontinuous albedo, a Poincaré map can be derived and analyzed exactly to determine stability boundaries for its fixed points. This approximation also introduces dynamics associated with Filippov piecewise-smooth systems, which we explore.

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CP14

Understanding Cellular Architecture in Cancer Cells

Progression to cancer causes a complex set of transformations in a cell. Neoplastic cells are known to display marked changes in the morphology of their organelles. However, there is still no clear mechanistic understanding of this transformation process. We present a dynamical systems approach for the evolution of organelles morphology in cancer cells. The results provided by this work may increase our insight on the mechanism of tumorigenesis and help build new therapeutic strategies.

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CP14
Structural Adaptation of a Microvascular Network

The cardiovascular network provides oxygen and other nutrients and removes waste from tissue. Network structure and function are thought to be maintained by vascular adaptation, the geometric structural change of microvessels in response to hemodynamic and metabolic stimuli - abnormal vascular adaptation is thought to be associated with conditions such as hypertension, diabetes, and obesity. In this presentation we examine the dynamics of an adaptation model in a small network, and demonstrate that bistability and limit cycles are to be expected.

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CP14
Robustness of Gene Regulatory Networks

The global dynamics of gene regulatory networks are known to show robustness to perturbations of different kinds: intrinsic and extrinsic noise, as well as mutations of individual genes. One molecular mechanism underlying this robustness has been identified as the action of so-called microRNAs that operate via different types of feedforward loops. We will present results of a computational study, using the modeling framework of generalized Boolean networks, that explores the role that such network motifs play in stabilizing global dynamics.

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CP14
Chemical Signal Processing for Biological Magnetic Sensors

Geomagnetic fields measurably affect some animals behavior but the mechanisms are poorly understood. In a leading theory supported by some experiments, quantum-mechanical oscillation modulates chemical reactions that are sensitive to angular momentum. To thoroughly probe this theory, one must consider downstream chemical reactions which may process photic and magnetic stimuli in complicated ways. Toward this, we consider singular chemical dynamics perturbed by coherent oscillation, both in the deterministic (thermodynamic) limit and with fluctuation.

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CP14
Stability and Hopf Bifurcation in a Mathematical Model for Erythropoiesis

We consider an age-structured model for erythropoiesis that describes the production of blood cells under the influence of the hormone erythropoietin. Hemoglobin and erythropoietin are involved in a negative feedback loop. We reduce the model to a system of two nonlinear ordinary differential equations with two constant delays for which we show existence of a unique steady state. We determine all instances at which this steady state loses stability via a Hopf bifurcation and establish analytical expressions for the scenarios in which these arise. We show examples of supercritical Hopf bifurcations for parameter values estimated according to physiological values and present numerical simulations in agreement with the theoretical analysis. We provide a strategy for parameter estimation to match empirical measurements and compare existing data on hemoglobin oscillation in rabbits with predictions of our model.

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CP15
Chaotic Sickle Cell Blood Flow

Sickle cell blood flow is governed by the Navier-Stokes and oxygen transport equations. For an assumed time varying solution, neglecting higher order terms, non-linear PDEs are transformed to autonomous ODEs and related algebraic equations. Fixed points, eigenvalues, and Lyapunov exponent for the ODEs are calculated. Computed deterministic, aperiodic, and initial condition sensitivity of the ODEs show the chaotic nature of sickle cell blood flow.

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CP15
Multistable Dynamics in Electroconvecting Liquid Crystals

By using a timescale separation algorithm based on diffusion map delay coordinates we have identified a small number of multistable dynamical states in a small, 30 m wide, electroconvecting liquid crystal sample. These dynamics are categorized by the repetitive formation, propagation, and annihilation of instabilities, or defects, in the sample. By perturbing the applied voltage at different phases of this defect cycle we are able to steer the system between

different multistable states.

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CP15

Marangoni Oscillations in Rehology of Langmuir Polymer Monolayers

The dynamics of monolayers is important in a wide variety of scientific and technological fields. In the case of Langmuir polymer monolayers, experiments are commonly performed to measure surface rheological properties on which the dynamics is strongly dependent. In these experimental configurations, a shallow liquid layer is slowly compressed and expanded in periodic fashion by moving two solid barriers, changing the free surface area and simultaneously measuring surface properties. Since the forcing frequency is small, current theoretical studies only include surface phenomena while ignoring fluid dynamics in the bulk. This approximation provides good results only if the dynamics is sufficiently slow. Here we present a long wave theory that does take fluid dynamics into account. This addresses the issue of flow effects in the measurement of surface properties and allows one to determine how small oscillation frequencies should be to obtain accurate values of rheological properties.

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CP15

Nonlinear Stability Analysis of Convective Rolls in Granular Fluid

In this talk we focus on granular convection. The granular convection resembles Rayleigh Benard convection as both are induced by the gravity and the temperature gradient. The linear stability analysis shows that the conduction becomes unstable above the critical parameters which trigger convection. The nonlinear stability analysis, around the critical parameters, predicts that the transition from conduction to convection state is via a supercritical bifurcation and this result agrees well with classical convection.

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CP15

Front Propagation in Steady Cellular Flows: A Large-Deviation Approach

We examine the propagation speed of Fisher–Kolmogorov–Petrovskii–Piskunov chemical fronts in steady cellular flows. A number of predictions have previously been derived assuming small molecular diffusivity (large Péclet number) and either slow (small Damköhler number) or fast (large Damköhler number) reactions. Here, we employ the theory of large deviations to obtain an eigenvalue problem whose matched-asymptotics solution provides a description of the front speed for all Damköhler values. Earlier results are recovered as limiting cases.

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CP16

Controlling Macroscopic Chaos in a Network of Coupled Oscillators

A non-autonomous infinite network of coupled oscillators can exhibit chaos. We derive a reduction that accurately describes its collective asymptotic behavior and design a control scheme based on this reduced system. The strategy is then applied to a finite network. Three examples are studied: a bimodal Kuramoto system, a network of theta neurons, and a network of Josephson junctions. We also examine robustness with respect to the network size and random link removal.

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CP16

Designing Pulse Coupled Oscillators

Pulse coupled oscillators have numerous real world applications in biology, and increasingly, applications in the control of and synchronization of system clocks. We describe a class of oscillators which mix excitation and inhibition as well as change their own frequencies so as to synchronize robustly, even when there is a complex network structure, time delays and heterogeneous oscillator frequencies. We present both numerical and analytical arguments for this highly non-linear system.

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CP16

Synchronous Dynamics and Bifurcation Analysis in Two Delay Coupled Oscillators with Recurrent Inhibitory Loops

In this study, the dynamics and low-codimension bifurcation of the two delay coupled oscillators with recurrent inhibitory loops are investigated. We discuss the absolute synchronization character of the coupled oscillators. Then the characteristic equation and the possible low-codimension bifurcations of the coupled oscillator system are studied. Applying normal form theory and the center manifold theorem, the stability and direction of the codimension bifurcations are determined. Finally, numerical results are applied to illustrate the results obtained.

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CP16

Effects of Degree-Frequency Correlations on Network Synchronization

We study network synchronization where internal dynamics (natural frequency) of each oscillator is correlated with local network properties (nodal degree). Recent studies have found that such correlations can enhance synchronizability and cause explosive synchronization. Here we provide a framework for studying the dynamics and describe a class of correlations with remarkable dynamical properties. These results show that collective behavior in network-coupled dynamical systems can be made complex by creating correlations between dynamical and structural properties.

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CP16

Loop Searching System with Self-Recovery Property

We propose an autonomous system which is capable of searching for closed loops in a network in which nodes are connected by unidirectional paths. A closed loop is defined as a phase synchronization of a group of oscillators belonging to the corresponding nodes. In addition, to develop a system capable of self-recovery, we have developed novel regulatory rules for the interaction between nodes.

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CP17

Spectral Representation of Oscillators

Nonlinear flows exhibiting self-sustained oscillations are represented by the spectrum of the linear Koopman operator. The resonances (Koopman eigenvalues) given by the trace of the Koopman operator form a lattice in the stable half of the complex plane. Near the critical parameters for the onset of oscillations, the associated basis of coherent structures (Koopman modes) is constructed from a multiple-scale expansion of the flow field and a spectral expansion of the corresponding amplitudes. Using the two-dimensional cylinder flow, it is shown that Ritz vectors and values extracted from the dynamic mode decomposition algorithm approximate the derived Koopman spectrum, as long as the flow is on or near the limit cycle. Nonlinear dynamics near the unstable equilibrium results in continuous damped branches of Ritz values, that do not correspond to any discrete Koopman eigenvalues.

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CP17

Building Energy Efficiency Using Koopman Operator Methods

Building energy models have widespread use in evaluating building performance. Models simulate thermal conditions at sub-hourly time-scales for the duration of a year. Despite their capability, zoning approximations, i.e., the subdivision of building volume into regions with uniform properties, is performed to manage complexity. By projecting temperature histories of zones onto eigenmodes of the Koopman operator, a systematic approach to zoning is introduced. This technique is illustrated on a building model of an actual building.

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CP17

Sparsity-Promoting Dynamic Mode Decomposition

Dynamic mode decomposition (DMD) represents an effective means for capturing the essential features of numerically or experimentally generated flow fields. In order to strike a balance between the quality of approximation (in the least-squares sense) and the number of modes that are used to approximate the given fields, we develop a sparsity-promoting version of the standard DMD algorithm. This is achieved by combining tools and ideas from convex optimization and the emerging area of compressive sensing. Several examples of flow fields resulting from simulations and experiments are used to illustrate the effectiveness of the developed method.

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CP17

Detecting Unstable Koopman Modes from Power Grid Disturbance Data

Emergent disturbances in large-scale interconnected power grids are repeatedly experienced in the world. We use the Koopman mode analysis based on the properties of the point spectrum of the Koopman operator for analysis of data on physical power flows sampled from a major disturbance. This unveils the existence of unstable power flow patterns that govern the complex dynamics occurring during the disturbance.

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CP17

Comparison of PCA and Koopman Mode Decomposition Applied to Estuary Flow

We analyze near-bank velocities recorded by HADCP at West Point NY in the Hudson River. To the north, a sharp bend and deep main channel disequilibrate flow during ebb (falling) tide, yielding an asymmetric temporal signature of the second PC. We want to characterize, then accurately compute, the dominant near-bank turbulent eddies. With PCA and KMD, we aim to quantify spatiotemporal dynamics from field data, thence permitting rational comparison with computation.

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CP18

Energy-Level Cascades in Physical Scales of 3D Incompressible Magnetohydrodynamic Turbulence

Working in physical scales, total energy in 3D magnetohydrodynamical turbulence is shown to cascade over an inertial range determined by a modified Taylor length scale. Direct cascades are investigated for energies transported by distinct mechanisms. Also included are a comment on flux locality, a scenario in which the inter-medium energy transfer is predominantly kinetic to magnetic, and a note regarding the cascade of kinetic energy for non-decaying fluid turbulence.

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CP18

Analytical Approaches of One-Dimensional Conservative Solute Transport in Hetrogeneous Porous Medium

To solves the analytically, conservative solute transport equation for a solute undergoing convection, dispersion, retardation in a one-dimensional inhomogeneous porous medium. In the present study, the solute dispersion parameter is considered uniform while the velocity of the flow is considered spatially dependent. Retardation factor and first order decay is also considered spatially dependent. The velocity of the flow is considered inversely proportional to the spatially dependent function while retardation factor and first order decay is considered inversely proportional to square of the velocity of flow. Analytical approaches introduced for two cases: former one is for uniform input point source and latter case is for varying input point source where the solute transport is considered initially solute free from the domain. The variable coefficients in the advection-diffusion equation are reduced into constant coefficients with the help of the transformations which introduce by new space variables, respectively. The Laplace transformation technique is used to get the analytical solutions. Figures are presented illustrating the dependence of

the solute transport upon velocity, dispersion and adsorption coefficient.

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CP18

Deterministic Signature for Intermittent Convective Transport in Turbulent Systems

In this letter we present evidences that intermittent transport observed in the scrape off layer of magnetically confined devices has a strong signature of determinism. We show that the universal distribution of density fluctuation as well as the unique parabolic relation between skewness and kurtosis observed in experimental data can be obtained by a superposition of stochastic and deterministic events. A well know deterministic effect, namely, the loose of transversal stability of periodic orbits embedded in an invariant (inertial) manifold is used to model the spiky nature of the emissions. The intermittent emissions are proposed to be due to local unstable transversal directions of the invariant manifold resulting in an ejection of particles and a consequent burst in the signal. We show that characteristics observed by the emissions namely an impulsive ejection followed by a slow recovery phase can be directly related to the deterministic mechanism proposed.

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CP18

Inclination-Flip Homoclinic Orbits in Ageostrophic Flows with Viscoelastic-Type Reynolds Stress

An alternative title for this paper would perhaps be "Onset of Lorenz-type chaos in ageostrophic flows with viscoelastic-type Reynolds stress". Although this paper is motivated by challenges in partial differential equations, our primary objective is to consider a two-mode Galerkin approximation to ageostrophic flows with viscoelastic-type Reynolds stress given by the system of singularly perturbed ordinary differential equations in R^4:

$$Ro\frac{dX}{dt} = Y - EkX - \lambda EkW,$$
$$\frac{dY}{dt} = rX - Y - XZ,$$
$$\frac{dZ}{dt} = -bZ + XY,$$
$$We\frac{dW}{dt} = \epsilon(\delta\lambda X - W).$$

We note the foundation for the study of the low dimensional model, which capture the dominant energy bearing scales, from ageostrophic flows with viscoelastic-type Reynolds stress, is the Lorenz equations modified through singular perturbation. Here, the variable X measures the rate of convective overturning, the variable Y measures the horizontal density variation, the variable Z measures the vertical density variation, and the variable W measures the Reynolds stress. The parameter Ro is the Rossby number, Ek is the Ekman number, δ is the temporal shear-rate viscosity, r is proportional to the reciprocal of the Froude number, and We is the Weissenberg number. We continue our investigation to illustrate the existence of inclination-flip homoclinic orbits, via a bifurcation with a special type of eigenvalue condition, taking account of degeneracies. In order to utilize geometric singular perturbation theory and Melnikov techniques, we perturb the problem and carry the nonlinear analysis further to the question of the persistence of inclination-flip homoclinic orbits. This result enables us to detect Lorenz-type chaos in singularly perturbed dynamical systems. Open challenges are raised as we celebrate the 50th anniversary of 1963 seminal papers by the troika of Lorenz, Melnikov and Smale.

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CP19

Chaos Induced Energy Hopping

A highly excited quasi one-dimensional Rydberg atom exposed to periodic alternating external electric ?eld pulses exhibits chaotic behavior. Time evolution of this system is governed by a geometric structure of phase space called a homoclinic tangle and its turnstile. We use the knowledge about the geometric structure of phase space to design short pulse sequences that quickly and efficiently transfer electronic wave packet from an initial state (n 306) to either a much lower energy state (n 150) or a much higher energy state (n 500). We present how the phase space geometry influences the efficiency of the transport between the energy states.

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CP19

Nonlinear Dynamics of Photoinduced Structural Change in Molecular Crystals

We discuss the nucleation dynamics of photoinduced structural change by a model of molecular crystals. The nonadiabaticity of electron dynamics is fully taken into account by quantizing the relevant phonon modes, and the spatiotemporal patterns of photoinduced domains are studied by methods of non-equilibrium statistical mechanics and multifractal analysis. We found that the formation of a precursor state of photoinduced nuclei in ultrashort time scale causes the nonlinearity of the nucleation dynamics.

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CP19

Modeling Temperature Dynamics of Inductively Heated Shape Memory Polymers Doped with Magnetic Nanoparticles

Various methods have been considered for heating shape memory polymers when noncontact heating is required, including inductive heating. However, nonlinear thermal dynamics and the hysteresis present significant challenges in modeling the dynamics. The purpose of this research is to develop a model for inductively heated polymers doped with magnetic nanoparticles. We discuss the well–posedness of the time discretized model and a comparison of the numerical results with experimental data in existing literature.

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CP19

Reduced Order Modeling of a Nonlinear Piezoelectric Energy Harvester

An infinite dimensional model has been developed for a bistable asymmetric broadband energy harvesting device consisting of piezoelectric beams in a buckled configuration. To aid in qualitative understanding of the behavior of this device, Galerkin projection onto analytic mode shapes has been used to reduce the order of this model. We review the reduced order model and compare to experimental results to confirm validity.

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CP20

The Sigma-Delta Modulator as a Chaotic Nonlinear Dynamical System

Sigma-Delta modulators are extensively used for analogue/digital signal processing. I explore their chaotic behaviour from the point of view of nonlinear dynamical systems analysis. I conduct a theoretical study of conditions for chaos using an adaptation of Devaney's definition of chaos. I then introduce a stochastic formulation of the long-run dynamics, which is applied to give conditions for uniformly distributed error behaviour (relevant to dithered control of error statistics).

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CP20

Families of Hyperbolic Lorenz Knots

We have defined families of hyperbolic Lorenz knots based on the Birman and Kofman lists which we conjecture to be hyperbolic, supported on extensive computational testing. We have also interpreted El-Rifai's satellite knots constructions in terms of Lorenz braids, Lorenz vectors and symbolic sequences, obtaining algorithms for this operation. This, along with previous work, allows us to compute several Lorenz knots invariants, and also to test if a given Lorenz knot is a satellite knot.

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CP20

On the Chaotic Cubic-Quintic Oscillator

In this paper, we used Hamiltonian formulation and Lie transform to investigate cubic-quintic nonlinear oscillator. Using Chirikov's overlap criterion we find the critical value, at which the chaos loses its local character and becomes global. The results of Lie transformation analysis and Chirikov's criteria for the oscillator are compared with numerically generated Poincare Maps.

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CP20

Invariants of Templates, Knots and Links Generated by Renormalizable Lorenz Maps

We describe the sub-Lorenz templates generated by renormalizable Lorenz maps, in terms of the templates generated by the renormalized map and by the map that determines the renormalization type. Consequently we obtain explicit formulas for the Williams ζ function of renormalizable sub-Lorenz templates and also for the genus and the braid index of renormalizable Lorenz knots and links.

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CP20

Almost Lyapunov Functions

A well-known method for showing convergence of all solutions of an ODE $\dot{x} = f(x)$ to an equilibrium consists in finding a Lyapunov function $V(x)$ which is a positive (away from the equilibrium) smooth function that decays along

all non-zero solutions $V'(x) \cdot f(x) < 0$. Suppose now that a candidate Lyapunov function decays everywhere except for a set of small measure. Given the measure of the "bad' set, this work gives necessary conditions on $f(x)$, $V(x)$ which still assure some type of stability.

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CP21

Synaptic Architecture that Promotes Robust Spatiotemporal Neural Dynamics

Spatial models of neuronal networks often assume that synaptic connectivity depends only on the distance between neurons. Such dynamical systems are marginally stable, so solutions diffuse in the presence of noise. More realistic models of neuronal connectivity include spatial heterogeneity. The resulting systems do not exhibit degeneracies such as translation invariance. In this talk, we will explore how breaking the symmetry of spatial connectivity in models of neuronal networks can make their dynamics more robust. Specifically, we focus on how well bumps stay in the vicinity of their initial position in the presence of noise.

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CP21

Formation and Maintenance of Multistability in Balanced Neuronal Networks with Plasticity

Neuronal networks in cortex exhibit complex and variable patterns of activity even in the absence of a stimulus. These dynamics may reflect fluctuations between different stable attractor states. However, attractor networks require specific connectivity patterns to ensure excitation and inhibition remain in balance while preserving multistability. We investigate how this connectivity may be maintained. We show that simple homeostatic plasticity rules that regulate excitatory and inhibitory synaptic strengths can lead to robust multistability in balanced networks without fine-tuning of parameters. These rules ensure that the system stochastically samples its full repertoire of attractor states, leading to rich spontaneous dynamics.

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CP21

Heterogeneity-induced Transitions in Large-scale Systems

I will present derivation and analysis of mean-field equations in the presence of heterogeneities i) in the synaptic connections and ii) in the transmission delays (related to the distances between neurons). The dynamics of the limit equation will evidence a number of phase transitions between stationary and periodic solutions as a function of the degree of heterogeneity, related in the case of heterogeneous delays to the topology of the cortical area.

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CP21

Complexity of Random Neural Networks

We investigate the explosion of complexity arising near the phase transition to chaos in random neural networks. We show that the mean number of equilibria undergoes a sharp transition from one equilibrium to a very large number scaling exponentially with the dimension on the system. Near criticality, we compute the exponential rate of divergence, called topological complexity. Strikingly, we show that it behaves exactly as the maximal Lyapunov exponent, suggesting a deep and underexplored link between topological and dynamical complexity.

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CP22

Accuracy and Stability of the Continuous-Time 3dvar-Filter for 2D Navier-Stokes Equation

We consider a noisy observer for an unknown solution of a deterministic model. The observer is a stochastic model arising in the limit of frequent observations in filtering, where noisy observations of the low Fourier modes together with knowledge of the deterministic model are used to track the unknown solution. We establish stability and accuracy of the filter by studying this for the stochastic PDE describing the observer.

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CP22

The Numerical Integration of a Convection Problem with Temperature Dependent Viscosity: Sim-

ulations and Results

We propose spectral numerical methods to solve the time evolution of a convection problem in a 2D domain with viscosity strongly dependent on temperature. At a fixed aspect ratio the analysis is assisted by bifurcation techniques such as branch continuation. Stable stationary solutions become unstable through a Hopf bifurcation after which the time dependent regime is solved by the spectral techniques. We discuss some results on how different viscosity laws affect the formation and morphology of thermal plumes.

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CP22
Navier-Stokes Equations on Rotating Surfaces: Regularity, Algorithm, Analysis, Simulations

Development of efficient algorithms with rigorous analysis for partial differential equations (PDE) on domains and surfaces requires knowledge of the regularity of solutions of the PDE. In this talk, for the Navier-Stokes equations on rotating spheres we discuss (i) the global regularity for real and complexified time; (ii) a high-order algorithm with stability and convergence analysis; (iii) long time simulation of a benchmark atmospheric flow model and justification of a turbulence theory.

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CP22
Study of Explicit and Implicit Time Integration Methods for Various Low Mach Number Preconditioners and Low Dissipation Schemes Applied to Steady and Unsteady Inviscid Flows

The performance of many existing compressible codes degrades as the Mach number of the flow tends to zero and leads to inaccurate computed results. To alleviate the problem, Roe-type based schemes have been developed for all speed flows, such as the preconditioned Roe and low dissipation schemes. To solve this preconditioned equations for steady and unsteady state solution, there exist many explicit and implicit time integration strategies. For explicit steady formulation Euler, classical RK4 and 5-stage Martinelli-Jameson(MJ) time integration techniques are considered, while for implicit backward Euler with flux linearization method is studied. In unsteady state simulation, Dual-time stepping formulation is used. For explicit unsteady state formulation Euler(τ)-BDF2(t), classical RK4 and 5-stage MJ with Euler(τ)-BDF2(t) discretization are considered, while for implicit physical time is discretized using backward Euler and BDF2 scheme with flux linearization are studied.

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CP22
An Online Manifold Learning Approach for Model Reduction

An online manifold learning method is developed for dimensional reduction of dynamical systems. The method may be viewed as a variant of Picard iteration combined with a model reduction procedure. Specifically, starting with a test solution, we solve a reduced model to obtain a better approximation, and repeat this process until sufficient accuracy is achieved. Convergence of the proposed method is proved. The accuracy of the proposed method is demonstrated by Navier-Stokes equation.

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CP23
Phase Characterization of Complex Systems

In this work we present a new approach for measuring the phase of complex systems. The approach is based on finding sinusoidal fits to segments of the signal therefore obtaining, for each segment, an appropriate frequency from which a phase can be derived. The method is adjustable to different types of signals and robust against moderate noise levels. Three cases are presented for demonstrating the applicability of the method.

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CP23
Gyrostatic Extensions of the Lorenz 1963 System as Novel Time Series Models for Atmospheric Data

The talk will discuss the authors finite systems of ODEs in the form of coupled Volterra gyrostats (gyrostatic models, the simplest being equivalent to the Lorenz system) developed for modeling atmospheric flows. Due to recent progress in understanding statistical properties of dynamical systems, exemplified by results for the Lorenz system, gyrostatic models may provide a viable alternative to those borrowed from standard time series analysis, which involve strong assumptions rarely met in real data.

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CP23
Stability of Intrinsic Localized Modes in Paramet-

rically Driven Coupled Cantilever Arrays

A micro-cantilever array can be modeled as the nonlinear coupled oscillator in which quartic nonlinearity appear in both on-site and inter-site potentials. It is known that the stability of intrinsic localized mode (ILM) is flipped when the ratio between the on-site and the inter-site nonlinearities. In this poster, the stability of ILM will numerically be discussed for the system in which the ratio is sinusoidally varied in time, namely the parametrically driven system.

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CP23
Challenges and Tools for State and Parameter Estimation from Time Series

Which model fits best to my data? Which parameters of the model of interest can be (reliably) estimated from observations? Has the identified model predictive power? Can the observed dynamics (approximately) be described by a “simple’ (low-dimensional) mathematical model? To address these questions we shall use coarse grained descriptions of the dynamics in terms of ordinal patterns, nonlinear dimension reduction methods, optimization based estimation methods, automatic differentiation, and a sensitivity analysis based on delay embedding of time series. All relevant tasks, major obstacles, and suggested solutions will be illustrated using chaotic dynamical systems including (spatially-extended) high-dimensional models from physics and biology (e.g. cardiac cells).

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CP24
Connecting Curves in Higher Dimensions

Chaotic attractors can exhibit large-scale bifurcations as their control parameters are varied. In higher dimensions, these bifurcations result in structural changes that can be understood in terms of vortices, hyper-vortices and the vortex core lines that identify them in phase space. We use cuspoid catastrophes An, n=3,4,5, to describe the structural changes that can occur in a class of n-dimensional differential dynamical systems.

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CP24
Explicit Inhomogeneities in Symmetry-Breaking Systems

Equivariant theory can be used to analyze pattern forming systems, and has been extended to encompass systems with explicit anisotropies. We use group theory to examine general (i.e., model-independent) pattern formation with an explicitly inhomogeneous background, such as for a Turing instability occuring on a periodic substrate. The presence of such inhomogeneities can create new solutions and dynamics.

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CP24
Mathematical Physics of Cellular Automata

A universal map is presented valid for all deterministic 1D cellular automata (CA). It can be extended to an arbitrary number of dimensions and topologies and its invariances allow to classify all CA rules into equivalence classes. Complexity in 1D systems is then shown to emerge from the weak symmetry breaking of the addition modulo an integer number p. The latter symmetry is possessed by certain rules that produce Pascal simplices in their time evolution.

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CP24
Unfolding the Piecewise Linear Analogous of Hopf-Zero Bifurcation

Three-dimensional symmetric piecewise linear differential systems near the conditions corresponding to the Hopf-zero bifurcation for smooth systems are considered. By introducing one small parameter, we study the bifurcation of limit cycles in passing through its critical value, when the three eigenvalues of the linear part at the origin cross the imaginary axis of the complex plane. The simultaneous bifurcation of three limit cycles is proved. Conditions for stability of these limit cycles are provided, and analytical expressions for their period and amplitude are obtained. A generalized version of Chua’s circuit is shown to undergo such Hopf-zero bifurcation for a certain range of parameters.

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CP24

Morse Theory for Lagrange Multipliers

Given $f, \mu : R^n \to R$, one studies critical points of $f \mid \mu^{-1}(0)$ using the Lagrange multiplier function $\mathcal{F} : \mathcal{R}^\setminus \times \mathcal{R} \to \mathcal{R}$, $\mathcal{F}(\S, \eta) = \{(\S) + \eta\mu(\S)$. The gradient flow of $\mathcal{F}$, after rescaling the metric on R by λ^{-2}, is

$$x' = -\left(\nabla f(x) + \eta \nabla \mu(x)\right), \quad \eta' = -\lambda^2 \mu(x).$$

The homology of the Morse-Smale-Whitten complex of $\mathcal{F}$ is independent of λ. We show that in the limit $\lambda \to \infty$ we obtain the complex for $f \mid \mu^{-1}(0)$, and in the limit $\lambda \to 0$ we obtain a complex whose homology can be computed using geometric singular perturbation theory.

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CP25

Existence and Stability of Left-Handedness: An Evolutionary Model

An overwhelming majority of humans are right-handed. I will present a novel mathematical model and use it to test the idea that population-level hand preference represents a balance between selective costs and benefits in human evolutionary history. Supporting evidence comes from handedness distributions among elite athletes; our model can quantitatively account for these distributions within and across many professional sports. The model can also explain the absence of consistent population-level “pawedness’ in many animal species.

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CP25

Ecological and Evolutionary Stability of Single-Species Dispersal in a Two-Patch Habitat

Natural selection is an evolutionary mechanism that strongly affects species diversity. At suitable spatial scales, landscapes are not heterogeneous. To begin to answer how movement strategies might evolve, we analyze a simple single-species ordinary differential equation model describing theoretical movement between two different habitats. Combining analytical and numerical methods, we identify evolutionarily singular dispersal strategies, show that they are evolutionarily and convergence stable, and describe how two different types of costs affect these strategies.

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CP25

Alternate Models of Replicator Dynamics

This work concerns models of evolutionary dynamics, which combine differential equations with game theory. In particular, we study systems of the form $\dot{x}_i = g(x_i)(f_i - \phi)$, called replicator dynamics, in the context of rock-paper-scissors (RPS) games. Here g is a natural growth function; $f_i = (A\vec{x})_i$ is the fitness of strategy i, where A is the RPS payoff matrix; and $\phi = \sum_i g(x_i) f_i / \sum_i g(x_i)$ is the average fitness. The standard replicator equation takes $g(x_i) = x_i$. We analyze the case $g(x_i) = x_i - \alpha x_i^2$, which exhibits richer dynamics.

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CP26

Competitive Modes As Reliable Predictors of Chaos Versus Hyperchaos, and As Geometric Mappings Accurately Delimiting Attractors

We consider real quadratic dynamics in the context of competitive modes. We consider hyperchaotic systems, and conclude that they exhibit three competitive modes, instead of two as for chaotic systems . And, in a novel twist, we re-interpret the components of the Competitive Modes analysis as simple geometric criteria to map out the spatial location and extent, as well as the rough general shape, of the system attractor for any parameter sets corresponding to chaos.

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CP26

Integrated Semigroups and the Cauchy Problem for Some Nonelinear Fractional Differential Equations

Let A be a linear closed operator defined on a dense set in a Banach space E to E. In this note it is supposed that A is the generator of α - times integrated semigroup, where α is a positive number. The abstract Cauch problem of the fractional abstract differential equation:

$$\frac{d^\beta u(t)}{dt^\beta} = Au(t) + f(t, u),$$

with the initial condition: $u(0) = u_0 \in E$, is studied, where $0 < \beta \leq 1$, and f, is a given nonelinear abstract function. The solution of the Cauchy problem is obtained under suitable conditions on f. An application is given.

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CP26

Classifying Workload Using Discrete Deterministic Nonlinear Models

We illustrate the use of a novel deterministically chaotic classification algorithm. The algorithm is used to classify human subject cognitive workload using only the subjects electrocardiogram (ECG) as input. Presented are the algorithm and a case study, in which the algorithm is used to discretely classify the level of a subjects cognitive workload for various tasks. Presentation is given to the accuracy of the chaotic classifier for the domain of cognitive workload using surrogate tasks.

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CP26

Finite-Time Lyapunov Analysis of Two Timescale Systems

Finite-time Lyapunov exponents and vectors are used to define and diagnose boundary-layer type, two-timescale behavior in finite-dimensional nonlinear systems and to determine an associated slow manifold when one exists. Two-timescale behavior is characterized by a slow-fast splitting of the tangent bundle for a not necessarily invariant state space region. Invariance-based orthogonality conditions are used to identify the associated manifold structure.

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CP26

The Memory of Non-Smooth Systems

Traditional mode decomposition techniques are inaccurate for impacting systems. The effect of the impact is of the same order for all modes, therefore increasing the number of modes leads to a diverging description. Here, I will introduce a method that decouples the impact from the infinitely many modes by transforming the system into an equivalent low-dimensional delay equation. Within this framework I obtain a converging description as the delay terms are independent of the impact.

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CP27

Parametrically Driven Oscillators with Added Noise

A theoretical model that describes the dynamics of parametrically driven oscillators with added thermal noise is reported here. Quantitative estimates for heating and quadrature thermal noise squeezing near the threshold to the first parametric instability are given [1]. Furthermore, we describe parametric amplification, which is extremely selective in frequency and phase of the external signal, and presents a high output signal-to-noise ratio [2].$[1]*A.A.Batista*, *Phys.Rev.E*86, 051107(2012).$[2] A.A. Batista and R. S. N. Moreira, Phys. Rev. E 84, 061121 (2011).

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CP27

Nondeterminism of Piecewise Smooth System

A close look at the dynamics of piecewise smooth systems reveals that their peculiarity goes way beyond nondifferentiable orbits and sliding regions. Lack of smoothness entails loss of uniqueness of solutions both forward and backward in time, and a consequential loss of determinism. I will discuss some of these exotic behaviours and their relation to the real-world phenomena that they attempt to describe.

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CP27

Conditionally Stationary Measures for Random Diffeomorphisms

For random diffeomorphisms the relations between conditionally stationary measures and controllability properties of an associated deterministic control system are investigated. The main result gives conditions implying that the support of such a measure is the closure of a relatively invariant control set. This result generalizes known results characterizing the supports of stationary measures by invariant control sets. This paper may be viewed as a contribution of open dynamical systems, here for random systems and control systems.

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CP27

Modelling Computer Dynamics: Can Complexity Overshadow Determinism?

To predict computer performance, one needs effective and informative models of computer dynamics. Traditional approaches to this employ linear stochastic methods; new work suggests that nonlinear deterministic methods are more appropriate. It turns out that neither approach is successful in all cases, which raises a larger research question: given a time series from an arbitrary dynamical system, how can one decide which modelling strategy will work better? We will propose information-theoretic metrics for this task.

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CP27

Dynamical Regimes and Transitions in Plio-Pleistocene Asian Monsoon

We propose a novel approach based on the fluctuation of similarity to identify regimes of distinct dynamical complexity in short time series. A statistical test is developed to estimate the significance of the identified transitions. Our method is verified by uncovering bifurcation structures in several paradigmatic models, providing more complex transitions compared with traditional Lyapunov exponents. In a real-world situation, we apply this method to identify millennial-scale dynamical transitions in Plio-Pleistocene proxy records of the South Asian summer monsoon system. We infer that many of these transitions are induced by the external forcing of the solar insolation and are also affected by internal forcing on Monsoonal dynamics, i.e., the glaciation cycles of the Northern Hemisphere and the onset of the Walker circulation.

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CP28

The Rhomboidal Symmetric Mass Four-Body Problem

We consider the existence and stability of periodic solutions with regularizable collisions in the rhomboidal symmetric-mass four-body problem. In two degrees of freedom, where the analytic existence of the periodic solutions is given by a variational method, the periodic solutions are numerically linearly stable for most of the values of the mass parameter. In four degrees of freedom, we establish the analytic existence of the periodic solutions and numerically investigate their linear stability.

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CP28

Integrable Many-Body Models on a Circle

We use generalized Lagrangian interpolation and finite-dimensional representations of differential operators to construct various many-body models, which describe N points confined to move on a plane circle. Their Newtonian equations of motion are integrable, i. e. they allow the explicit exhibition of N constants of motion in terms of the dependent variables and their time-derivatives. Some of these models are moreover solvable by purely algebraic operations, by (explicitly performable) quadratures and, finally, by functional inversions. This is a joint work with Francesco Calogero from the University of Rome "La Sapienza".

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CP28

Collinear Equilibrium Points and Linear Stability in the Generalized Photogravitational Chermnykh-Like Problem with Power-Law Profile

We have considered the motion of infinitesimal mass in the generalized photogravitational Chermnykh-like problem with power-law profile. The collinear equilibrium points of the proposed problem are determined. In addition with three, a new collinear equilibrium point is obtained. Again, we have examined linear stability of the points and noticed that generally, all the collinear points are unstable but some are stable for specific values of inner and outer radii of the disk.

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CP28

Stability of Relative Equilibria in the N-Vortex Problem

In the weather research and forecasting models of certain hurricanes, "vortex crystals' are found within a polygonal-shaped eyewall. These special configurations can be interpreted as relative equilibria (rigidly rotating solutions) of the point vortex problem introduced by Helmholtz. Their stability is thus of considerable importance. Adapting an approach of Moeckel's for the companion problem in celestial mechanics, we present some useful theory for studying the linear stability of relative equilibria in the planar N-vortex problem. For example, we show that when the vorticities are all of the same sign, a relative equilibrium is linearly stable if and only if it is a minimum of the Hamiltonian restricted to a level surface of the moment of inertia. Some symmetric examples will be presented, including a linearly stable family of rhombi in the four-vortex problem.

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CP28

Implementation of Dynamical Systems Techniques for the Mars-Phobos Three-Body Problem with Additional Gravity Harmonics

Following ESAs proposal for a sample-return mission to Phobos, this paper analyses the orbital dynamics of the Mars-Phobos system to provide low-cost observation points for exploration. The proposed nonlinear model of a spacecrafts motion in the vicinity of Phobos incorporates the highly inhomogeneous gravity field into a restricted three-body problem. State-of-the-art analytical and numerical

methodologies from dynamical systems theory are used to identify periodic orbits around the libration points.

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CP29

Intra-Community Clustering and Solvency in a Simulated Banking Network Model

We present a model of a banking network where connectivity occurs in the form of simulated 3-day interbank loans occurs based on two selection models. Average system solvency is assessed in the context of community average betweeness centrality for each of 300 banks. Results show that while fundamental clustering characteristics do not change between the two selection methods, system solvency is impacted by the method used to select overnight lenders.

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CP29

Twitter Reciprocal Reply Networks Exhibit Assortativity with Respect to Happiness

The advent of social media has provided an extraordinary, if imperfect, big data window into the form and evolution of social networks. Based on nearly 40 million message pairs posted to Twitter between September 2008 and February 2009, we construct and examine the revealed social network structure and dynamics over the time scales of days, weeks, and months. At the level of user behavior, we employ our recently developed hedonometric analysis methods to investigate patterns of sentiment expression. We find users average happiness scores to be positively and significantly correlated with those of users one, two, and three links away. We strengthen our analysis by proposing and using a null model to test the effect of network topology on the assortativity of happiness. We also find evidence that more well connected users write happier status updates, with a transition occurring around Dunbar's number. More generally, our work provides evidence of a social sub-network structure within Twitter and raises several methodological points of interest with regard to social network reconstructions.

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CP29

Time-Scale Lyapunov Functions for Incentive Dynamics on Riemannian Geometries

Time-scale calculus allows the study of difference and differential equations simultaneously. In this talk we present the application of time-scale Lyapunov stability theory to game-theoretically inspired incentive dynamics on the simplex for a wide class of Riemannian geometries, giving time-scale Lyapunov functions in terms of information divergences for a large class of discrete and continuous-time dynamics that include many well-known dynamical systems in evolutionary game theory. These results include discrete time extensions of the adaptive dynamics of Hofbauer and Sigmund. We also discuss the relationship between incentive stability and evolutionary stability through a series of illustrative examples.

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CP29

Fractal Encoding of Recursive Dynamics

Under a standard model of human language, recursive structures are encoded as complex constellations of interdependent rules. One wonders how children learn such constellations because every part needs to be in place for the system to function at all. Neural network dynamical systems solve the all-at-once problem by adopting fractal encodings, which grow continuously from simple sets. We examine conditions under which the learning is robust in the presence of neural and sequence noise.

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CP29

Optimal Control of the Spread of Marijuana Smoking Among the Youth

Reducing the number of individuals involved in substance abuse in any community is usually a challeging problem. We consider the control of the spread of Marijuana smok-

ing, one substance that is majorly abused, among the youth. We propose a deterministic model for con- trolling the spread of Marijuana smoking incorporating education and awareness campaign as well as rehabilitation as control measures. We formulate a fixed time optimal control problem subject to the model dynamics with the goal of finding the optimal combination of the con- trol measures that will minimize the cost of the control efforts as well as the prevalence of marijauna smoking in a community. We use Pon- tryagin's maximum principle to derive the optimality system and solve the system numerically. Results from our simulations are discussed.

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CP30

Topological Structures and Parameter-Sweeping Techniques in the Hindmarsh-Rose Neuron Model

The use of computer techniques permits to help the understanding of natural phenomena. Among the mathematical models of neuronal activity, the Hindmarsh and Rose model is one of the most used in simulations. In this talk we show the use of new techniques based on neurocomputing parameters to study the global behaviour of the system and we link them with bifurcation techniques. Moreover we study the structure of the chaotic attractors that may appear when the parameters are changed, providing us with topological templates which "quantify" the differences and similarities between the structures observed.

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CP30

Singularity Theory Sheds Light on Bursting Mechanisms in Conductance-Based Models

In recent work, we have shown that a pitchfork bifurcation organizes the excitability of arbitrary conductance-based models. Here we study a two-dimensional universal unfolding of this bifurcation augmented with a slow adaptation variable. The resulting three-dimensional dynamics provide a minimal model of bursting as paths in the universal unfolding of the pitchfork. We discuss the generality of this approach and argue that it provides a physiological route to neuronal bursting.

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CP30

Minimum Energy Control for *in Vitro* Neurons

The applicability of control theory in regulating the interspike interval for single periodically-firing *in vitro* neurons is demonstrated. Combining electrophysiology experiments with optimal control theory, first the phase response curve for each neuron is measured, then continuous-time, charge-balanced, minimum energy control waveforms are designed that optimally change the next spike time for the neuron with significantly lower levels of energy compared to those of previous approaches.

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CP30

Singularly Perturbed Phase Response Curves

Motivated by models of spiking neurons, we determine the shape of (non-infinitesimal) phase response curves for slow-fast systems from the singular limit. It is completely determined by the bistable range of the fast subsystem and the bifurcations that delineate its onset and its termination. We apply this geometric approach to relaxation oscillators and bursters, recovering among others the fast threshold modulation phenomenon.

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CP30

Global Sensitivity of Spiking Neuron Models: The Power of a Local Analysis

This study focuses on two important sensitivity measures for reliable transmission of information in single neuron models: the variability of the first spike latency and the probability of doublets. Our analysis, supported by singular perturbation theory, shows that these two global sensitivity measures can be characterized locally, in the vicinity of local bifurcations. Results are illustrated on several conductance-based models of spiking neurons.

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CP31

Network Topological Conditions for Stochastically Amplified and Coherent Oscillations

We investigate relationship between stochastic oscillations and topologies of biochemical reaction networks. We consider all topologies of three-nodes biochemical reaction networks with mass-action kinetics and characterize noisy oscillatory behaviors by using linear noise approximation of the corresponding master equations. All networks with both negative and positive feedbacks are deterministically stable, but capable to generate stochastically amplified and coherent oscillations. We use stochastic center manifold reduction to demonstrate that various network topologies that exhibit the same stochastic oscillations could be mapped onto the same stochastic normal form.

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CP31

Stochastic Asymptotic Analysis for Cooperative Multiple Motor Systems

We develop and examine a coarse-grained model for multiple motors bound to a cargo, which resolves the spatial configuration as well as the thermal fluctuations. Through stochastic asymptotic reductions, we derive the effective transport properties of the multiple-motor-cargo complex, and provide analytical explanations for why a cargo bound to two molecular motors moves more slowly at low applied forces but more rapidly at high applied forces than when bound to one molecular motor.

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CP31

Analytical Approach to Noise-Induced Phase Synchronization of Chaotic Oscillators

The phase description has played a key role in analytically investigating the dynamics of limit-cycle oscillators. Here, we introduce a new type of phase description, which enables us to analyze various synchronization phenomena of chaotic oscillators. Using our formulation, we study noise-induced phase synchronization of chaotic oscillators subjected to common random forcing. We theoretically predict probability distributions of phase differences between two chaotic oscillators, which characterize statistical properties of noise-induced synchronization dynamics.

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CP31

Stochastic Resonance in a Self-Repressing Gene with Transcriptional Memory

Biochemical reaction networks are subjected to large fluctuations, yet underlie reliable biological functions. They are usually described as either deterministic or stochastic dynamical systems. Here, we investigate the dynamics of a self-repressing gene using an intermediate approach based on a moment expansion of the master equation. We thereby obtain deterministic equations describing how nonlinearity feeds back fluctuations into the mean-field equations. We thus identify a region of parameter space where

fluctuations induce relatively regular oscillations.

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CP31
Mathematical Analysis of Flows on Stochastic Fractal Networks

We present an analytical method to predict the properties of the process resulting from a convolution between a stochastic fractal network and a stochastic process. We quantify the influence of network topology by comparing linear (autocovariance function) and nonlinear (generalised entropies, higher-order spectra) characteristics of the initial and resulting processes. It depends on the initial stochastic process and, in cases, saturates after a low number of network iterations. This has important consequences in hydrological modelling.

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CP32
Analysis of Bifurcations and the Study of Competition in Phase Oscillator Networks with Positive and Negative Coupling

Globally coupled phase oscillators of the Kuramoto type with positive (conformist) and negative (contrarian) coupling are considered in (Hong & Strogatz (HS), 2011). We generalize the HS system including a phase shift in the interaction function. The bifurcation theory and detailed study of the geometry of invariant manifolds is applied. The results include a rich repertoire of dynamical regimes (multistability, complex heteroclinic cycles, chaos, etc.). Some of these regimes are not possible in HS systems.

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CP32
Rate-Induced Tipping Points

Open systems which are stable for any fixed external conditions may tip if the external conditions change too fast. Such non-autonomous instabilities are important in the natural world, but cannot be captured by classical bifurcations. We obtain critical rates of external forcing above which the system tips. This is done numerically and analytically for canonical models using an approach related to the validity boundary of geometrical singular perturbation theory.

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CP32
Transition Curves for the Elliptic Mathieu Equation

This work investigates the equilibria and stability of a parametrically excited pendulum when the forcing function is of an elliptic type. Stability charts are generated in the parameter plane for different values of the elliptic function modulus. A method combining Floquet theory and Numerical integration is used to generate stability charts that are later obtained by the mean of harmonic balance analysis. It is shown that the size and location of the instability tongues is directly dependent on the elliptic function modulus. Comparisons are also made between the stability charts of Mathieu equation and the elliptic Mathieu equation.

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CP32
Periodically Forced Hopf Bifurcations

We classify the existence and stability of dynamical responses to small amplitude periodic forcing of a system near a Hopf bifurcation point. We use forcing frequency ω_f as a distinguished bifurcation parameter and vary ω_f near the Hopf frequency. This analysis uses a third order Hopf normal form truncation, though we identify regions of parameter space where higher order terms are necessary. Time permitting, applications to physical systems will be discussed.

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CP32

On States with Two Frequencies in Ensembles of Coupled Oscillators

I discuss a mechanism which ensures onset of oscillatory states with two frequencies in a class of ensembles where all elements share the intrinsic timescale and the pattern coupling is arbitrary. At the onset of oscillations, the spectrum of the linearized flow contains not one (as usually) but two pairs of purely imaginary eigenvalues. Of the two critical frequencies, one is typically much lower than the individual frequency of an element, whereas the other one is distinctly higher. Accordingly, in the nonlinear regime the ensembles are potentially able to display both slow and fast modes of oscillations.

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CP33

A Comparison of the Local and Global Dynamics of Monotone and Antimonotone Maps in the Plane

Monotone and antimonotone maps have widespread applications in many areas of real life. For example, monotone maps are associated to discrete competitive mathematical models in Biomathematics such as the Leslie-Gower population model. Antimonotone maps are associated to discrete mathematical models involving negative feedback loops such as mechanical control systems and gene regulatory networks. Although planar monotone maps are very well-understood at this point due to the works of Hirsch, Smith, Dancer and Hess, Kulenovic and Merino etc., the same is not necessarily true for planar antimonotone maps. In this talk, I will discuss the local and global dynamics of orbits of a class ofplanar antimonotone maps. I will also compare this to the local and global dynamics of orbits of a similar class of planar monotone maps to get some very interesting results.

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CP33

Adaptation for Fast Chaos Control

In recent years, chaos control has lead to numerous applications. We examine convergence speed of chaos control, an aspect which is crucial in applications such as stabilizing heart rhythms and robotics. Adaptation provides a way to optimize convergence speed of chaos control methods [Bick, Timme, Kolodziejski. SIADS, 11(4), 1310, 2012]. In particular, we focus on Predictive Feedback Control for discrete time dynamics and study some aspects of time-delayed feedback control of time continuous systems.

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CP33

Robustness of Periodic Windows in the Presence of Sporadic Noise

For a dynamical system $x_{n+1} = F(C, x_n)$, there may be infinitely many periodic windows, that is, intervals in C in which there is stable periodic behavior. However, the high period windows are easily destroyed with small perturbations. For a fixed perturbation size ϵ, we characterize and enumerate the 'ϵ-robust windows', that is those periodic windows such that for some C in that window, the general periodic behavior persists despite noise of amplitude $\leq \epsilon$.

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CP33

Trichotomy of Singularities of 2-Dimensional Bounded Invertible Piecewise Rational Rotations

It is known that the singularities of 2-dimensional bounded invertible piecewise isometric dynamical systems can be classified as, removable, shuffling and sliding singularities, based upon their geometrical traits; and that the the removable and the shuffling singularities do not generate Devaney-chaos, leaving the sliding singularity as the only candidate for the Devaney-chaos. However, the afore-mentioned classification and the connection had been somewhat incomplete in that the clear distinction between the sliding and shuffling singularities had not been made. In this talk, the speaker will establish the complete trichotomy, by characterizing the self-shuffling behavior of bounded invertible piecewise rational rotations, and lead toward finalizing the necessary and sufficient condition of the Devaney-chaos.

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CP33

Dynamics of Certain Rational Maps of the Plane

We investigate the dynamics of rational maps of the form $z \mapsto z^n + c + \beta/\overline{z}^d$. The case when $c = 0$ and $n = d$ can be solved completely because the radial dynamics decouples from the angular dynamics. In the other cases, numerical investigation is necessary. Especially interesting are the critical sets for $n \neq d$ and comparisons of the Julia sets for $\beta = 0$ to the analogues for $\beta \neq 0$.

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CP34

Disease Persistence in Epidemiological Models:

The Interplay Between Vaccination and Migration

We consider the interplay of vaccination and migration rates on disease persistence in epidemiological systems. We show that short-term and long-term migration can inhibit disease persistence. As a result, we show how migration changes how vaccination rates should be chosen to maintain herd immunity. In a system of coupled SIR models, we analyze how disease eradication depends explicitly on vaccine distribution and migration connectivity. The analysis suggests potentially novel vaccination policies that underscore the importance of optimal placement of finite resources.

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CP34

Epidemiological Model for X-Linked Recessive Diseases

We developed a discrete time, structured, mathematical model describing the epidemiology of X-linked recessive diseases; the model accounts for de novo mutations and distinct reproduction rates of procreating couples depending on couples health conditions. We found the exact solution to the model when de novo mutations are not relevant and negligible reproduction rates are assigned to affected males. Moreover, relying on Lyapunovs second method, we proved asymptotic stability properties of model equilibrium points for the case of relevant de novo mutations and identical reproduction rates assigned to all procreating couples. The equilibria we obtained are a generalization of Hardy-Weinberg equilibrium.

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CP34

Modeling the Role of the Biofilm Formation in the Development of Plant Diseases

The role of biofilms within bacterial infections has been a topic of recent interest due to the prevalence of the biofilm mode of life as well as the inability to fully eliminate the bacteria within the biofilm. Despite multiple diseases causing widespread damage to the citrus, wine, and other fruit industries, there has been little attention paid to modeling the development and progression of these infections. A multiphase modeling framework will be used to examine the dynamic behavior and fluid/structure interactions of the biological system. Perturbation analysis will be used to determine potential causes and tendencies of patterns discovered within the biofilm.

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CP34

Epidemics in Adaptive Social Networks with Temporary Link Deactivation

Epidemic spread depends on the topology of the network of social contacts. Individuals may respond to the epidemic by adapting their contacts to reduce the risk of infection, thus changing the network structure and affecting future spread. We propose an adaptation mechanism where healthy individuals temporarily deactivate their contacts with sick individuals, allowing reactivation once both individuals are healthy. Slow and fast network dynamics are considered and compared to mean field analysis.

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CP34

A Mathematical Model Studying Mosquito-Stage Transmission-Blocking Vaccines

In this talk, I will present a mathematical model of malaria control, particularly investigating the efficacy of imperfect vaccination. The model consists of deterministic ordinary differential equations. Based on our model, a backward bifurcation very likely occurs, which suggests that using the basic reproduction number as the threshold to eradicate the disease is questionable. This finding might provide some valuable suggestions to health policy makers.

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CP35

Necessary Condition for Frequency Synchronization in Network Structures

We present the necessary condition that a network structure should satisfy for frequency synchronization of coupled phase oscillators. A parameter called surface area describes critical network structure for synchronization. The surface area of a set of sites is defined as the number of links between the sites within the set and those outside the set. On the basis of the condition, we can identify networks in which synchronization do not occur.

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CP35

Nonuniversal Transitions to Synchrony in the Sakaguchi-Kuramoto Model

The
Sakaguchi-Kuramoto model is a fundamental paradigm for the emergence of collective behavior (synchrony) in a system of non-identical oscillators that are weakly coupled by their mean field. We show that for certain *unimodal* frequency distributions, this model exhibits *unusual* types of synchronization transitions, where synchrony can decay with increasing coupling, incoherence can regain stability for increasing coupling, or multistability between partially synchronized states and/or the incoherent state can appear.

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CP35

Chimera States on Periodic Spaces

Although incoherence and synchronization are the norm in arrays of coupled oscillators, complex spatiotemporal patterns such as "chimera states'—where incoherence and coherence coexist—have been observed both computationally and experimentally in a wide variety of systems. I will use an analytical approach to characterize various types of chimera states (including stripes and spots) that appear in a two-dimensional periodic space, and discuss their changing stability and bifurcations as the coupling is varied.

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CP35

The Kuramoto Model with Distributed Shear

The Kuramoto model (KM) is a paradigmatic model of collective synchronization, a phenomenon observed in a variety of natural and technological systems. An analytical derivation of the KM is possible via phase-reduction of the mean-field complex Ginzburg-Landau equation with disorder. Nevertheless, this derivation assumes shear (non-isochronicity) is not distributed. We avoid this simplifying assumption and obtain analytical results for the KM with distributed shear. Remarkably we find that too much shear diversity prevents collective synchronization.

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CP35

Spontaneous Formation of Two-Dimensional Chimera States in Oscillatory Media

Chimera states are spatiotemporal patterns in coupled oscillatory media, where synchronized and incoherent domains coexist. A nonlocal coupling is believed to be indispensable for the formation of such states. By means of a modified complex Ginzburg-Landau equation we demonstrate, however, that chimera states arise spontaneously through a bifurcation from cluster states when just a strong global coupling is present. Experiments made during the electro-oxidation of silicon confirm this theoretical prediction.

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CP36

Numerical Solutions of Delay Reaction-Diffusion Equations of Lotka-Volterra Type

In this paper we consider a system of delay differential equations of Lotka-Volterra type describing the one-stage model of carcinogenesis mutations. A numerical scheme based on spectral postprocessing technique was employed to the simplified model from [R. Ahanger and Lin. X. B.: Multistage evolutionary model for carcinogenesis mutations, Electron. J. Diff. Eqns. Conf. 10 (2003), 33-53.]. We check our scheme for different value of time delay and compare the results with other available schemes.

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CP36

Efficient Algorithms for Rigorous Integration of Dpdes

We are dealing with nonlinear partial differential equations of dissipative type (dPDEs). Assuming that the initial condition is sufficiently regular the unique solution of such system can be explicitly bounded using a computer algorithm involving the interval arithmetic. In our research we have focused on efficient computational methods for the problem of rigorously integrating dPDEs. We focus on a circumvention of computational difficulties by combining the FFT algorithm + the automatic differentiation.

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CP36

High Precision Periodic Orbits

Nowadays, high-precision becomes a requirement in fine analysis of dynamical systems. We present an algorithm to locate and continue families of periodic orbits with high precision (100-1000 digits). As example, we apply this tool to show the final spiral structure of the Copenhagen problem. Finally, we combine the high-precision numerics with Computer Assisted Proof techniques in order to provide a rigorous high-precision data-base of periodic orbits of the Lorenz problem.

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CP36

Adaptive Numerical Simulation of Intracellular Calcium Dynamics Using Discontinuous Galerkin Methods

We present an adaptive in space and time simulation of intracellular calcium dynamics using discontinuous Galerkin(DG) methods. The two-dimensional parabolic system of partial differential equations models the diffusion, reaction, binding and membrane transport of calcium ions within a cell. The current issues for further research in intracellular calcium dynamics aim at moving modelling and simulation much closer to experimental data. Our work has addressed this challenge by implementing the model using a highly accurate method in space and time that goes adaptively to high order, being efficiently scalable. This has involved using the DG method of weighted interior penalties and the linearly implicit Runge-Kutta methods of Rosenbrock type. A hybrid method that couples the solution of the deterministic and stochastic part of the model is adopted.

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CP36

Comparison of ODE Solvers for Parallel Uses. GPGPU and CPU

In this talk we present some results comparing Runge Kutta schemes and the Taylor Series Integrator executed both in CPU and GPGPU using different parameters: Tolerance level, Global or Local Memory execution, and 4 and 8 Bytes floating point arithmetic. We present diagrams of CPU/GPU time vs Error in two test problems: Hénon-Heiles system (dimension 4), and the same one with first order variational equations (dimension 16).

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CP37

Decomposition of Nonlinear Network Dynamics: Understanding Oscillations In Multi-Vehicle Systems

Understanding the nonlinear behavior of networked systems is crucial in the modern world; such systems are becoming ubiquitous. Traditional nonlinear analysis (e.g., center manifold reduction) becomes extremely complicated for systems containing large number of interacting components. In this talk we propose a novel technique where we decompose networked systems into nonlinear modes and carry out traditional analysis using the obtained mode equations. As a case study we analyze Hopf bifurcations arising in vehicular traffic.

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CP37

Nonlinear Dynamics in the Transverse Plane of High-Speed Planing Boats

When operating at high speed, planing boats are subject to nonlinear hydrodynamic loads affecting rigid body motions such as pitch, heave, and roll. Resulting instabilities are often a constraining factor for high-speed operations. This presentation will describe roll motion as a nonlinear system parametrically excited through coupling with heave and pitch, and investigate the occurrence of nonlinear roll behavior such as steady heel and chine walking.

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CP37

Lyapunov Stability of Rigid Bodies with Frictional Supports

The Lyapunov stability of systems of rigid bodies interacting via impacts, persistent contacts and friction is poorly understood. This talk addresses a model system of this type: a single planar object with two support, for which only highly conservative stability conditions have been found earlier. By restricting my attention to ideally plastic impacts, a nearly sharp stability condition is derived. It is also demonstrated that intriguing phenomena of frictional hybrid dynamics are captured by this system.

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CP37

An Artificial Neural Network Approach for the Mass Balance of a Reactor in Steady State

The conservation of mass has been an active research area in the field of chemical engineering. In this article, a mathematical model for mass balance of a chemical in a cylindrical reactor is presented and the steady state case for the mass balance of a chemical is examined by providing the numerical solution using artificial neural network technique. Numerical simulations are performed for various hidden nodes with different number of training points and initial weight parameters to show the dependence of results on the number of hidden nodes, training points and initial weights. The neural network solution is also compared with the well known finite difference method for variable step size and analytical solution shows the efficiency of neural network with higher accuracy. The main advantage of the proposed approach is that once the network is trained, it allows instantaneous evaluation of solution at any desired number of points spending negligible computing time and memory.

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CP38

A Grand Model to Predict the Complex Combinatorial Stress Responses of Candida Albicans

Candida albicans is a major opportunistic fungal pathogen. Their ability to grow in yeast, pseudohyphal and hyphal forms help them survive, invade and kill an host organism. Their timely transition from one morphological form to another depends upon three major stress response pathways (SRPs): (i) oxidative, (ii) osmotic and (iii) nitrosative. A grand mathematical model, first of its kind, encompassing these three different SRPs is presented that can predict the system responses to combinatorial perturbations.

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CP38

Stable Periodic Oscillations in the Biotic Pyrite Iron Cycle

Based on geomicrobiology literature, a model for the biotic pyrite iron cycle by Acidithiobacillus ferrooxidans bacteria is proposed. This model exhibits is some circumstances, up to two stable steady states, stable and unstable periodic orbits, Hopf, SNP and homoclinic bifurcations, as well as other dynamical structures (doubling period, chaos, etc.). It provides a possible explanation of oscillations in pH and bacteria population mentioned in the literature.

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CP38

Nonlinearity Explains Inefficient Energy Strategy of Cancer Cells

The use of energy-inefficient metabolism is a common yet largely unexplained property of cancer. We demonstrate that this property is in fact a consequence of a trade-off between the selective advantage of rapid growth and a concurrent nonlinear increase in protein cost. We developed a metabolic model that incorporates protein cost and allows us to identify candidate targets for therapeutic interventions. These findings provide a novel computational framework to analyze and potentially control cancer metabolism.

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CP38

The Relation Between Two-Cell Model and N-Cell Model on Somitogenesis of Zebrafish

Somitogenesis is the process of the development of somites. Herein, we consider two-cell and N-cell models with delays to investigate the scenarios in zebrafish somitogenesis. We derive the analytical theories for the oscillation-arrested and synchronous oscillation for these two models. By the parameter regimes in our theories, we design suitable gradients of degradation rates and delays in the N-cell model to generate the chief dynamics, synchronous oscillation, traveling wave pattern, and oscillation-arrested, in somitogenesis.

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CP38

Firing Threshold Manifolds: Folded Saddle Canards in a Model of Propofol Anaesthesia

We investigate firing threshold manifolds in a mathematical model of propofol anaesthesia, investigating the phenomenon of post-inhibitory rebound spiking. Propofol modulates the decay time-scale of an inhibitory GABAa synaptic current. This system gives rise to rebound spiking within a specific range of propofol doses. Using techniques from geometric singular perturbation theory we identify canards of folded saddle-type, which form the firing threshold manifolds. The position and orientation of the canard separatrix is propofol dependant.

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CP39

Linking Graph Motifs and Collective Spiking in Neuronal Networks

Correlations between neuron outputs (spikes) in biological neural networks are important characterizations of their collective dynamics, and can determine how these dynamics encode input signals. We studied how spike correlations are shaped by complex graph structures, defined via statistics of network motifs. We show that network-averaged spike correlations are determined by a novel set of network statistics – *motif cumulants* – which are endowed with a combinatorial relationship similar to that between moments and cumulants for random variables.

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CP39

Exact Collective Dynamics for a Heterogeneous Network of Theta Neurons

We have developed an exact model that examines the emergent dynamical properties of Type I neurons. Our model considers individual neuronal heterogeneity with respect to excitability and type of coupling. We employ a mean-field approach and reduce the higher dimensionality of this complex nonlinear system to a simple exact two-dimensional description. We characterize all the macroscopic states of the network and conduct a comprehensive bifurcation analysis under which transitions in these collective states occur.

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CP39

Core-Periphery Organization of Human Brain Dy-

namics

As a person learns a new skill, distinct synapses, brain regions, and networks are engaged and change over time. To better understand the dynamic processes that integrate information across a set of regions to enable the emergence of novel behaviour, we measure brain activity during motor sequencing and characterize network properties based on coherent activity between brain regions. Using our recently developed algorithms to detect time-evolving communities of brain regions that control learning, we find that the complex reconfiguration patterns of local communities can be described parsimoniously by the combined presence of a relatively stiff core of primary sensorimotor and visual regions whose connectivity changes little in time and a flexible periphery of multimodal association regions whose connectivity changes frequently. The separation between core and periphery changes with the duration of task practice and, importantly, is a good predictor of individual differences in learning success. This temporally defined core-periphery organization corresponds with notions of core-periphery organization established previously in social networks: The geometric core of strongly connected regions tends to also be the temporal core of stiff regions. We then show using hypergraphs that the core is dominated by the co-evolution of network edges, demonstrating that core regions turn on and off with the same set of partner regions over the slow time scale of learning. Our results demonstrate that core-periphery structure provides a new approach for understanding how separable functional modules are linked. This, in turn, enables the prediction of fundamental capacities, including the production of complex goal-directed behavior, in humans.

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CP39

Networks of Theta Neurons with Time-Varying Excitability: Macroscopic Chaos, Multistability, and Final-State Uncertainty

Using recently developed analytical techniques, we study the macroscopic dynamics of a large heterogeneous network of theta neurons in which the neurons' excitability parameter varies in time. We demonstrate that such periodic variation can lead to the emergence of macroscopic chaos, multistability, and final-state uncertainty in the collective behavior of the network. Finite-size network effects and rudimentary control via an accessible macroscopic network parameter is also investigated.

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CP39

Learning Cycles in Hopfield-Type Networks with Delayed Coupling

We study the storage and retrieval of cyclic patterns in Hopfield-type networks with delay using the pseudoinverse learning rule. We show that all cyclic patterns satisfying the transition conditions can be successfully stored and retrieved; topology of the networks constructed from these cyclic patterns are determined by the subspace structures of the row spaces of the cyclic patterns; transitions from fixed points to attracting limit cycles (cyclic patterns) are multiple saddle-node bifurcations on limit cycles.

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MS1

Asymptotic Classification of Affine and Linear Stochastic Functional Differential Equations, and Applications to Volatility Modelling

In this talk, we give a classification of the pathwise and mean-square asymptotic behaviour of affine and linear stochastic functional differential equations. In each case, stability of an underlying deterministic system plus a noise intensity below a critical level guarantee stability, while above that critical level, instability ensues. The results can be applied to consider rates of convergence to stable solutions, and to analyse when soultions of stochastic functional equations arising in finance have stationary solutions, and long–range dependence.

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MS1

Large Deviations in Affine Stochastic Functional Differential Equations

In this talk we explore the size of the running (or the running maximum of the norm) of the solution of a stochastic functional differential equation (SFDE). In a recent paper with Appleby and Mao, we investigated this phenomenon for equations with a finite memory; however, the method of proof precluded the analysis being carried through for equations with unbounded memory, or for stochastic neutral equations. In this work, we show that the size of the large deviations is the same for these classes of equations as it is for the standard finite delay SFDE

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MS1

Mean-square Stability of Stochastic Systems with

Memory Terms

We present a method to calculate the mean-square stability of dynamical systems described by Stochastic Differential Equations with Delay (SDDEs), which give a mathematical formulation of problems with time-lag or memory terms, as well as stochastic effects. We use this method to investigate the interplay of noise and delay, including noise structure. Further, we apply our method to models arising in Neuroscience and Biology, comparing the results obtained with the deterministic case.

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MS1

Stochastic Dynamical Systems in Finance

This talk is devoted to the study of stochastic dynamical systems (SDS) and their applications in finance. Usually, a SDS consists of two parts: the first part is a model for the noise path, leading to a SDS, and the second part is the dynamics of a model. In this talk, we shall present many models of SDS and develop techniques in the SDS which can be implemented in finance. Among of these models we have: stochastic Ramsay model for a capital that takes into account past-dependent history; geometric Markov renewal process for a stock price with many possible values; fractional Brownian motion model for a stock price; regime-switching, delayed with Poisson jumps model for a stock price; delayed Heston model for a stochastic volatility. Based on the latter model, we shall show, for example, how to price variance and volatility swaps and how to hedge a position with volatility swap using a portfolio of variance swaps.

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MS2

The Role of Cardiac Tissue Anatomy during Electric-Field Stimulation

Designing low-energy control strategies for cardiac arrhythmias is an area of major scientific and medical interest. We present experimental evidence showing that the cardiovascular tree is an anatomical substrate for field-induced wave sources observed in quiescent tissue, a mechanism that permits Low-Energy Anti-Fibrillation Pacing to achieve considerable energy reduction compared to conventional defibrillation [S. Luther, F.H. Fenton et al., Nature, 2011]. Further theoretical investigations reveal a curvature-dependent sensitivity of tissue boundaries to electric-field stimulation [PB et al., Phys. Rev. Lett., 2012], indicating the relevance of additional endocardial structures.

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MS2

Cardiac Alternans Annihilation by Model Predictive Control Techniques

In this research efforts, the model of alternation of action potential dynamics is described by the small amplitude of alternans parabolic partial differential equations (PDE) that account for electric and calcium based alternation dynamics. We are seeking to explore model predictive control to suppress alternans and to account for naturally present constraints in control of cardiac systems and to relate this application to realistic physiological models.

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MS2

Continuous-time Feedback Control of Alternans in Purkinje Fibers

We use a novel model of canine Purkinje fibers which accurately reproduces the experimental bifurcation diagram of action potential duration to compare discrete- and continuous-time feedback for suppression of alternans. In the discrete-time approach, control current is applied for a brief time interval following each pacing stimulus. In the continuous-time approach, a piece-wise constant control current is applied at all times. We show that the continuous-time approach suppresses alternans significantly faster compared with the discrete-time approach.

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MS2

Coherent Structures and Nonlinear Control of 2D Cardiac Tissue

Representation of cardiac tissue dynamics corresponding to spatiotemporally complex rhythms such as fibrillation as a walk through neighborhoods of a hierarchy of coherent structures opens up unprecedented possibilities for prediction and control. This talk describes the computational approach for identifying unstable periodic orbits representing these coherent structures and using them and their heteroclinic connections to guide the dynamics through phase space, e.g., from fibrillation to normal rhythm.

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MS3

A Balance Model for Equatorial Long Waves

As slow dynamics often dominate in geophysical fluid models, it is desirable to filter out fast motions by constructing simplified 'balance' models (e.g. the quasi-geostrophic model for mid-latitude dynamics). Attempts to derive its equatorial counterpart have not been entirely successful, as Kelvin waves, which contribute significantly to tropical low-frequency variability, are generally filtered out. I will describe how a balance model that captures Kelvin waves can be constructed via asymptotic expansion.

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MS3

A Fast and Accurate Parallel-in-time Integrator for Nonlinear PDEs with Scale Separation

We present a new time-stepping algorithm for nonlinear PDEs that exhibit scale separation in time. Our scheme combines asymptotic techniques (which are inexpensive but can have insufficient accuracy) with parallel-in-time methods (which, alone, can be inefficient for equations that exhibit rapid temporal oscillations). In particular, we use an asymptotic coarse solver for computing, in serial, a solution with low accuracy, and a more expensive fine solver for iteratively refining the solutions in parallel. We present examples on the rotating shallow water equations that demonstrate that significant parallel speedup and high accuracy are achievable.

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MS3

Multiscale Asymptotic Approaches to Rotationally Constrained Flows

Geophysical fluid dynamical flows by their nature span a large number of scales in both space and time. In this talk we discuss the development of a multiscale reduced modeling approach for rotationally constrained convective flows. Particularly, we present simulation results for small-scale quasigeostrophic (i) Rayleigh Benard convection and (ii) quasigeostrophic one-sided convection. The ability of coupling (i) and (ii) to large scale hydrostatic motions is also discussed.

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MS3

Approaching the Limit of Strong Rotation in the Rotating, Stratified Boussinesq System

We investigate the dynamics of weakly stratified flow in the presence of increasingly strong rotation rate. In reality the limit of infinitely fast rotation (zero Rossby number) is not realized, so we consider the effect of rapid, but finite rotation (Rossby number small, but finite). We use a new decomposition and direct numerical simulations to investigate this limiting behavior.

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MS4

Experimental Observation of Chimeras in Coupled-map Lattices

While chimeras states are often found in populations of phase oscillators, chimeras can also exist in networks of chaotic systems with nonlocal coupling. We present the experimental realization of these states in a feedback system which uses a liquid crystal spatial light modulator to achieve optical nonlinearity in a network of coupled chaotic maps. We also describe scaling properties of these states and their transition between spatial coherence and incoherence.

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MS4
The Spectrum of Chimera States: From Discrete Maps to Neural Systems

Chimera states exhibit surprising dynamics in compound systems of nonlocally coupled, identical elements that consist of both spatially coherent and synchronized as well as incoherent parts. Initially discovered for phase oscillators, they have been recently found in a large variety of different models and have also been realized in experiments. In my presentation, I will give an overview of the wide spectrum of possible local dynamics ranging from time-discrete maps via chaotic models to neural oscillators. Furthermore, I will address analytical results on the symmetry and stability of these hybrid states.

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MS4
Chimera in Space-time Representation of Optoelectronic Nonlinear Delay Dynamics

Delay dynamical systems are known to have a space-time interpretation. We propose to use this feature for the quest of experimental Chimera. A benchmark optoelectronic delay oscillator is considered as the physical setup intended to emulate a high dimensional spatio-temporal dynamics of coupled virtual nodes. Theoretical analysis, as well as numerical simulations, are proposed to identify the temporal and amplitude parameter conditions under which Chimera could be obtained in an experimental delay dynamics.

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MS4
Chimera States for Repulsively Coupled Phase Oscillators

We discuss the appearance of chimera states for *repulsively* coupled phase oscillators of the Kuramoto-Sakaguchi type, i.e., when the parameter $\alpha > \pi/2$ and hence, the network coupling works against synchronization. We find that chimeras exist in a wide region of the parameter space as a cascade of the states with increasing number of the regions of irregularity - chimeras heads. They grow from the so-called multi-twisted states in three different scenarios: via snic, blue-sky catastrophe, and homoclinic transition.

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MS5
May We Interpret Swimming as a Limit Cycle?

There is something periodic and stable about the motion of a fish swimming. Specifically, it seems natural to surmise that swimming is a limit cycle. In this talk I will leverage various Lie group symmetries to find a space on which this interpretation makes sense. The resulting observations can be abstracted, and then specialized to a number of dissipative Lagrangian systems and perhaps used to analyze other types of locomotion including terrestrial locomotion and pumping of fluids.

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MS5
Pinch-off and Optimal Vortex Formation in Biological Propulsion

A wide class of swimming animals propel themselves by forming vortex rings and loops. It is known that vortex rings cannot grow indefinitely, but rather ‘pinch-off’ once they reach their physical limit, and that a decrease in efficiency of fluid transport is associated with pinch-off. Therefore, in this study, we consider models for the vortex rings in the wakes of swimming animals, and characterize their perturbation response in order to assess their optimality.

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MS5
A Variational, Second-order Integrator for Point Vortices on the Sphere

I will introduce a novel formulation of point vortex dynamics on the sphere using unit quaternions. In this way, point vortex dynamics on the sphere is recast a Schrodinger-like equation, which facilitates the construction of geometrical numerical integrators. I will derive this formulation using the Hopf fibration, and I will derive a numerical integrator with good long-term qualitative behavior, which will be illustrated on the spherical von Karman vortex street.

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MS5
Computationally Tractable Tools for the Identification of Hybrid Dynamical Models of Human Movement

Given the loss of freedom common to injuries arising due to falls, the development of techniques capable of pinpoint-

ing instabilities in gait is critical. Devising an algorithm capable of detecting such deficiencies requires employing models rich enough to encapsulate the discontinuities in human motion. Hybrid systems, which describe the evolution of their state both continuously via a differential equation and discretely according to a discrete input, are capable of representing such motion. This talk begins by illustrating how a sequence of contact point enforcements along with a Lagrangian intrinsic to the human completely determines a hybrid system model. The detection of contact point enforcement is then transformed into an optimal control problem for switched systems which is solved by relaxing the discrete input and performing optimization over a relaxed discrete input space. The utility of this approach is illustrated by considering several examples.

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MS6

Spectral Variational Integrators

Using techniques from Galerkin variational integrators, we construct a scheme for numerical integration that converges geometrically, and is symplectic and momentum preserving. Furthermore, we prove that under appropriate assumptions, variational integrators constructed using Galerkin techniques will yield numerical methods that are in a certain sense optimal, converging at the same rate as the best possible approximation in a certain function space. We further prove that certain geometric invariants also converge at an optimal rate.

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MS6

Controlled Lagrangians and Stabilization of Discrete Spacecraft with Rotor

This talk discusses the method of controlled Lagrangians for discrete mechanical systems and its application to the problem of stabilization of rotations of a spacecraft about its intermediate inertia axis. The distinction between the stability conditions for a continuous-time system and its discretization will be discussed. It will be shown that stability of the discrete system is sufficient for stability of its continuous counterpart but not vice versa.

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MS6

The Hamilton-Pontryagin Principle and Lie-Dirac Reduction on Semidirect Product

We consider the Hamilton-Pontryagin variational principle on Lie groups and its associated Lie-Dirac reduction, which may yield the reduced implicit Euler-Poincaré equations. Especially, we focus on the case of the variational principle with advective parameters as well as reduction of Dirac structures on semidirect product. Finally, we show some illustrative examples of rigid body and fluids.

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MS6

Variational Structures for Hamel's Equations

Hamel's equations are an analogue of the Euler-Lagrange equations of Lagrangian mechanics when the velocity is measured relative to a frame unrelated to the system's local configuration coordinates. This formalism is particularly useful in nonholonomic mechanics. We will discuss the variational structures associated with Hamel's equations, along with applications to nonholonomic integrators.

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MS7

Homoclinic Bifurcations Leading to Merging and Expansion of Chaotic Attractors

Chaotic dynamics in piecewise smooth maps may persist under parameter variations. Still, the chaotic domain in such maps may be well-structured by crisis bifurcations, caused by homoclinic bifurcations of unstable cycles. We discuss how the effect of these bifurcations depends on the properties of the cycles and how the resulting generic bifurcation scenarios depend on the properties of the map (which may be continuous or discontinuous, may possess one or several border points).

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MS7

Global Attractors for Slowly Non-Dissipative Equations with Jumping Nonlinearities

This talk presents new results in the study of non-compact global attractors for slowly non-dissipative reaction-diffusion equations. We analyze grow-up equations with asymptotically asymmetric growth rates, where the operator controlling the behavior at infinity contains a jumping nonlinearity. We present bifurcation, stability, and nodal property results which determine the connecting orbit structure as well as how the jumping nonlinearity at infinity introduces Fučik spectrum theory to the analysis in the sphere at infinity.

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MS7

Dynamics at Infinity for a PDE with Jumping Nonlinearity

A jumping nonlinearity naturally arises in the study of the dynamics at infinity for slowly nondissipative reaction-diffusion equations $u_t = \Delta u + f(u)$ where f goes to infinity along different slopes b^+ and b^- at positive and negative infinity. Although the behavior at infinity is well understood in the symmetric case $b^+ = b^-$, lack of smoothness in the nonsymmetric case jumbles the classical picture of heteroclinic connections. The behavior near the sphere at infinity is described via Poincaré "compactification" .

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MS7

Grazing Induced Bifurcations in Impact Oscillators: Theory and Experiments

Abstract not available at time of publication.

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MS8

Random Dynamical Systems Approach to the Problem of Gene Expression

A genetic regulatory network (GRN) is a collection of DNA segments in a cell which interact with each other through their RNA and protein expression products, thereby governing the rates at which genes in the network are transcribed into mRNA. These interactions are made by special proteins called transcription factors which bind the DNA at the promoter site to regulate the rate that specific gene targets are expressed. Much theoretical work on the structure of GRN focused on the static aspects of networks (topological or statistical properties). However, general studies of the dynamics (the processes that take place on a network) are fairly rare. In this work we propose an approach to the dynamics of genetic regulatory networks, whcih moreover accounts for the noise observed in the transcription process, by modelling the interaction of a transcription factor with the promoter region of a gene through suitable random dynamical systems resembling the Michaelis-Menten enzymatic kinetics.

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MS8

Wilson Networks for Binocular Rivalry

In rivalry the two eyes of a subject are presented with two images. Usually, the subject reports *seeing* the two images alternating. Wilson proposed a class of neuronal networks for multiple competing patterns. The neuronal network has learned patterns that help define the network structure. These networks also support patterns that were not learned, which we call *derived*. There is evidence for perception of derived patterns in binocular rivalry experiments. We consider Wilson networks corresponding to experiments of Kovács, Papathomas, Yang, and Fehér. The first experiment is the noted monkey-text rivalry experiment. We show that a simple Wilson model makes expected the surprising outcome. The second experiment concerns rivalry between dots of different colors. We construct a Wilson network for the dots experiment and use symmetry to make predictions regarding states that a subject might perceive. This is joint work with C. Diekman and Y. Wang.

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MS8

Normal Forms and Bifurcations of Semigroup Networks

The local bifurcation analysis of network dynamical systems is complicated by the fact that the normal form of a network near a local equilibrium may not have a nice network structure. We resolve this issue here by introducing so-called semigroup networks. It turns out that such networks are determined by a semigroup of symmetries. In particular, the synchronous solutions and the spectral degeneracies of any network are determined by hidden symmetries in an appropriate semigroup network.

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MS8

Rigid Phase-shifts in Periodic Solutions of Network Systems

Networks of differential equations can be described abstractly by a directed graph whose nodes correspond to systems of differential equations and arrows correspond to coupling between the systems. Suppose that $x(t)$ is a T-periodic solution and $x_i(t)$ and $x_j(t)$ are the coordinates of $x(t)$ corresponding to nodes i and j. The two nodes are *phase-related* if there exists $0 \leq \theta < 1$ such that $x_j(t) = x_i(t + \theta T)$. The phase relation θ is *rigid* if it remains unchanged on perturbation of the coupled system. In this talk we discuss joint work with M. Golubitsky and D. Romano that shows how rigid phase-shifts are related to network architecture (the graph) and network symmetries.

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MS9

Stochastic Prediction and Control in Time-dependent Dynamical Systems

We consider the problem of stochastic prediction and control in a time-dependent stochastic environment, such as the ocean, where escape from an almost invariant region occurs due to random fluctuations. In particular, a control strategy is formulated that utilizes knowledge of the underlying flow and environmental noise. The control policy enables mobile sensors to autonomously and efficiently pursue a variety of tasks by maintaining a desired distribution in the environment. The control strategy is evaluated with experimental data.

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MS9

Relatively Coherent Sets as a Hierarchical Partition Method in Time-dependent Chaotic Dynamical Systems

We present an extension of finite-time coherent pairs in time-dependent dynamical systems to generalize the concept to hierarchically defined relatively coherent sets. The idea is based on specializing the finite-time coherent sets to use relative measures restricted to sets that are developed iteratively and hierarchically in a tree structure of partitions and the resulting restricted Frobenius-Perron operators. Several examples are used to illustrate our method.

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MS9

Revealing the Phase Portrait of Aperiodic Time Dependent Dynamical Systems: New Tools and Applications

A very useful approach for studying dynamical systems is based on Poincar ideas of seeking geometrical structures on the phase space that divide it into regions corresponding to trajectories with different dynamical fates. These ideas have demonstrated to be very powerful for the description of transport in purely advective flows. We study the performance of recently proposed tools, the so called Lagrangian descriptors, for achieving phase portrait representations in geophysical flows. We analyze the convenience of different descriptors from several points of view and compare outputs with other methods proposed in the literature. We discuss applications of these tools on oceanic and atmospheric realistic datasets.

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MS9

Chaotic Advection in a Steady, Three-dimensional, Ekman-driven Eddy

We investigate chaotic advection within a three-dimensional, steady or steady, rotating-cylinder flow, driven by a surface stress. A high-resolution spectral element model is used to map out the barriers, manifolds, and resonances. Invariant tori for cases with O(1) Ekman number are found to be remarkably stable to the perturbation. A formula for the resonance width is derived, and this and a version of the KAM theorem are used to interpret our findings.

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MS10

Truth-model Synchronization and Model-model Synchronization: A Path to Intelligent Compact Representation of a High-dimensional Reality

Predictive computational models that assimilate new observations of a real system as they run are intended to synchronize with that system, defining a new application of chaos synchronization to the problem of machine perception. A recent extension is to arrange for several alternative models of the same reality to synchronize with one another, a strategy suggestive of conscious mental processing, that gives improved modeling with ODE systems and a PDE representing the large-scale atmospheric circulation.

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MS10

Improvement in Predictive Modeling by Coupling Imperfect Models

A supermodel is an interconnected ensemble of existing imperfect models of a real, observable system, intended to combine the best features of the individual models. The connections between the models can be learned from observational data using methods from machine learning. We present new efficient, robust and scalable learning strategies to optimize supermodels for dynamical systems of low complexity, in particular for the case where connection coefficients appear only in equations for unobserved variables.

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MS10

Synchronous Coupling of Large Climate Models for Improved Climate Change Projection

Models used internationally to project climate change give divergent predictions in regard to the magnitude of globally averaged warming and in regard to specific regional changes. An “interactive ensemble of three different global climate models (GCMs) has been formed using inter-model data assimilation. Even with crude assignment of assimilation weights based on historical data, the resulting supermodel promises improved performance as compared to any single model or weighted average of model outputs.

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MS10

Climate Model Intercomparison at the Dynamics Level

We address how well models agree when it comes to dynamics they generate, by adopting an approach based on climate networks. We considered 98 runs from 23 models and constructed networks for the 500 hPa, surface air temperature (SAT), sea level pressure (SLP), and precipitation fields for each run. We find that with possibly the exception of the 500 hPa filed, the consistency for the SLP and especially SAT and precipitation fields is questionable.

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MS11

On the Generation of Beta Oscillations in the Subthalamic Nucleus-globus Pallidus Network

A key pathology of Parkinsons disease is the occurrence of persistent beta oscillations. We investigate an earlier model of the network composed of subthalamic nucleus (STN) and globus pallidus (GP) that identified the conditions under which this circuit could generate beta oscillations. We derive stability conditions that are valid for arbitrary synaptic transmission delays. Our analysis explains how and why changes in inputs to the STN-GP network influence circuit oscillations.

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MS11

Striatum as a Potential Generator of Beta Oscillations in Parkinson's Disease

Prominent beta frequency oscillations arise in the basal ganglia in Parkinsons disease. The dynamical mechanisms generating these oscillations are unknown. Using mathematical models, we show that robust beta oscillations can emerge from interactions between striatal medium spiny neurons. The interaction between the membrane M-current and the synaptic GABAa current provides a cellular-level interaction promoting the formation of the beta oscillation. Experimental testing of our model in normal, mouse striatum resulted in pronounced, reversible

beta oscillations

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MS11

Dynamical Circuits Coupling Between Basal Ganglia and Cerebral Cortex

Elevated level of synchrony in the beta band across cortico-basal ganglia-thalamo-cortical circuitry is related to the motor symptoms of Parkinsons disease. We will discuss our studies of phase synchronization between cortical and basal ganglia oscillatory neural activity, in particular we consider the temporal patterns of this synchronization and the use of the mathematical models to investigate the mechanisms underlying observed synchronous dynamics.

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MS11

Intrinsic Dynamics of Dopamine Neurons: Modeling and Experiments

Dopaminergic (DA) neurons are slow intrinsic pacemakers that undergo depolarization block upon stimulation. In response to several pharmacological manipulations, they also exhibit bursting and tonic firing. These activities are relevant to the dysfunctional dopaminergic signaling observed in Parkinson's disease and schizophrenia. We present a comprehensive multicompartment model of DA neurons to uncover the ionic basis of the signaling described above. Furthermore, we use a reduced three-compartment model to study its underlying dynamics using bifurcation analysis.

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MS12

Instability in Nearly Integrable Hamiltonian Systems with Three Degrees of Freedom

This talk is to sketch the proof of Arnold diffusion in nearly integrable Hamiltonian systems with three degrees of freedom and related problems.

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MS12

Geometric and Topological Structures in Hamiltonian Dynamics

An important problem in the study of Hamiltonian systems is to identify geometric/topological templates that organize the dynamics, and to develop constructive methods that can applied to concrete examples and implemented in rigorous numerical experiments. We will present several models of unstable Hamiltonian systems, and will survey some geometric, topological, and variational methods that can be used to describe the dynamics. We will discuss some applications to celestial mechanics, engineering, population dynamics, and medicine.

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MS12

Low-dimensional Dynamics in Nnonlinear Wave Systems

The nonlinear Schrdinger equation (NLS) is a ubiquitous model in mathematical physics. In diverse settings–light propagation in coupled nonlinear waveguides and induced vortex motion in Bose Einstein condensate, the dynamics are well-described by small systems of Hamiltonian ODE. Using Hamiltonian reductions and normal form analysis, we investigate bifurcations discover hidden and surprising structures in the dynamics of these ODE models and relate them to direct numerical simulation of NLS.

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MS12

Regularizing Transformations in the Planar Three-body Problem

I will describe an interesting way to regularize all three binary collisions and blow-up the triple collision in the planar three-body problem and discuss progress on extensions to the planar four-body problem.

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MS12

Small Generalized Breathers with Exponentially Small Tails for Klein-Gordon Equations

Breathers are solutions to PDEs which are periodic in time and localized in space. One famous example is the family of the breathers of the sine-Gordon equation. On the one hand, as shown by Birnir-McKean-Weinstein and Denzler, these breathers are rigid in the sense that they do not persist under small perturbations to the sine-Gordon equation. On the other hand, the formal analysis by Segur-Kruskal, for the ϕ-4 model, which can be viewed as a perturbation to the sine-Gordon equation for small amplitude waves, the obstacle to solving the equation for breathers is exponentially small with respect to the amplitude of the breathers. In the talk, we consider a class of Klein-Gordon equation and show that generically there exist small breathers with exponentially small tails.

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MS13

Data-driven Mesoscopic Neural Modelling

This presentation will discuss methods for developing subject-specific mesoscopic neural models. The ability to create subject-specific models will enable estimation of normally hidden aspects of physiology. Imaging physiological parameters will lead to a greater understanding of diseases and provide new targets for novel therapies. The model-data fusion framework in this presentation is based on nonlinear Kalman filtering. In particular, we will demonstrate estimation accuracy using synthetic data before showing results from real intracranial EEG data.

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MS13

Optimal Control of Spiking Neuron Ensembles

Altering neuronal spiking activity using external stimuli is a subject of active research and is imperative for wide-ranging applications from the design of neurocomputers to neurological treatment of Parkinson's disease. We study the control of an ensemble of neuron oscillators described by phase models. We examine controllability of a neuron ensemble and derive time-optimal and minimum-energy controls for spiking a neuron ensemble by using a robust computational method based on pseudospectral approximations.

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MS13

Transient Neurodynamics and the Role of Sensory Dead Zones

Sensory thresholds can produce complex transient neurodynamics. We illustrate this phenomenon through a study of stick balancing at the fingertip. Although stick balancing stability is well accounted for by the presence of time-delayed feedback, the experimentally-observed transient dynamics (Weibull-type survival functions, intermittency, Lvy-distributed variables) are most easily explained by incorporating a sensory threshold into the control mechanism. Sensory thresholds and transient dynamical phenomena necessitate a reconsideration of current models for neural computation and control.

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MS13

Controlling Populations of Neurons

There is evidence that an effective treatment for neurological diseases such as Parkinson's disease and epilepsy would be to desynchronize appropriate populations of neurons, for example through the use of deep brain stimulation. This talk will serve as an overview of different methods which have been proposed to accomplish this goal, with an emphasis on methods which exploit ideas from the theory of dynamical systems.

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MS13

Symmetry in the Observability and Controllability of Neuronal Networks

The theory of observers is a mature one for linear systems. But it is far less developed for nonlinear systems, and very incomplete for nonlinear networks. Nevertheless, there is growing interest in model-based control of neural systems, and accordingly, we have begun to investigate the effect of network symmetries on the observability and controllability of neuronal networks.

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MS14

An Overview of Localized Pattern Formation, with Comments on Non-variational and Non-local Problems

I will introduce the minisymposium by reviewing the underlying structure that supports the existence of localized states near subcritical pattern-forming instabilities. Comments on recent work concerning non-variational or non-local terms in model equations will follow; some of this is joint work with John Burke (Boston).

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MS14

Exponential Asymptotics and Homoclinic Snaking

Homoclinic snaking of localized patterns has been observed in a variety of experimental and theoretical contexts. The phenomenon, in which a multiplicity of localized states exists within an exponentially small parameter range, is due to the slowly varying amplitude 'locking' to the underlying pattern. We show how conventional methods, such as multiple scales near bifurcation, must be extended to incorporate exponentially small effects if a complete asymptotic description of snaking behaviour is to be achieved.

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MS14

Radially Symmetric Spot Solutions for the Swift–Hohenberg Equation

The existence of stationary localized spots for the planar and the three-dimensional Swift–Hohenberg equation is proved using geometric blow-up techniques. The spots have a much larger amplitude than that expected from a formal scaling in the far field. One advantage of the geometric blow-up methods is that the anticipated amplitude scaling does not enter as an assumption into the analysis but emerges during the construction. The stability of these solutions will also be addressed.

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MS14

Localized Patterns in Systems with Two Length Scales, and Oscillons in Parametrically Forced Systems

We present two examples of one-dimensional localized patterns. In the first, the model system is unstable to two wavelengths and we find patterns with one wavelength embedded in a background of patterns with the other wavelength. In the second example, the model system is parametrically forced and the patterns are analogues of the oscillons found in Faraday wave experiments. In both cases, we analyse the system by carrying out long-wavelength expansions.

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MS14

Spatial Patterns in Shear Flows

When shear flows become turbulent spatio-temporal patterns emerge in the chaotically fluctuating flow. Those patterns such as localized turbulent spots or laminar-turbulent stripes appear to be captured by spatially localized exact invariant solutions of the 3D Navier-Stokes equations. Specific equilibrium and traveling wave solutions are organized in a snakes-and-ladders structure strikingly similar to that observed in simpler pattern-forming PDE systems, suggesting that well-developed theories of patterns in simpler PDE models carry over to transitional turbulent flows.

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MS15

Identification and Tracking of Optimally Coherent Sets in the Ocean and Atmosphere via Transfer Operators

Optimally coherent sets are those sets that are the most efficient transporters of geophysical flow mass. We describe a recent numerical method that uses Lagrangian information to detect and track optimally coherent sets in time-dependent geophysical flows. We illustrate the new approach by tracking Agulhas rings, and accurately determining the locations of the Antarctic polar vortex. The method works naturally in two- and three- dimensions, and can handle both advective and advective/diffusive dynamics.

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MS15

Scale-dependent Relative Dispersion and Application to Submesoscale Lagrangian Parametrization

The scale-dependent Finite Scale Lyapunov Exponent(FSLE(delta)) is a metric closely related to tracer dispersion problems as it differentiates the scales of dispersion. It is also particularly suited to investigate the dispersive regimes at the submesoscales, which tends to be underestimated in numerical models and can help in the development of Lagrangian parametrization. Results will be presented on existing Lagrangian subgridscale models adapted to tackle the muti-scale ocean transport problem.

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MS15

Space-Filling Lattices of 3D Vortices Created by the Self-Replication of Critical Layers in Linearly Stable, Shearing, Stratified, Rotating Flows

A space-filling lattice of 3D vortices spontaneously forms in linearly- stable, rotating, stratified shear flows. The lattice is due to a new family of easily-excited critical layers with singular vertical velocities. The layers draw energy from the background shear and roll-up into vortices that generate waves. The waves excite new critical layers and vortices. The vortices nonlinearly and self-similarly replicate to create a vortex lattice. This self- replication occurs in stratified Couette flows and in protoplanetary disks.

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MS15

Hyperbolic Lagrangian Coherent structures (LCSs) and LCS-cores

Underlying the flow are structures, broadly known as Lagrangian Coher- ent structures (LCSs), which form the skeletons of passive tracer patterns. Some LCS can sustain highly attracting cores whose identification can help predicting the development of an instability in a tracer distribution. Here I exemplify this using data collected during the Deepwater Horizon oil spill and the eruption of the Eyjafjallajokull volcano in 2010, and a Lagrangian drifter experiment in Gulf of Mexico recently carried out.

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MS15

Lagrangian Fronts and Potential Fishing Grounds

Lagrangian fronts in the ocean delineate boundaries between waters with different Lagrangian properties. We propose a general method to identify them in any velocity field based on computing synoptic maps of the drift of synthetic tracers and other indicators. It is shown with the altimetric geostrophic velocity fields that fishing grounds with maximal catches are located mainly along those Lagrangian fronts where converge dissimilar wa- ters of different origin and history. The proposed method may be applied to forecast potential fishing grounds for pelagic fishes in different regions.

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MS16

Stabilization of Difference Equations with Stochastic Perturbations

A map which experiences a period doubling route to chaos, under a stochastic perturbation with a positive mean, can have a stable blurred 2-cycle for large enough values of the parameter. The limit dynamics of this cycle is described, and it is demonstrated that most well-known population dynamics models (for example, Ricker, truncated logistic, Hassel and May, Bellows maps) have this stable blurred 2-cycle. For a general type of maps, in addition, there may be a blurred stable area near the equilibrium.

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MS16

Stochastic Effects in Non-normal Systems: An Example from Ecology

Consider the linearisation of a predator-prey model around an equilibrium representing species coexistence. The dynamics are governed by a non-normal coefficient matrix, which may display a large transient response to initial-value perturbation even when the equilibrium is asymptotically stable. We examine the effect of persistent stochastic perturbation of each species on mean-square dynamics, extending to the stochastic case measures of asymptotic and transient response to initial value perturbations proposed by Neubert & Caswell (1997).

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MS16

The Poincare Map of Randomly Perturbed Periodic Motion

For a system of differential equations in $\mathbf{R}^n$ perturbed by small white noise, we construct the Poincare map in the vicinity of a stable limit cycle. We show that the time of the first exit from a small neighborhood of the fixed point of the map is approximatelly geometric and provide applications of this result to the analysis of bursting and mixed-mode oscillations in neuronal models. This is joint work with Pawel Hitczenko.

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MS16

On Discrete Itô Formula and Applications

We discuss several variants of the Discrete Itô formula which was originally developed by J. A. D. Appleby, G.Berkolaiko and A.Rodkina. We demonstrate how this formula can be applied in the proofs of almost sure stability and instability of the solutions of the stochastic difference equations, systems of the stochastic difference equations, as well as the Euler-Milstein discretisation of an Itô stochastic differential equation. We also discuss application of the Discrete Itô formula to the optimal control problem for the stochastic difference equations.

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MS17

Cardiac Wave Instabilities in Tissue with Inhomogeneous Distribution of Calcium Alternans

Despite the important role of electro-mechanical alternans in cardiac arrhythmogenesis, its molecular origin is not well understood. In this talk we consider alternans associated to instabilities in the cytosolic calcium transient. Particularly, we study how a malfunction of the ryanodine receptor (RyR) recovery time from inactivation may induce beat-to-beat alternations in intracellular calcium concentration and how this could affect the stimulus propagation in inhomogeneous tissue, whose cells exhibit different calcium dynamics.

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MS17

Dynamically Generated Complex Spatiotemporal Patterns in Cardiac Tissue

Alternans of action potential duration has been associated with T-wave alternans and the development of arrhythmias because it produces large gradients of repolarization. However, little is known about alternans dynamics in large mammalian hearts. Using optical mapping to record electrical activations simultaneously from the epicardium and endocardium of large mammalian hearts, we demonstrate five novel arrhythmogenic complex spatiotemporal dynamics not previously observed.

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MS17

Mechanisms of Spatially Discordant Alternans

Spatially discordant alternans (SDA) occurs when the action potential duration (APD) of different regions of tissue alternate out-of-phase. This phenomenon is arrhythmogenic since it induces a heterogeneous distribution of refractoriness which can induce wave break. In this study we propose a novel mechanism to generate SDA which is due to the spatial heterogeneity of calcium (Ca) cycling within cells in cardiac tissue. This mechanism is robust and is likely to underlie a wide range of experimentally observed SDA patterns.

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MS17

Reduced Order Modeling of Cardiac Dynamics and Prediction of Alternans

We developed a reduced order model to describe spatiotemporal patterns of cardiac alternans. A statistical learning method based on the reduced order model was developed to predict the local spatial onset of alternans from time series of optical mapping data from the rabbit heart .

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MS18

Parameterization Methods for Computing Normally Hyperbolic Invariant Tori

We explain numerical algorithms for the computation of normally hyperbolic invariant manifolds and their invariant bundles, using the parameterization method. The framework leads to solving invariance equations, for which one uses a Newton method adapted to the dynamics and the geometry of the invariant manifolds. We illustrate the algorithms with several examples. The algorithms are inspired in current work with A. Haro and R. de la Llave.

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MS18

Trajectory Design in the Spatial Circular Restricted Three-Body Problem using Higher-Dimensional Poincaré Maps

The Circular Restricted Three-Body Problem (CR3BP) serves as a useful framework for preliminary trajectory design in a multi-body force environment; however, trajectory design, even in this simplified dynamical regime, is often nontrivial. The Poincaré map is a powerful tool that reduces the dimension of the problem and provides invaluable insight into the solution space. In the spatial problem, Poincaré maps must represent at least four states and are therefore challenging to visualize. In this investigation, a method to represent the information in higher-dimensional Poincaré maps is explored. These map representations are demonstrated to compute heteroclinic and homoclinic connections associated with libration point orbits, as well as to locate families of periodic orbits about the Moon and transfers to these orbits in the spatial problem.

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MS18

Computing Singularity-Free Paths on the Configuration Manifold for Closed-Chain Manipulators

In Robotics a mechanism may have singular configurations, for which local "velocity control" is not possible. At a singularity the mechanism "locks". In order to get the mechanism to move from one configuration to another controls must be chosen in a way that these singularities are avoided. I will describe an algorithm for computing singularity-free paths on the configuration manifold for Closed-Chain Manipulators. The algorithm uses higher-dimensional continuation techniques to explore the manifold using a type of shortest path algorithm, and barriers to avoid singularities.

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MS18

Computing Global Manifolds in the Lorenz System

The transition from simple to chaotic dynamics in the Lorenz system is organised by two global bifurcations: a homoclinic bifurcation of the origin and a heteroclinic connection between the origin and a saddle periodic orbit. This talk will demonstrate how the computation of two-dimensional stable manifolds as one-parameter families of orbit segments can be employed to understand the organization of phase space during this transition via preturbulence to the well-know chaotic Lorenz attractor.

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MS19

Integro-differential Equations in Epidemiology Explored via Delays

The sojourn time for diseases processes, e.g., recovery or immunity time, are often assumed to be exponentially distributed resulting in ODE based models. Consideration of more general sojourn-time distributions results in integro-differential equations (IDEs). We study IDEs as perturbations of ODEs or delay-differential equations. We use asymptotic methods and bifurcation theory developed for these latter problems to understand how the properties of the more general sojourn-time distributions affect the stabilty and properties of the IDE system dynamics.

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MS19

Networks with Multiple Connection Delays: Dynamical Properties, Scaling bBhaviour and Synchronisation Patterns

The dynamics of networks with delayed interactions have received much interest, as coupling delays play an important role in diverse systems as population dynamics, traffic, communication networks, genetic circuits, and the brain. In general the different interaction delays in a network are not equal, or may even differ by several orders of magnitude. Here, we consider a network of networks of chaotic units: the coupling delay within a subnetwork is much shorter than the delay between the subnetworks. We show that the spectrum of Lyapunov exponents has a hierarchical structure, with different parts of the spectrum scaling with the different delays. From the scaling properties of the maximal Lyapunov exponent, we can deduce the synchronisation properties of the network: units within a subnetwork can synchronise if the maximal exponent scales with the shorter delay, synchronisation between different subnetworks is only possible if the maximal exponent scales with the long delay.

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MS19

Delay- and Coupling-Induced Firing Patterns in Oscillatory Neural Loops

We investigate the emergence of stable spiking patterns in feed-forward loops of interacting neurons which are generic components of nervous systems. We show that such neural networks may possess a multitude of stable spiking patterns and provide explicit conditions for the communication delays and/or synaptic weights resulting in a desired pattern. It can be obtained by a modulation of the coexisting stable in-phase synchronized states or traveling waves propagating along or against the direction of coupling in the homogeneous network. We also show that the delays directly affect the time differences between spikes of interacting neurons, and the synaptic weights control the phase differences.

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MS19

Control of Desynchronization Transitions by the Balance of Excitatory and Inhibitory Coupling in Delay-Coupled Networks

We discuss multiple synchronization and desynchronization transitions in networks of delay-coupled excitable systems, which arise due to a change of the ratio of excitatory and inhibitory couplings. We use a generic model of type-I excitability for the local dynamics of the nodes. Utilising the method of the master stability function, we investigate the stability of the zero-lag synchronous dynamics and its dependence on coupling strength, delay time, and the relative number of inhibitory links.

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MS20

Extreme Events in Networks of Excitable Units

We investigate networks of excitable FitzHugh–Nagumo units that are capable of self-generating and -terminating extreme events at irregular times and without employing parameter changes, external input or stochasticity. We discuss dynamical properties and mechanisms that may be responsible for the generation and termination of these extreme events.

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MS20

The Dynamics of Two Coupled Excitable Units

Networks of excitable elements of FitzHugh Nagumo type exhibit high amplitude events which are recurrent on large time scales. To understand the mechanism of the generation of such events, we study two diffusively coupled, nonidentical FitzHugh Nagumo models. These rare spikes are found for a parameter range where the system is chaotic. This chaotic dynamics consists of small subthreshold oscillations with irregular spikes immersed. Possible mechanisms behind this "extreme" behavior of the system are discussed.

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MS20

Detecting Precursors of Bursting Dynamics in Simplified Neuronal Networks

Spiking dynamics of simplified neuronal networks exhibits complex patterns with transitions in and out synchronous bursting. We use integrate-and-fire networks with complex topologies to investigate dynamical precursors of transitions in and out of the bursting on the level of correlations of cellular groups. We compare spontaneous and evoked dynamics for excitatory only and mixed excitatory-and-inhibitory networks. We show distance dependent cluster formation and progressive homogeneity in neuronal dynamics just before the transition to synchronous bursting. These results may provide insights on dynamical correlates of seizure seizure onset in epileptic networks.

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MS21

Reduced Model of Internal Waves

Abstract not available at time of publication.

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MS21

Internal Waves in the Ocean: Theoretical Perspective

Abstract not available at time of publication.

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MS21

Internal Waves: Synthesis Between Theory and Observations

Abstract not available at time of publication.

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MS21

Hamiltonian Formalism for Internal Waves and Turbulence in Stratified Flows

Abstract not available at time of publication.

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MS22

From Bearings to Biscuits, Practical Applications of Nonsmooth Dynamics

Abstract not available at time of publication.

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MS22

Sustained Oscillations in a Nonsmooth Idealized Ocean Circulation Models

Stommel developed a model which captures the basic dynamics of thermohaline circulation but the model settles into a fixed mode of circulation under constant forcing. Saha modified a model by Colin de Verdière which exhibits oscillations in the strength of the circulation, however the model is analytically intractable. Changes in circulation are a possible trigger to rapid climate fluctuations known as Dansgaard-Oeschger events. The goal is to determine minimal conditions under which an ocean box model exhibits this qualitative behavior, and geometric singular perturbation theory is used to do so.

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MS22

Regularization and Singular Perturbation Techniques for Nonsmooth Systems

The purpose of this talk is to present some aspects of the qualitative-geometric theory of nonsmooth dynamical systems. We present a survey of the state of the art on the connection between the regularization process of non-smooth vector fields and singular perturbation problems. We focus on exploring the local behavior of systems around typical singularities.

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MS22

Dynamics of a Fast Slow Piecewise Smooth Conceptual Climate Model

A recent augmentation of Earth's temperature profile model includes a coupling with an ice line and a green house effect. The model could be reduced further to a two dimensional fast slow system on a subset of the plane. The resulting system is piecewise smooth with switches on the boundary. In this talk, I will briefly introduce a hybrid dynamical system arises from this climate model, discuss the wellposedness of the system and summarize the most recent advances on the stability analysis.

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MS23

Bifurcations in Symmetrically Coupled Devices

I will give an overview of recent bifurcation results in models of symmetrically coupled devices (lasers and gyroscopes). The lasers are delay-coupled and bifurcations are from a rotating wave. I will present some symmetry-breaking steady-state and Hopf bifurcations from the rotating wave. The symmetrically coupled network of gyroscopes has Hamiltonian structure and I will show how the bifurcation results persist under time-dependent and dissipative perturbations. This is joint work with J. Collera (lasers), A. Palacios and B. Chan (gyroscopes).

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MS23

Synchrony in Coupled Cell Networks

Coupled cell systems (CCS) are systems of ordinary differential equations associated with a network architecture – a finite set of nodes or cells and a finite number of arrows, representing individual dynamics and the interactions between the individuals, respectively. The network structure forces the existence of certain flow-invariant subspaces, defined in terms of equalities of certain cell coordinates (the synchrony subspaces) for all the associated CCS. We show how to obtain the lattice of synchrony subspaces of a network based on the eigenvalue structure of the network adjacency matrices and we present an algorithm that generates the lattice.

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MS23

Dynamics on Asynchronous Networks

For dynamicists, a network consists of interconnected dynamical systems (or "nodes"). Classical networks encountered in dynamics are synchronous: nodes all run on the same clock and connectivity is fixed. Biological networks, computer networks and distributed systems generally are asynchronous: nodes may run on different clocks, connectivity may vary in time and nodes may stop and start running. In this talk we describe and illustrate recent results about dynamics on asynchronous networks.

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MS24

Collaborative Tracking of Coherent Structures in

Flows by Robot Teams

Tracking Lagrangian coherent structures in dynamical systems is important for many applications such as oceanography and weather prediction. We present a collaborative robotic control strategy designed to track Lagrangian coherent structures without requiring global information about the dynamics. The collaborative tracking strategy is implemented on a team of three robots and relies solely on local sensing, prediction, and correction. We present simulation and experimental results and discuss theoretical guarantees of the collaborative tracking strategy.

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MS24

Lagrangian and Eulerian Indicators in a Model of the Chesapeake Bay

Numerical simulations and analysis of the Chesapeake Bay will be the focus of this presentation. Data from ROMS (Regional Ocean Model), specially modified for the Bay's bathymetry, geometry, and wind forcing, is analyzed. We will discuss the challenges associated with interpolating the data to acquire a velocity field to which we apply recent tools from dynamical systems to study the behavior of trajectories, transport and mixing, and coherence of structures. Our goal is to apply Lagrangian as well as Eulerian tools and indicators and discuss the strengths and weaknesses of each technique in the context of the Chesapeake Bay.

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MS24

LCS Based Detection of Key Ocean Transport Barriers: Advances and Applications

The detection of transport barriers in fluid flows has wide spread application, one example being the ability to improve predictions of the transport of pollution and debris in the ocean, which has been become a globally important topic over the past few years. For this purpose, we provide an overview of the LCS-based methodolgy for detecting key transport barriers within two-dimensional flows, describing some mathematical and practical improvements to existing methods. To demonstrate the utility of the approach, we apply this procedure to several different case real-world studies.

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MS24

Lagrangian Data Assimilation Within the Ocean: Subsurface Observations and Three Dimensional Models

A simple kinematic model of a wind-forced three dimensional ocean eddy can illuminate complex dynamics of the fluid flow. However, a kinematic model alone cannot hope to perfectly describe reality or the data one may collect. As such we propose modeling the difference between the kinematic model and data as a random function which we refer to as a bias. Once the random function is fit, we use the now bias-corrected kinematic model to explore the eddy dynamics.

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MS25

Rigorous Continuation of Solutions of Infinite Dimensional Nonlinear Problems

We present a rigorous numerical method to compute global smooth manifolds of solutions of infinite dimensional nonlinear problems. We use a parameter continuation method on a finite dimensional projection to construct a simplicial approximation of the manifold. This simplicial approxima-

tion is then used to construct local charts and an atlas of the global manifold in the infinite dimensional space. The idea behind the construction of the smooth charts is to use the so-called radii polynomials to verify the hypotheses of the uniform contraction principle on each simplex. The construction of the manifold is then finalized by proving smoothness along the common lower dimensional faces of adjacent simplices. The method is applied to compute one- and two-dimensional bifurcation manifold of equilibria and time periodic orbits for PDEs.

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MS25

Rigorous Computation of Connecting Orbits in Higher Dimensions

Abstract not available at time of publication.

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MS25

Rigorous Numerics for Nonlinear ODEs Using Chebyshev Series

We propose a rigorous numerical method to validate solutions of initial and boundary value problems for nonlinear ODEs. Our approach is based on the notion of Chebyshev expansions, an analogue of Fourier series for nonperiodic problems. We derive an equivalent problem on the infinite dimensional space of Chebyshev coefficents and compute rigorous error bounds for solutions to this problem. The method is illustrated with an application to connecting orbit problems in the Gray Scott System.

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MS25

Recent Advances in Rigorous Numerics for Periodic and Connecting Orbits

The past few decades have seen enormous advances in the development of computer assisted proofs in dynamics. For finite dimensional systems there have been stunning results. Attention is now turning to *infinite* dimensional nonlinear dynamics generated by PDEs, integral equations, delay equations, and infinite dimensional maps. In this talk we will review recent developments, such as the use Chebyshev polynomials to attack connecting orbit problems, as well as applications in the setting of spatio-temporal periodicity.

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MS26

An Iterative Method for the Canard Explosion in General Planar Systems

The canard explosion is the change of amplitude of a limit cycle in a narrow parameter interval. It is well understood in singular perturbation problems where a small parameter controls the slow/fast dynamics but also occurs in systems with no explicit small parameter. We show how the iterative method of Roussel and Fraser, devised to construct regular slow manifolds, can be used to determine a canard point in a general planar system.

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MS26

Inflection Methods for Singular Perturbation Problems

Inflection methods for dynamical systems rely on computing (analytically and/or numerically) the locus of points in the phase space where a solution curve has zero local curvature. In problems with multiple time scales, parts of these inflection sets approximate slow manifolds and, in the neuronal context, offer a tractable access to excitability thresholds. In this talk, I will review inflection techniques for slow-fast dynamical systems and present recent results on canards in ε-free systems investigated using these techniques.

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MS26

An Iterative Approach for the Computation of Canards and their Transients

The computation of canards in slow-fast systems using collocation methods is potentially hampered by the fact that the computational complexity increases with decreasing epsilon. Here we suggest a different approach that circumvents this issue. It is based on iterative methods for the computation of the slow manifold and approximations to the fiber projections that allow for a splitting of the system into non-stiff sub-systems. We present some convergence estimates and numerical results.

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MS26

Algorithmic Multiscale Reduction: Analysis, Chal-

lenges, Hits and Misses

Nonlinear multiscale reduction methods originated in the applied sciences a century ago. Their mathematical formalization proved invaluable but riddled them with an $\varepsilon \ll 1$, whose explicit identification is problematic for complex models. I will first present methods understandable within a simple differential geometric framework, outlining results and research opportunities. I will then consider a glycolysis model, show how inopportune applications of the classic QSSA method *reverse* system behavior and discuss QSSA robustness for large biochemical models.

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MS27
Identifiability and Parameter Estimation of Multiple Transmission Pathways in Disease

Waterborne diseases such as hepatitis A, cholera, and a wide range of other bacterial and viral diseases cause over 1.8 million deaths annually. These diseases often exhibit multiple pathways or timescales of transmission. In this talk I will discuss some of our recent work examining the identifiability, parameter estimation and dynamics of multiple transmission pathways in disease, including initial work examining how the structure of networks of connectivity for human and water movement affect disease dynamics.

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MS27
Mathematical Model of Infection by Genetically-Engineered Viruses to Induce An Anti-Cancer Immune Response

A new strategy for cancer treatment relies on using genetically-engineered viruses to infect and kill tumor cells and potentially induce an anti-tumor immune response. Recent experiments with engineered adenovirus have caused substantial reduction in growth rates of tumors in mice; however, the tumors always relapse. By fitting time series data to mathematical models, we attempt to elucidate underlying cancer-virus and cancer-immune dynamics and propose improved methods of treatment.

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MS27
The Impact of Vaccination and Transgenic Mosquitoes on the Evolution of the Dengue Virus

Dengue is a mosquito-borne viral pathogen that causes large amounts of disease in the tropics and sub-tropics. Two new interventions for dengue are currently in intense development: a vaccine that protects against all four serotypes and transgenic mosquitoes that are less-suitable vectors. We developed a mathematical model for evolution of dengue viruses in response to these new interventions. I will discuss results from the model, including interventions that would pose the least risk of selecting for more virulent dengue strains.

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MS27
A Perspective on Multiple Waves of Influenza Pandemics

A striking characteristic of the past four influenza pandemic outbreaks in the United States has been the multiple waves of infections. However, the mechanisms responsible for these waves are uncertain. In this talk several distinct mechanisms are exhibited each of which can generate two waves of infections for an acute infectious disease. Each is incorporated into a susceptible-exposed-infected-removed model. The models are used to examine the effects of border control and vaccination.

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MS28
Effects of Reduced Discrete Coupling on Filament Tension in Excitable Media

Wave propagation in the heart is mediated by discrete intercellular connections via gap junctions. Effects of discreteness on waves in two and three dimensions are explored. We study the effect of discrete cell coupling on the filament dynamics in a generic model of an excitable medium. We find that reduced cell coupling decreases the line tension of scroll wave filaments and may induce negative filament tension instability in three-dimensional excitable lattices.

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MS28

Dynamics of Scroll Filaments, and Buckling of Scrolls in Thin Media

Scroll wave turbulence occurs in excitable media with negative filament tension. In a thin layer, a scroll can be stabilized by “filament rigidity’. Above a critical thickness, scroll deforms into a buckled, precessing state. On the surface this is seen as spiral wave meandering, the amplitude of which grows with the layer thickness, until a break-up to the scroll turbulence happens. We present a simplified theory for this phenomenon and illustrate it with numerical examples.

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MS28

Low-energy Control of Electrical Turbulence in the Heart

Control of complex spatio-temporal dynamics underlying life-threatening cardiac arrhythmias is difficult, because of the nonlinear interaction of excitation waves in a heterogeneous anatomical substrate. We show that in response to a pulsed electric field, heterogeneities related to coronary vascular structure serve as nucleation sites for intramural electrical waves, which allow targeting of electrical turbulence near the cores of the vortices of electrical activity. Using this control strategy, we demonstrate low-energy termination of fibrillation *in vivo*.

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MS28

Filament Interaction and Self-Wrapping Filaments in An Excitable Reaction System

The three-dimensional Belousov-Zhabotinsky reaction self-organizes scroll waves that rotate around one-dimensional phase singularities called filaments. These filaments move with speeds proportional to their local curvature and filament loops shrink and annihilate in finite time (positive filament tension). Local pinning of the filament can affect this process and induce stable vortex patterns. In this talk I will discuss recent results on the pinning of filament loops to small unexcitable heterogeneities. Such configurations allow the investigation of filament interaction. In addition, I will present results on the self-wrapping of filaments around unexcitable cylinders with radii much smaller than the vortex wavelength. This self-wrapping reshapes the rotation backbone and wave field of the vortex profoundly. The relevance of these findings for cardiology are discussed. All experimental results are complemented by numerical simulations with a piece-wise linear reaction-diffusion model.

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MS29

Particle Size Segregation and Spontaneous Levee Formation in Geophysical Mass Flows

Hazardous geophysical mass flows, such as debris flows, pyroclastic flows and snow avalanches, often develop coarse particle rich levees that channelize the flow and enhance run-out. They are formed by large particles rising to the surface and being preferentially transported to the flow front, where they experience greater resistance to motion and are shouldered aside. A first attempt at modelling such segregation-mobility feedback effects is made using depth-averaged models.

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MS29

Analysis of a Dynamical Systems Model for Granular Flow

We describe an infinite-dimensional dynamical system (the BSR model) devised to study granular flows, but which has also proven effective in predicting general material interaction phenomena. After briefly treating the well-posedness of this system, we prove it is Hamiltonian for certain perfectly elastic interactions and present results on complete integrability. Finally, we show that the system can be reduced, in an approximate sense, to a finite-dimensional discrete dynamical system that yields information on chaotic transitions.

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MS29

Important Time Scales in the Dynamics of Granular Material

The state of granular media can be represented by a persistence diagram. This representation provides an interesting insight into the physical properties of the granular media as demonstrated on a system undergoing compression. Time evolution of the system can be seen as a curve in the space of persistence diagrams. Different notions of distance in this space provide a useful tool for understanding the dynamic. In particular the compressed systems (viewed as a discrete dynamical system) exhibit a few different regimes where dynamics changes from fast to slow. Dependence of the system on its previous state is strongly affected by the sampling rate. We conclude the talk by addressing the problem of determining the 'appropriate' sampling rate.

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MS29

Mixing by Cutting and Shuffling in 3D Granular Flow

We study chaotic dynamics of granular flow in a spherical tumbler rotating alternately about two orthogonal axes in the limit of an infinitely thin flowing layer. Mixing occurs through cutting and shuffling, is sensitive to the combination of rotation angles about each axis and can be reduced to dynamics on a hemispherical shell (2D). Poincare maps on this shell show patterns that include elliptic regions reminiscent of partitions generated by piecewise isometries (PWI).

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MS30

Network Structure and Predictive Dynamics of Brain Systems

The human brain is a network of cortical areas connected by structural or functional highways along which information propagates. Using non-invasive neuroimaging data, we show that brain network structure varies both over time and between individuals. We identify dynamic network properties that predict individual differences in cognitive behaviors such as learning. These results inform statistical approaches to predict individual brain responses to clinical interventions, potentially enabling personalized monitoring of disease progression and rehabilitation.

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MS30

Geometric Network Models of the Functional Connectome

Null network models, such as Erdos Renyi random graphs or random graphs with fixed degree distributions provide a foundation for modern network analyses, both in the design and evaluation of network metrics. In this talk we describe a class of null models which capture both geometry and degree distribution, while maintaining analytic tractability, and discuss several applications to the analysis of functional connectomes.

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MS30

Statistical Aspects of Diffusion Fiber Tracking

Abstract not available at time of publication.

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MS30

A Linear Model Based on Network Diffusion Predicts Functional Correlation Networks in the Brain from Structural Connectivity Networks

Abstract not available at time of publication.

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MS31

Exploiting Numerical Diffusion to Study Transport and Chaotic Mixing

In this talk I will demonstrate that the purely convective mapping matrix approach provides an extremely versatile tool to study advection-diffusion processes for extremely large Peclet values. This is made possible due to the coarse-grained approximation that introduces numerical diffusion, the intensity of which depends in a simple way on grid resolution. This observation permits to address fundamental physical issues associated with chaotic mixing in the presence of diffusion. Specifically, we show that in partially chaotic flows, the dominant decay exponent of the advection diffusion propagator will eventually decay as Pe to the power -1 in the presence of quasiperiodic regions of finite measure, no matter how small they are. Examples of 2d and 3d partially chaotic flows are discussed.

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MS31

Global Stability Design of Autonomous Time-continuous Systems

Given a stable non-linear system, one would like to compute its stability region. Often, the system depends on parameters, which should be tuned to shape this region according to one's needs. More generally, one would like to perform an efficient quantitative study of the global stable behavior of the system; and to optimize this. In this talk I introduce a fairly general framework for doing that by approximating the deterministic dynamics via a finite dimensional stochastic process. Translating the desired objectives in the terms of this process yields a simple computation and also the application of optimization algorithms. The probabilistic nature of the approximation enables an understanding beyond that what standard numerical analysis can offer. In particular, no trajectory simulation is needed during the computation. The main advantage of the method lies in the resulting numerical efficiency and the general applicability for a wide range of objectives.

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MS31

Transfer Operator Based Numerical Methods for Analysing Coherent Structures in Time-dependent Systems

After a short review of recent developments in transfer operator methods for studying finite-time transport, we will introduce a modified construction for characterizing Lagrangian coherent sets in nonautonomous dynamical systems. This approach takes into account both future and past information on the dynamics and is suited to tracking coherent sets over several finite-time intervals. We will explore in example systems how diffusion and finite-time duration influence the structures of interest.

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MS31

Identifying Topological Chaos Using Set-oriented Methods

The transfer operator eigenspectrum for a dynamical system can identify sets in (phase) space that remain nearly invariant (by some appropriate definition). A continuous, non-autonomous dynamical system such as a fluid flow can contain multiple distinct sets that move about one another in a non-trivial way. The topology of the set trajectories enables a classification of the global flow that includes quantification of the topological entropy. Viscous fluid examples will be discussed.

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MS32

Relating the Water Wave Pressure to its Surface Elevation

A new method is proposed to recover the water-wave surface elevation from pressure data obtained at the bottom of the fluid. The new method requires the numerical solution of a nonlocal nonlinear equation relating the pressure and the surface elevation which is obtained from the Euler formulation of the water-wave problem without approximation. From this new equation, a variety of different asymptotic formulas are derived. The nonlocal equation and the asymptotic formulas are compared with both numerical data and physical experiments.

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MS32

Solitary Waves on Water and Their Stability

The talk will discuss recent development on the existence and stability of two- and three-dimensional solitary waves on the surface of water with finite depth using various model equations or exact Euler equations. It was known that these equations have solitary-wave solutions and the stability of these waves in many problems is still open. Here, some stability results for these waves will be addressed, such as transverse instability, conditional stability or asymptotic linear and spectral stability.

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MS32

A Dimension-breaking Phenomenon for Steady Water Waves with Weak Surface Tension

I will discuss the bifurcation of three-dimensional periodically modulated solitary waves from two-dimensional line solitary waves in the presence of weak surface tension. The new waves decay in the direction of propagation and are periodic in the transverse direction. The proof is based on spatial-dynamics and an infinite-dimensional version of the Lyapunov centre theorem. The method also reveals that the line solitary waves are linearly unstable to transverse perturbations.

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MS32

Quasi-periodic Perturbations of Time-periodic Water Waves

We develop a high-performance shooting algorithm to compute new families of time-periodic and quasi-periodic solutions of the free-surface Euler equations involving breathers, traveling-standing waves, and collisions of solitary waves of various types. The wave amplitudes are too large to be well-approximated by weakly nonlinear theory, yet we often observe behavior that resembles elastic collisions of solitons in integrable model equations. A Floquet analysis shows that many of the new solutions are stable to harmonic perturbations.

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MS33

The Curse of Dimensionality for the Border Collision Normal Form

I will discuss the dynamics of higher dimensional border collision bifurcations, showing that there exist parameters for which the n-dimensional normal form has attractors that cannot exist in the (n-1)-dimensional version. These results also have implications for grazing-sliding bifurcations of continuous time systems. This is joint work with Mike Jeffrey (University of Bristol).

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MS33

The Uncertainties of Nonsmooth Dynamics

A discontinuity in a set of differential equations generally leads to infinitely many possible solutions. Why, then, has Filippov's 'sliding' solution been successful in studying everything from stick-slip dynamics to electrical switching? We show that an idealized mathematical model with discontinuities has infinitely many solutions, but that by assuming a lack of exact knowledge of the system, Filippov's solution becomes valid, and one can quantify the balance of modelling errors for which this remains true.

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MS33

Singular Dynamics in Gene Network Models

Gene regulatory networks are commonly modeled by steep/step sigmoid interactions which leads to difficulties when the gene expressions are close to their thresholds. A method to analyze this situation is the framework based on singular perturbation techniques. We present 3-dimensional examples that do not fit the classical singular perturbation theory. We therefore suggest a generalization of the classical singular perturbation techniques that is based on the Artstein theory of dynamic limits of the fast flow.

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MS33

Singular Matching Near a Visible Fold-regular Point: Asymptotics of the Return Map

We combine geometric singular perturbation theory with matching perturbation methods to study the local map of near-grazing solutions at the boundary between crossing and sliding dynamics, in the smoothing of a Filippov-type nonsmooth dynamical system. We show that the Lipchitz constant is of order $O(\varepsilon^{\alpha})$, $\alpha > 0$, in terms of the singular perturbation parameter ε. The value of α depends on the smoothness of the function regularizing the discontinuity. The persistence of periodic orbits is discussed.

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MS34

Linearization Theorems and Koopman Operator

Spectrum

The spectrum of Koopman operator describes the change of distributions in the phase space and is crucial for a global analysis of system properties from a measure theoretic point of view. We present a new way of analyzing this spectrum based on linearization of nonlinear systems in its basin of attraction.

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MS34
Isochrons and Isostables of Dynamical Systems: Relationship to Koopman Operator Spectrum

The spectral properties of the Koopman operator are related to the well-known isochrons of limit cycles. This observation yields an efficient method to compute the isochrons in high-dimensional spaces and provides a new perspective to extend this notion to nonperiodic systems (e.g. quasiperiodic tori). For a stable fixed point, the isochrons are defined through the same framework and complemented with the so-called isostables required for the (action-angle) reduction of the dynamics.

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MS34
Koopman Operator Methods: An Overview

Koopman (or composition) operator is a linear infinite-dimensional operator that can be defined for any nonlinear dynamical system. The linear operator retains the full information of the nonlinear state-space dynamics. The formalism based on Koopman operator representation holds promise for extension of dynamical systems methods to systems in high-dimensional spaces as well as hybrid systems, with a mix of smooth and discontinuous dynamics. Recently, Koopman operator properties have been intensely studied, and applications pursued in fields as diverse as fluid mechanics and power grid dynamics. We will overview the current status of Koopman operator methods in dynamical systems and their applications.

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MS34
Koopman Operator Methods in Fluid Mechanics

We study coherent structures in fluid flows using analysis of the Koopman operator. Given a vector of observables for a dynamical system (for instance, flow information in a particular region of space), one may determine a corresponding set of "Koopman modes," which are the coefficients in an expansion in Koopman eigenfunctions. These modes may be extracted from data using Dynamic Mode Decomposition, a variant of the Arnoldi algorithm, and elucidate coherent structures in the flow.

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MS35
Approximate Deconvolution Large Eddy Simulation of the Quasi-Geostrophic Equations of the Ocean

This talk introduces a new approximate deconvolution closure modeling strategy for the quasi-geostrophic equations modeling the large scale oceanic flows. The new large eddy simulation model is successfully tested in the numerical simulation of the wind-driven circulation in a shallow ocean basin, a standard prototype of more realistic ocean dynamics. This first step in the numerical assessment of the new model shows that approximate deconvolution could represent a viable alternative to standard eddy viscosity parameterizations in the large eddy simulation of more realistic turbulent geophysical flows.

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MS35
Approximate Deconvolution Models for LES of Atmospheric Boundary Layer Flows

Atmospheric boundary layer flows exhibit a range of turbulent conditions over the course of a diurnal cycle. Our interest is in approximate deconvolution method algorithms for subfilter-scale closures in large-eddy simulation to better represent intermittent turbulence and to facilitate flow transitions across mesh refinement boundaries. The explicit filtering and reconstruction approach allows generation of intermittent turbulence even under strong nighttime stratification and improves representation of appropriate scales as the flow transitions across grid nesting interfaces.

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MS35
Modeling Error in Approximate Deconvolution Models

We investigate the asymptotic behaviour of the modeling error in approximate deconvolution model in the 3D periodic case, when the order N of deconvolution goes to infinity. We consider successively the generalised Helmholz filters of order p and the Gaussian filter. For Helmholz filters, we estimate the rate of convergence to zero thanks to energy budgets, Gronwall's Lemma and sharp inequalities about Fouriers coefficients of the residual stress. We next show why the same analysis does not allow to conclude convergence to zero of the error modeling in the case of Gaussian filter, leaving open issues.

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MS35

Unconditionally Stable and Optimally Accurate Timestepping Methods for Approximate Deconvolution Models

We address an open question of how to devise numerical schemes for approximate deconvolution models that are efficient, unconditionally stable, and optimally accurate. We propose, analyze and test a scheme for these models that has each of these properties. There are several important components to the derivation, both at the continuous and discrete levels, which allow for these properties to hold. The proofs of unconditional stability and optimal convergence are carried out through the use of a special choice of test function and some technical estimates. Numerical tests are also provided.

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MS36

Response of the Sea Ice Seasonal Cycle to Climate Change

The Northern Hemisphere sea ice cover has diminished rapidly in recent years and is projected to continue to diminish in the future. The year-to-year retreat is faster in summer than winter, which has been identified as one of the most striking features of satellite observations as well as of IPCC model projections. This is typically understood to imply that the sea ice cover is most sensitive to climate forcing in summertime. However, in the Southern Hemisphere it is the wintertime sea ice cover that retreats fastest in IPCC model projections. Here, we address the seasonal structure of observed and simulated sea ice retreat in both hemispheres. We propose a physical theory that primarily involves the shape of coastlines and eddy heat fluxes in the atmosphere. We demonstrate that the theory accurately describes a wide range of climates simulated with a hierarchy of models ranging from an idealized ffatmosphere-sea ice model to a state-of-the-art coupled GCM.

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MS36

Multiple Sea Ice States and Hysteresis in Simple and Complex Climate Models: Why the Oceans Matter

Sea ice exerts a positive radiative feedback which can give rise to multiple equilibria and hysteresis in the climate system. Climate simulations with a coupled atmosphere-ocean-sea ice general circulation model that permit at least four different stable states ranging from warm ice-free conditions to 100% ice cover, all of which are consistent with present-day greenhouse gas and solar radiation. The interaction between sea ice and ocean heat transport provides key constraints on the number and type of possible equilibria, as well as governing many aspects of the transient adjustment between stable states. I will discuss how this interaction is misrepresented in many simple climate models, and how to fix it. Finally I will discuss implications of multiple equilibria in past climate change, including Snowball Earth and the last ice age.

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MS36

Reversibility of Arctic Sea Ice Retreat - A Conceptual Multi-scale Modeling Approach

A lattice-type thermodynamic complex systems model for the ice-albedo feedback is introduced that includes the basic physics of ice-water phase transition, a nonlinear diffusive energy transport in a possibly heterogeneous ice-ocean layer, and spatiotemporal atmospheric and oceanic drives. At the local scale the model reveals bistability in sea ice loss. At the regional scale, however, hysteresis in sea ice retreat is structurally not stable.

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MS36

On the Existence of Stable Seasonally Varying Arctic Sea Ice in Simple Models

Within the framework of lower order thermodynamic theories for the climatic evolution of Arctic sea ice we isolate the conditions required for the existence of stable seasonally-varying solutions, in which ice forms each winter and melts away each summer. We construct a two-season model from the continuously evolving theory of Eisenman and Wettlaufer (2009) and showing that seasonally-varying states are unstable under constant annual average short-wave radiative forcing. However, dividing the summer season into an ice covered and ice free interval provides sufficient freedom to stabilize seasonal ice. The condition for stability is determined viz., when the ice vanishes in summer and hence the relative magnitudes of the summer heat flux over the ocean versus over the ice. Finally, a new stochastic perturbation theory is developed for the original non-autonomous continuously varying model and its moments are analyzed in light of observations.

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MS37

Understanding Homoclinic Bifurcations via the Computation of Global Invariant Manifolds

In three-dimensional vector fields, if the one-dimensional unstable manifold of a saddle equilibrium lies on its two-dimensional stable manifold, then a homoclinic orbit exists. Typically, breaking the homoclinic orbit leads to a

rearrangement of these invariant manifolds and a reorganization of the overall dynamics in phase space. We show how the computation of global two-dimensional invariant manifolds helps us to understand their role as separatrices and basin boundaries near several codimension-one and -two homoclinic bifurcations.

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MS37

Global Bifurcations Lead to Bursting in a Two-Mode Laser

We present an unusual bursting mechanism in a two-mode semiconductor laser with single-mode optical injection. By tuning the strength and frequency of the injected light we find a transition from purely single-mode intensity oscillations to bursting in the intensity of the uninjected mode. We explain this phenomenon on the basis of a simple two-dimensional dynamical system, and show that the bursting in our experiment is organised by global bifurcations of limit cycles.

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MS37

Interacting Invariant Sets in a Noninvertible Planar Map Model of Wild Chaos

We study a noninvertible planar map that is a model for wild Lorenz-like chaos in a five-dimensional vector field. We are concerned with the transition to wild chaos via the interaction between the stable and unstable sets of a saddle fixed point and the critical set of the map, which consists of the images and preimages of the critical point. These interactions correspond to homo- and heteroclinic bifurcations in the underlying vector field.

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MS37

Global Bifurcations in a Non-Invertible Model of Asset Pricing

We introduce a canonical form for a standard model of asset pricing. The resulting (non-invertible) two-dimensional dynamical system depends on two parameters only, a rate of geometric decay and a mean reversion parameter. We detect parameter regimes for which homoclinic and heteroclinic orbits exist and illustrate corresponding intersections of stable and unstable sets. Finally, autocorrelations of prices and returns before and after these global bifurcations are discussed.

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MS38

The Topology of Non-Linear Global Carbon Dynamics: From Tipping Points to Planetary Boundaries

In this talk, I will present a minimal model of land use and carbon cycle dynamics and explores the relationship between nonlinear dynamics and planetary boundaries. Only the most basic interactions between land cover, terrestrial carbon stocks and atmospheric carbon stocks are considered. The goal is not to predict global carbon dynamics as it occurs in the actual earth system, but rather, to construct a conceptually reasonable representation of a feedback system between different carbon stores like that of the actual earth system and use it to explore the topology of the boundaries of what can be called a safe operating space for humans. The analysis of the model illustrates the potential complexity of planetary boundaries and highlights some challenges associated with navigating them.

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MS38

Forecasting the Truth with a Cleverly Inflated Ensemble

Predictions of the future state of the Earth's atmosphere are typically based on a collection of numerical simulations whose variance represents the forecast uncertainty. Inspired by techniques from shadowing theory, we develop a novel method for improving forecasts during integration of a weather model. The algorithm involves injecting artificial uncertainty into the forecast, but only in directions of state space experiencing contraction in the form of negative local Lyapunov exponents.

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MS38
Dynamical Systems and Planet Earth

This overview talk will introduce the audience to various applications of dynamical systems in climate science. The emphasis will be on a system-level approach, where the Earth's climate system is viewed as a complex system and manifestations of collective behavior are more important than details of the internal dynamics. Topics to be presented include energy balance models, ocean circulation models, oscillatory networks and teleconnections, Lorenz models, biogeochemical processes, and the carbon cycle.

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MS38
Tipping Points: Overview and Challenges

Mathematical mechanisms for tipping points will be introduced, starting with the conceptual framework of bifurcation theory, and then highlighting some of the challenges and limitations of exploiting this framework for problems arising in applications. Parts of the discussion will be developed in the setting of case studies of possible tipping points in models of (1) Arctic sea-ice retreat, and (2) desertification.

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MS38
Exploring the Decision-support Component of MPE Questions

One of the ways that climate and sustainability applications differ from other applications of dynamical systems is their close connection with decision-making and policy. We will explore how a decision-support viewpoint may inspire new dynamical questions.

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MS39
Ionic Dynamics Mediate Pattern Generation in Epilepsy

Many types of epileptic seizures involve repetitive periods of tonic spiking and bursting activity. We found that the changes of the intracellular and extracellular ion concentrations can have profound effects on the network dynamics and may be responsible for the characteristic patterns of electrical activity observed during seizures. Our results will likely have implications onto drug development and deepen our understanding of the origin of seizures.

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MS39
The Impact of Network Structure on Criticality in Cortical Circuits

Cortical circuits have been hypothesized to operate near a critical point for optimality. Previous evidence supporting this came from bulk signals that did not show individual neuron activity. Using a 512 electrode array, we recorded hundreds of spiking neurons and found two main things: (1) Avalanche shapes can be collapsed onto a universal scaling function, a key indicator of criticality; (2) The network structure of effective connections strongly influences the critical exponents of the system.

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MS39
From Neuron Dynamics to Network Plasticity

Spatiotemporal dynamics in neural networks depends on two factors: dynamical properties of individual neurons and characteristics of network connectivity. In the brain, however, these two factors vary dynamically and are intertwined in a highly complex way. Through simulations of large-scale spiking neuron network models, we will discuss how heterogeneity in network structure, heterogeneity in cellular excitability and plasticity of synaptic connectivity interact to collectively influence network spatiotemporal dynamics.

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MS39

Distributed Control in Mean-field Cortical Network Models

Brain stimulation has been proposed to control pathological neuronal activity during seizure. Such activity can be viewed as a network event that begins with or without a clear spatial focus and spreads through a cortical network. This talk will assess distributed control, envisioned as grids of local stimulating electrodes, in this scenario through the use of mean-field neuronal network models. The control efficacy as a function of topology and connection dynamics will be shown.

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MS39

Performance Limitations of Thalamic Relay: New Insights into Thalamo-Cortical Processing, Parkinson's Disease and Deep Brain Stimulation

Humans have the remarkable ability to selectively process sensory information. In the motor system, we select which muscles to turn on and off during movement. In this talk, we describe how and when selective processing occurs in a thalamic cell. We compute bounds on thalamic relay reliability that explain observed patterns of neural activity in the basal ganglia in (i) health (ii) in Parkinsons disease (PD), and (iii) in PD during therapeutic deep brain stimulation.

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MS40

Collision of a Flexible Filament with a Point Vortex

I will first review vortex methods for flows coupled to deforming flexible filaments, which can serve as models for fish bodies, fins, and other immersed structures. I will then focus on the attraction between a flexible filament is attracted to a point vortex when they move together as a coupled system. The point vortex collides with the filament at a finite time. I will explain the power laws describing the collision.

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MS40

Improving Vortex Models for Agile Bio-inspired Flight via Optimal Control Theory

We formulate a constrained minimization problem which allows us to relax the usual edge regularity conditions of point vortex models in favor of empirical determination of vortex strengths. The strengths are determined by minimizing the error with respect to empirical force data, while vortex positions are allowed to evolve freely. We show that, for a flat plate undergoing various maneuvers, the optimized model leads to force predictions remarkably close to empirical data.

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MS40

Dipole Interactions in Doubly-periodic Domains

We consider the interactions of finite dipoles in a doubly-periodic domain as a model that captures the "far-field hydrodynamic interactions in fish schools. A finite dipole is a pair of equal and opposite strength point vortices separated by a finite distance. We examine the dynamic evolutions of single dipoles and dipole pairs per box and focus on the stability of two families of relative equilibria: rectangular (1 dipole/box) and diamond (2 dipoles/box). We conclude by commenting on the insights these models offer in the context of fish schooling.

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MS40

Vortex Dipoles

Point vortices of opposite strength propagate at a constant speed proportional to the inverse of their separation. Hence a straightforward Matched Asymptotic Expansion approach struggles to produce the appropriate equations for the motion of a vortex dipole, that is a singularity one order higher than a point vortex. We review vortex dipoles, including this limiting process, and also study quasi-analytic solutions for dipoles with viscosity.

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MS40

Numerical Study of Viscous Starting Flow Past Flat Plates

Viscous flow past a finite plate of zero thickness moving normal to itself with velocity $U = U_0 t^p$ is investigated numerically, using a high order finite difference method. The simulations resolve detailed features of the flow, including the singular nature of the starting flow, and the dependence of various quantities on the Reynolds number and the parameter p describing the plate motion. The results provide a basis of comparison to evaluate simpler inviscid models for flow separation.

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MS41

Perturbed Restricted Few-Body Problems and their Applications

This talk will present recent advances in the analysis of orbital dynamics in restricted two, three and four body problems perturbed by a conservative force. In particular, we consider the orbital dynamics of a continuous low thrust spacecraft and the inhomogeneous gravitational field of a celestial body. Novel orbits including displaced non-Keplerian and frozen orbits are iden- tified and applications to future Earth and asteroid observation missions are presented. The analytical and numerical tools used to study these different classes of orbits are described.

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MS41

Spacecraft Transfer Trajectory Design Exploiting Resonant Orbits and Manifolds in Multi-Body Regimes

The application of dynamical systems techniques to trajectory design has demonstrated that leveraging invariant manifolds and resonant orbits expand the trajectory design options. Transfer trajectories between two- and three-dimensional resonant orbits are explored in a three-body system via Poincar mapping tech- niques. Incorporating strategic maneuvers, trajectories that support various mission scenarios can be constructed.

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MS41

Dynamics in Astronomical and Astrodynamical Problems

In this talk it will be shown how modern techniques of the Dynamical Systems field are able to provide tools to explain in a natural way different astronomical patterns as well as to simplify and make more systematic mission analysis.

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MS41

Constant Sun Angle Solar Sail Trajectories

The natural trajectories of spacecraft with solar sails that are maintained at constant angles to their sun lines are described. The six dimensional equations of motion are reduced to a two dimensional hodograph equation for the motion in the instantaneous orbital plane. This drives another two dimensional equation for the motion of the orbital plane itself. All possible tra- jectories are classified, and potential applications to trajectory design are described.

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MS41

Attainable Sets, Fast Numerical Approximation of Invariant Manifolds and Applications

The paper presents the attainable sets, i.e., admissible low-thrust trajectories and the approximation of invariant manifolds with fast numerical methods based on splines. These features are used in the preliminary design of transfer trajectories defined in a typi- cal three-body problem. Each feature provides a trajectory that is based on a reduced number of parameters, so that transfer trajectories can be found by matching the corresponding parameters of the different trajectory arcs. Examples are provided with reference to transfer between Libration point orbits.

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MS42

Epidemics Dynamics in a City: A Network Model

and Season Variations

We are considering a model for dengue epidemics spreading in a densely populated town, where people move daily from one neighborhood to another. For this purpose we consider a network generalization of SIR model with and without birth and death. We are particularly interested in understanding how the geometry of the network, its homogeneity or non homogeneity, the flux of people and a possible seasonal periodicity of climate have an effect in the occurrence of an epidemics. [Bacaer and Gomez, "On the final size of epidemics with seasonality', Bulletin of Mathematical Biology, 71 : 1954-1966 (2009); Howard Weiss, "A Mathematical Introduction to Population Dynamics', IMPA (2009); Lucas Stolerman, Master thesis, "Um Modelo em Rede para a dinamica de uma epidemia em uma cidade' (2012); Horst R. Thieme, Mathematics in Population Biology, Princeton (2003)]

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MS42
Branching Process Models for HIV and SIV Infection

Differential equation models for HIV and SIV infection are of questionable validity when the numbers of a player in the model (virus or infected cell) are small. We have worked on branching process models for very early infection and successfully treated infection. Although direct simulation is always an option, analytic or mixed methods are often possible. I will summarize our progress and outline directions for future work.

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MS42
Modeling Dengue Fever: Recent Developments

Dengue is the most significant mosquito-borne viral infection of humans, causing 50-100 million infections annually. The main line of attack against dengue has been traditional mosquito control measures, such as insecticides. The coming years will see the broadening of our anti-dengue arsenal to include genetically-modified mosquitoes, biocontrol methods such as *Wolbachia*, and vaccines. In this talk, I will discuss mathematical modeling that is being used to help design dengue control efforts using one, or a combination, of these methods.

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MS42
Sharing Infectious-Disease Risk Across Communities

In recent research, we have combined economic theory and population biology, and explored how the interactions of biology and management dynamics can alter the nature of social planning choices, and predicting the emergence of policy-resistance or policy-reinforcement. These theoretical advances, however, have relied on strong-mixing assumptions. But in many situations, financial, spatial, and social heterogeneities which make the problem of policy design much more vexing. In this talk, I'll present some of our recent research on the influences of heterogeneity on the stability of management practices across a spectrum of scales.

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MS43
Curvature-Dependent Excitation Propagation in Cultured Cardiac Tissue

Excitation front bent above critical value may cease to propagate and give origin to re-entry. We found that in cardiac tissue culture with normal excitation, neither narrow isthmuses nor sharp corners of obstacles affect wave propagation. Curvature related propagation block and wave detachment from obstacles observed only after Lidocaine partial suppression of sodium channels. Computer simulations confirmed experimental observations. That is non-inhibited single cells keep excite neighbors irrespective of curvature radii smaller than cardiomyocyte size.

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MS43
Asymptotic Dynamics of Spiral and Scroll Waves in a Mathematical Model of Ischaemic Border Zone

We use asymptotics based on response functions to predict dynamics of re-entrant excitation waves in a moving boundary of a recovering ischaemic cardiac tissue, due to gradients of cell excitability and cell-to-cell coupling, and heterogeneity of individual cells. In three spatial dimensions, theory predicts conditions for scroll waves to escape into the recovered tissue, where they are either collapse or develop fibrillation-like state, depending on filament tension. We confirm these predictions by direct simulations.

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MS43
Dynamics of Spiral Waves on Non-Uniformly Curved Anisotropic Surfaces

Spiral waves in two-dimensional excitable media have been observed to drift according to shape of the surface, as well as due to the anisotropy within the surface. We present a unified mathematical description to these effects using the equivalence of an anisotropic excitable medium to a Riemannian manifold. The resulting equation of motion for the spirals rotation center allows to determine trajectories and the position of attractors for spiral waves on the surface. The results are applicable to thin layers of electrically active cardiac tissue.

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MS43
Mechanisms of Low Energy Fibrillation Termination in the Cardiac Muscle. Role of Pinned Vortices

We found that the mechanism explaining the experiment [1]: Nature 475, 235-239, 2011 is termination of vortices pinned to local heterogeneities in the heart. During electric field pulses, a pinning center is effectively a stimulating electrode situated exactly in the vortex core. A vortex is terminated when an electric field pulse is delivered during the 'critical time interval'.

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MS44
Anomalous Diffusion in Granular Flow: Fractional Kinetics or Intermediate Asymptotics?

Granular materials do not perform Brownian motion, yet diffusion is observed because flow causes inelastic collisions between particles. Experiments suggest that this process might be "anomalous" in the sense that the mean squared displacement of particles follows a power law in time with exponent less than unity. We show that such a "paradox" can be resolved using intermediate asymptotics. We derive the instantaneous scaling exponent of a macroscopic concentration profile as a function of the initial distribution. Then, by allowing for concentration-dependent diffusivity, we show crossover from an anomalous scaling (consistent with experiments) to a normal scaling at long times.

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MS44
Molecular Dynamics Based Calculation of the Coefficient of Restitution in Collision between Two Identical Nanoscale Grains

The Coefficient of Restitution (COR) is a useful phenomenological concept for describing the interaction of macroscopic bodies. However, little is known about the detailed microscopic processes. We investigate the COR between nanoscale particles of various sizes composed of face-centered cubic (fcc) Lennard-Jones (L-J) atoms via nonequilibrium molecular dynamics simulations. We find that above a critical collision velocity the COR $\sim v^{-1.03}$ weakly dependent on the amount or kind of deformation. We find that the critical collision velocity is a function of the particle size and approaches a continuum theoretical value for fcc L-J solid in the limit of large sphere radius.

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MS44
Visualization of the Dynamics of Granular Flow Models

We will present some recent results from our ongoing research on the effective visualization and structural analysis of granular flows. Our work focuses primarily on the study of both computational simulation and dynamical systems modeling of granular systems undergoing tapping boundary constraints. We show that an approach leveraging traditional concepts from dynamical systems such as invariant manifolds and attractors but also graph theoretical concepts can reveal interesting properties from such systems and offer new insights into their behavior.

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MS44
Analysis and Simulation of the BSR Model

The BSR model is an integro-partial differential equation

developed to predict granular flows. Using techniques similar to those employed for the Boltzmann-Enskog equation, we prove that under fairly general assumptions, the BSR model has a unique global solution that depends continuously on auxiliary conditions. Our proofs inspired the creation of a semi-discrete numerical scheme for obtaining approximate solutions of the BSR model, which was used to produce the results of simulations that will be presented.

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MS45

On the Approximation of Transport Phenomena in Ocean Dynamics

Over the last years so-called *set oriented numerical methods* have been developed for the numerical treatment of dynamical systems. We will show how to make use of such techniques for the approximation of *transport processes*. These play an important role in many real world applications, and we will focus on transport phenomena in ocean dynamics. Here the underlying mathematical models depend explicitly on time which makes the numerical analysis inherently more complicated.

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MS45

Dynamic Programming Using Radial Basis Functions

We approximate the optimal value function and the associated optimal feedback of general nonlinear discrete-time optimal control problems by a radial basis function approach. Questions like stability, accuracy and efficiency as well as code complexity are discussed and demonstrated by selected numerical experiments.

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MS45

Anticorrelated Sampling Techniques for Variance-reduced Simulation of Markov Processes

Accurate stochastic simulation benefits from reduction of sampling variance and, consequently, computational cost. We extend classical variance reduction techniques (antithetic and stratified sampling) for application to continuous-time Markov jump processes. Our algorithms introduce localized anticorrelation between samples to reduce variance in mean estimates, and apply to both exact SSA and approximate tau-leaping simulation methods. Significant reductions in computational cost are achievable for linear and nonlinear systems, as demonstrated by analytical results and numerical examples.

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MS45

Weighted Particle Methods for Atmospheric Aerosol Simulation

We present a new time-evolution scheme for generating realizations of Markov jump processes for particle systems, which can efficiently simulate highly multiscale particle distributions and disparate event rates. Multiscale particle distributions are represented as weighted point samples, and time evolution occurs using a binned tau-leaping scheme with approximate rate sampling. A convergence proof is given as well as numerical examples of applications to atmospheric aerosol particle simulation.

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MS46

Mathematical Modeling of Nanofluids: Properties and Applications in the Renewable Energy and Biomediacal Field

Nanofluids are colloids containing a liquid phase, (usually water or ethylene), and nanoparticles (usually gold or oxides) or nanotubes (usually carbon nanotubes) with diameter below 100 nm. Classical models fail to accurately describe their thermal conductivity (depending on nanoparticles concentration), and thus their behavior; novel models are being proposed. In this talk we present some results (analytical and numerical), towards applications of nanofluids in the renewable energy and biomedical field

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MS46

The Mathematical Modelling and Numerical Simulation of Organic Photovoltaic Devices

We present some recent results and ongoing work on drift-diffusion-reaction systems modelling organic photovoltaic devices. While classical semiconductors show recombination typically throughout the whole device feature organic photovoltaic devices significant charge generation only in the very proximity of an interface between two different organic polymers. We discuss basic questions of modelling, existence and stationary states. Moreover, we present some interesting asymptotic approximations and discuss the use of entropy.

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MS46

Solar Updraft Towers for High Latitudes

This presentation is concerned with the modelling and simulation of solar updraft towers with sloped collector fields in higher latitudes. The main idea is to study if the reduction of the solar power (per aerea) at higher latitudes can be compensated by a special non-planar collector of the power plant. For this the gas dynamics in the collector and in the chimney of the power plant has to be described. I comes out that this is a typical low Mach number flow and therefore an appropriate low Mach number asymptotics leads to a resonable reduced model. This limit model is going to be simulated. Comparisons with planar power plants and with estimates of the power output from the literature are presented.

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MS46

Renewable Energy Incentive Schemes: Performance Comparison Using Optimal Control

To meet renewable energy targets, many governments have instituted incentive schemes for renewable electricity producers that aim to boost growth in renewable energy industries. Our work examines four such schemes; we present a generalised mathematical model of industry growth, and fit the model with data from the UK onshore wind industry. We consider the optimization of the quantity and timing of subsidy through each scheme, and conclude by comparing their relative performance.

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MS47

On the Existence and Stability of Solitary-wave Solutions to a Class of Evolution Equations of Whitham Type

We consider a class of pseudodifferential evolution equations of the form $u_t + (n(u) + Lu)_x = 0$, in which L is a linear smoothing operator and n is at least quadratic near the origin; this class includes the Whitham equation. Solitary-wave solutions are found using constrained minimisation and concentration-compactness methods. The solitary waves are approximated by the corresponding solutions to partial differential equations arising as weakly nonlinear approximations; in the case of the Whitham equation the approximation is the Korteweg-deVries equation. The family of solitary-wave solutions is shown to be conditionally energetically stable.

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MS47

Existence and Conditional Energetic Stability of Solitary Gravity-capillary Water Waves with Constant Vorticity

We present an existence and stability theory for gravity-capillary solitary waves with constant vorticity on the surface of a body of water of finite depth. Exploiting a classical variational principle, we prove the existence of a minimiser of the wave energy $\mathcal{E}$ subject to the constraint $\mathcal{I} = 2\mu$, where $\mathcal{I}$ is the wave momentum and $0 < \mu \ll 1$. Since $\mathcal{E}$ and $\mathcal{I}$ are both conserved quantities a standard argument asserts the stability of the set D_μ of minimisers: solutions starting near D_μ remain close to D_μ in a suitably defined energy space over their interval of existence. In the applied mathematics literature solitary water waves of the present kind are modelled as solutions of the long-wave equations of KdV or NLS type. We show that the waves detected by our variational method converge (after an appropriate rescaling) to solutions of the appropriate model equation as $\mu \downarrow 0$.

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MS47
On the Benjamin-Feir Instability

I will speak on the Benjamin-Feir (or sideband) instability of Stokes waves on deep water. I will begin by describing the variational framework that I recently developed with Bronski to determine an instability under long wavelengths perturbations for abstract Hamiltonian systems. I will explain the asymptotic approach that Johnson and I adapted for Whitham's water wave model, deriving a dispersion relation for the modulational instability. I will discuss on the exact water wave problem, if time permits.

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MS47
Large-amplitude Solitary Water Waves with Vorticity

We provide the first construction of exact solitary waves of large amplitude with an arbitrary distribution of vorticity. We use continuation to construct a global connected set of symmetric solitary waves of elevation, whose profiles decrease monotonically on either side of a central crest. This generalizes the classical result of Amick and Toland.

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MS48
Shearless Elliptic LCS, Shearless Cantori and non-local heat transport

We present a notion of shearless barriers in unsteady flows and a method for their accurate detection. This complements recent work on hyperbolic and shear transport barriers by G. Haller and F.J. Beron-Vera. We then discuss how shearless Cantori act as partial barriers for heat transport in magnetically confined plasma. We investigate the slow relaxation of heat across the Cantori and the strong non-locality of the relaxation process.

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MS48
Onset of Shearless Tori in Twist Maps

Secondary shearless tori were analytically predicted for generic maps in the neighborhood of the tripling bifurcation of elliptic fixed points. For the twist standard map, we use numerical profiles of the internal rotation number to identify the onset of secondary shearless tori around elliptic fixed points within islands of stability. Moreover, we use the proposed procedure to find shearless tori in a map describing chaotic magnetic field lines escape in tokamaks.

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MS48
Annular Billiard Dynamics in a Circularly Polarized Laser Field

We model the dynamics of a valence electron of buckminsterfullerene C_{60} subjected to a circularly polarized laser by the motion of a charged particle in an annular billiard. Its phase space is composed by three distinct types of trajectories: whispering gallery orbits which hit only the outer wall; daisy orbits which hit both walls; and "pringle orbits" that only visit the downfield part of the billiard. This robust separation is attributed to the existence of twistless tori.

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MS48
Breakup of Shearless Tori in Multi-harmonic Area-preserving Nontwist Maps

I will discuss recent work on the breakup of shearless invariant tori in multi-harmonic nontwist maps, in particular in a two-harmonic, three-parameter map. The breakup threshold is determined using Greene's residue criterion. I will report on the effect of map symmetry on torus breakup, reconnection studies, and the comparison with

a two-harmonic twist map.

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MS49

Conductance Fluctuations in Graphene Systems: The Relevance of Classical Dynamics

Conductance fluctuations associated with transport through quantum-dot systems are currently understood to depend on the nature of the corresponding classical dynamics, i.e., integrable or chaotic. However, we find that in graphene quantum-dot systems, when a magnetic field is present, signatures of classical dynamics can disappear and universal scaling behaviours emerge. In particular, as the Fermi energy or the magnetic flux is varied, both regular oscillations and random fluctuations in the conductance can occur, with alternating transitions between the two. By carrying out a detailed analysis of two types of integrable (hexagonal and square) and one type of chaotic (stadium) graphene dot system, we uncover a universal scaling law among the critical Fermi energy, the critical magnetic flux, and the dot size. We develop a physical theory based on the emergence of edge states and the evolution of Landau levels to understand these experimentally testable behaviours.

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MS49

Complex Paths for Regular-to-chaotic Tunneling Rates

For generic non-integrable systems we show that a semiclassical prediction of tunneling rates between regular and chaotic phase-space regions is possible. Our prediction is based on complex paths which can be constructed despite the obstacle of natural boundaries. The tunneling rates are shown to have excellent agreement to numerical rates for the standard map where few complex paths dominate. This gives a semiclassical foundation of the long-conjectured and often observed exponential scaling with Planck's constant of regular-to-chaotic tunneling rates.

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MS49

Application of Chaos in Harnessing Quantum Systems: Modulating Quantum Transport by Transient Chaos

We propose a scheme to modulate quantum transport in nanostructures based on classical chaos. By applying external gate voltage to generate a classically forbidden region, transient chaos can be generated and the escape rate associated with the underlying non-attracting chaotic set can be varied continuously by adjusting the gate voltage. We demonstrate that this can effectively modulate the quantum conductance-fluctuation patterns. A theory based on self-energies and the spectrum of the generalized non-Hermitian Hamiltonian of the open quantum system is developed to understand the modulation mechanism. This is joint work with Ryan Yang (ASU), Liang Huang (ASU), Louis M. Pecora (NRL), and Celso Grebogi (Univ. Aberdeen, UK).

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MS49

Conductances and Electron Interactions in Regular and Chaotic Quantum Dots

Transmission of electrons through quantum dots leads to interesting conductance effects in devices. Quantum dot conductance depends on the tunneling barriers to the dots and the wave functions in the dot. We developed a theory of conductance through quantum dots including electron-electron interactions. We examined regular and chaotic dot geometries. The distribution of conductances varies often by several orders of magnitude with the dot geometry with chaotic dots having much lower fluctuations than regular dots.

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MS50

The Entropy-Viscosity Method For Hydrodynamic Models

The entropy-viscosity technique is a new class of high-order numerical methods for approximating scalar conservation laws which have recently been adapted as a numerical regularization for the Navier-Stokes equations. A nonlinear, LES-type viscosity is based on the numerical entropy residual, causing the numerical dissipation to become large in the regions of (numerical) shock, and small in the regions where the solution remains smooth. This method applies to systems with one or more entropy inequalities and is easy to implement on a large variety of meshes and polynomial approximations. I will discuss this method as a numerical regularization for the Navier-Stokes equations, along with related regularizations and applications to other equations if time permits.

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MS50

Spectral Scaling of the NS-α and Leray-α Model for Two Dimensional Turbulence

Viewed from the Large Eddy Simulation point of view, the α turbulence models modify the nonlinearity in the NSE, which adaptively filters the high wavenumbers and thereby enhances the stability and regularity without affecting the low wavenumber behavior. One important aspect to investigate is the spectral scaling transition from the observed Kolmogorov (for three-dimensional flows) or Kraichnan (for two-dimensional flows) power laws in the sub-α scales. The spectral scaling roll-off behavior for wavenumbers representing scales smaller than the lengthscale α has important implications for the computational performance of the particular α model and especially in its resolution requirements. In this talk I will show how one can establish the characteristic timescale of an eddy of size less than the filter width α and hence the scaling of the energy spectrum in the sub-α scales for 2D turbulence.

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MS50

Large-eddy Simulation for Lattice Boltzmann Models

Lattice Boltzmann methods receive a growing intetest in the field of Computational Fluid Dynamics, for both theoretical and engineering purposes. The closure of the LB equations for turbulent flow simulations in the LES framework will be discussed. A interesting point is that the nonlinearities exhibit an exponential form, instead of the usual quadratic form in Navier-Stokes equations

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MS50

Reduced-order Modeling of Complex Flows

In many scientific and engineering applications of complex flows such as the flow control and optimization problem, computational efficiency is of paramount importance. Thus, model reduction techniques are frequently used. To achieve a balance between the low computational cost required by a reduced-order model and the complexity of the target turbulent flows, appropriate closure modeling strategies need to be employed. In this talk, we present reduced-order modeling strategies synthesizing ideas originating from proper orthogonal decomposition and large eddy simulation, develop rigorous error estimates and design efficient algorithms for the new reduced-order models.

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MS51

Coarse-grained Bifurcation Analysis in Agent Based Bodels: Lifting Using Weights

We discuss lifting and restriction operators in coarse-grained bifurcation analysis for Agent-Based Models. We will introduce a new lifting strategy, based on weighted realisations, which requires the solution of a minimisation problem at each continuation step, allowing an accurate estimation of Jacobian-vector products and optimal convergence of the underlying Newton-GMRES solver. We apply the new lifting strategy to a model of opinion formation, interpreting globally-polarised states in terms of a coarse pitchfork bifurcation.

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MS51

Numerical Methods for Stochastic Travelling Waves

Abstract not available at time of publication.

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MS51

Some New Numerical Methods for Stochastic Des and Pdes

We seek numerical methods for second-order stochastic differential equations that accurately reproduce the stationary distribution for all values of damping. A complete analysis is possible for linear second-order equations (damped harmonic oscillators with noise), where the statistics are Gaussian and can be calculated exactly in the continuous-time and discrete-time cases. The "reverse leapfrog" method has remarkably good properties in the postion variable. The analysis permits the construction of new family of explicit partitioned Runge-Kutta methods whose accuracy coverges to that of the implicit midpoint method with increasing number of stages. New methods are illustrated on double-well SDEs and SPDEs.

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MS51

The String Method for the Study of Rare Events

Many problems in applied sciences can be abstractly formulated as a system that navigates over a complex energy landscape of high or infinite dimensions. Well known examples include nucleation events during phase transitions, conformational changes of bio-molecules, chemical reactions, etc. The system is confined in metastable states for long times before making transitions from one metastable state to another. The disparity of time scales makes the study of the transition event a very challenging task. In this talk, we will discuss the string method for the study of complex energy landscapes and rare events.

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MS52

Instability of Travelling Waves in a Singular Chemotaxis Model

The parabolic Keller-Segel model is a strongly coupled system which describes the directed movement of cells towards the gradient of a chemical (chemotaxis). We show existence and nonlinear instability of travelling waves in the case when the coupling in the highest order terms is singular. To handle the resulting unbounded terms in the equations for a perturbed wave we work in exponentially weighted function spaces.

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MS52

Pattern Formation in Unstable Media in Binary Fluids

We discuss about pattern formation and its asymptotic behaviour of convective patterns in binary fluid flow. When the conductive state is unstable and the size of the domain is large enough, finitely many spatially localized time-periodic travelling pulses (PTPs), each containing a certain number of convection cells, are generated spontaneously in the conductive state and are finally arranged at nonuniform intervals while moving in the same direction. Strong interactions (collision) among PTPs are important in characterizing the asymptotic state.

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MS52

Breathers in Singularly Perturbed Reaction-diffusion Systems

The existence of stationary pulses can be established for a general class of two-component, singularly perturbed systems of reaction-diffusion equations. Their (linear) stability is analyzed using Evans function techniques. For the most general setting, a number of instability results are presented; detailed analysis of the bifurcation structure is shown in the context of an explicit example. Here, one can even go beyond the linear analysis; using center manifold reduction and normal form theory, the nonlinear pulse stability is explored; the latter is inspired by some striking numerical results.

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MS52

Stochastic Reaction and Diffusion on Growing Domains: Understanding the Breakdown of Robust Pattern Formation

Many deterministic mathematical models have been proposed to account for the emergence of complexity. However, deterministic systems can often be highly sensitive to changes in initial conditions, domain geometry, etc. Due to this sensitivity, we seek to understand the effects of stochasticity and growth on paradigm biological patterning models. We do this by using spatial Fourier analysis and growing domain mapping techniques to encompass stochastic Turing systems.

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MS53

Beyond the Neural Master Equation

We present a stochastic model of neural population dynamics in the form of a velocity jump Markov process. The population synaptic variables evolve according to piecewise deterministic dynamics, which depends on population spiking activity. The latter is characterized by a set of discrete stochastic variables evolving according to a jump Markov process, with transition rates that depend on the synaptic variables. We consider the particular problem of rare transitions between metastable states of a network operating in a bistable regime in the deterministic limit. Assuming that the synaptic dynamics is much slower than the transitions between discrete spiking states, we use a WKB approximation and singular perturbation theory to determine the mean first passage time to cross the separatrix between the two metastable states. Such an analysis can also be applied to other velocity jump Markov processes, such as stochastic ion channel gating and gene networks.

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MS53

Effective Stochastic Behavior in Dynamical Systems with Incomplete Information

Complex systems are generally analytically intractable and difficult to simulate. We introduce a method for deriving an effective stochastic equation for a high-dimensional deterministic dynamical system for which some portion of the configuration is not precisely specified. We use a response function path integral to construct an equivalent distribution for the stochastic dynamics from the distribution of the incomplete information. We apply this method to the Kuramoto model of coupled oscillators to derive an effective stochastic equation for a single oscillator interacting with a bath of oscillators and also outline the procedure for other systems.

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MS53

The Impact of Architecture on Higher Order Statistics of Network Dynamics

How does network architecture impact the level of synchronized spiking activity in a recurrent network? We show that for a range of network architectures, average pairwise correlation coefficients can be closely approximated using only three statistics of network connectivity: the connection probability, and the frequencies of two second order motifs. We also discuss how relation between higher order statistics of network dynamics and connectivity.

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MS53

Capturing Effective Neuronal Dynamics in Random Networks with Complex Topologies

We introduce a random network model in which one can prescribe the frequency of second order edge motifs. We derive effective equations for the activity of spiking neuron models coupled via such networks. A key consequence of the motif-induced edge correlations is that one cannot derive closed equations for the average activity of the nodes (the average firing rate of neurons) but instead must develop the equations in terms of the average activity of the edges (the synaptic drives). As a result, the network topology increases the dimension of the effective dynamics and allows for a larger repertoire of behavior. We demonstrate this behavior through simulations of spiking neuronal networks.

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MS54

Termination of Reentrant Cardiac Action Potential Propagation Using Far-Field Electrical Pacing

Previously, we demonstrated that there exist patterns of weak electric field stimuli that can terminate fibrillation in the heart, when fibrillation is modeled as multiple action potential waves circulating around one-dimensional rings. In the present work, we extend our fibrillation model to the case of multiple spiral waves. If this approach is successful, it could lead to new, low-energy defibrillation protocols that cause less harm and trauma to patients when applied.

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MS54

Spiral Waves and the Onset of Labor in Pregnant Uterus

The spontaneous appearance of uterine contractions shortly before labor is not yet fully understood. Particularly surprising is the fact that none of the uterine cells is spontaneously oscillating, when taken in isolation. The strong increase of the gap junction expression before delivery strongly suggests a prominent role of the coupling. I will discuss models of excitable cells, coupled to passive cells. In finite tissues, fast spiral waves of electrical activity are spontaneously observed. I will discuss their role, in relation with the generation of force necessary for mechanical contraction.

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MS54

Anchoring of Spirals

Anchoring of spiral and scroll waves in excitable media has attracted considerable interest in the context of cardiac arrhythmias. Here, by bombarding inclusions with drifting spiral and scroll waves, we explore the forces exerted by inclusions onto an approaching spiral and derive the equations of motion governing spiral dynamics in the vicinity of inclusion. We demonstrate that these forces nonmonotonically depend on distance and can lead to complex behavior: (a) anchoring to small but circumnavigating larger inclusions; (b) chirality-dependent anchoring.

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MS54

Selection of Spiral Waves in Excitable Media with

a Phase Wave at the Wave Back

A free-boundary approach is elaborated to derive universal relationships between the medium excitability the parameters of a rigidly rotating spiral wave in excitable media, where the wave front is a trigger wave and the wave back is a phase wave. Two universal limits restricting the existence domain of spiral waves in the parameter space are demonstrated. The predictions of the free-boundary approach are in good quantitative agreement with results from numerical reaction-diffusion simulations.

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MS55
Population Scale Physiologic Measurement, Dynamics, Prediction, and Control

In this talk I will discuss various methodologies for deriving and explaining data-driven physiologic signals derived from clinically collected physiologic data and some of the results that these methodologies have generated. The particular results will be primarily related to endocrine (e.g., glucose/insulin) and neurophysiologic dynamics. The methodologies range from signal processing, information theory and nonlinear time series analysis to mechanistic physiologic modeling that hints at potential applications of data assimilation and control theory.

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MS55
Capturing Intermittent and Low-frequency Variability in High-dimensional Data through Nonlinear Laplacian Spectral Analysis

Nonlinear Laplacian spectral analysis (NLSA) is a method for spatiotemporal analysis of high-dimensional data, which represents spatial and temporal patterns through singular value decomposition of a family of maps acting on scalar functions on the nonlinear data manifold. Through the use of orthogonal basis functions (determined by means of graph Laplace-Beltrami eigenfunction algorithms) and time-lagged embedding, NLSA captures intermittency, rare events, and other nonlinear dynamical features which are not accessible through classical linear approaches such as singular spectrum analysis. We present applications of NLSA to detection of decadal and intermittent variability in the North Pacific sector of comprehensive climate models, and multiscale physical modes of the Madden-Julian Oscillation in infrared brightness temperature satellite data.

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MS55
Data Assimilation of Biological Dynamics

We have successfully applied a Data Assimilation (UKF) framework centered on the Unscented Kalman Filter (UKF) to track and reconstruct dynamics from biologically-inspired models of both sleep regulation and of glucose. Tools weve implemented include a ranked assessment of observability, optimization of UKF covariance inflator, parameter estimation and tracking. The next steps to apply to read data streams are to address how to differentiate between models to best observe real systems.

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MS55
Random Dynamics from Time Series: An Overview in Relation to Noise-induced Phenomena

Interaction between deterministic chaos and stochastic randomness has been an important problem in nonlinear dynamical systems studies. Noise-induced phe- nomena are understood as drastic change of natural invariant densities by adding external noise to a deterministic dynamical systems, resulting qualitative transition of observed nonlinear phenomena. Stochastic resonance, noise-induced synchronization, and noise-induced chaos are typical examples. The simplest mathematical model for these phenomena is one-dimensional map stochastically perturbed by noise. In this presentation, we discuss typical behavior of noised dynamical systems based on numerically observed noise-induced phenomena. Applications of these phenomenologies to time-series analysis are also exhibited.

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MS56
New Developments in Evans Function Computation and Shock Layer Stability

We examine some our latest techniques in Evans function computation and apply them to problems in compressible fluid flow. Specifically, we describe a new way to locate and track roots of the Evans function and apply them to problems in combustion. We also describe some of our latest results in the computation of viscous shock layers in compressible Navier-Stokes and other related models. Finally, we discuss some recent changes to our numerical STABLAB toolbox.

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MS56

The Morse and Maslov Indices for Matrix Hill's Equations

For Hill's equations with matrix valued periodic potential, we discuss relations between the Morse index, counting the number of unstable eigenvalues, and the Maslov index, counting the number of signed intersections of a path in the space of Lagrangian planes with a fixed plane. We adapt to the one dimensional periodic setting the strategy of a recent paper by J. Deng and C. Jones relating the Morse and Maslov indices for multidimensional elliptic eigenvalue problems.

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MS56

Coherent Structures in a Model for Mussel-algae Interaction

We consider a model for formation of mussel beds on soft sediments. The model consists of coupled nonlinear pdes that describe the interaction of mussel biomass on the sediment with algae in the water layer overlying the mussel bed. Both the diffusion and the advection matrices in the system are singular. We use Geometric Singular Perturbation Theory to capture nonlinear mechanisms of pattern and wave formation in this system.

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MS56

Linear Stability and Instability of Water Waves

In this talk, I will discuss linear stability and instability regions for several water-wave models such as the Benney-Luke equation and the Klein-Gordon periodic waves. The results take advantage of the abstract stability criteria developed recently to compute the threshold speed of the stable waves when explicit solutions are known. In cases when explicit formulas for the waves are not available, we compute the stability regions numerically.

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MS57

Microscale Granular Crystals and Surface Acoustic Waves

Granular crystals are densely packed arrays of elastic particles that interact nonlinearly via Hertzian contact. Studies have demonstrated myriad nonlinear dynamical phenomena to occur in granular crystals, and shown how such phenomena can be utilized in acoustic engineering applications. Thus far, granular crystals are generally macroscopic, and affect sonic-frequency acoustic waves. In this work, we study the interaction of surface acoustic waves (with frequencies in the hundreds of MHz), with two-dimensional microscale granular crystals.

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MS57

On the Existence of Breathers in Periodic Media: An Approach via Inverse Spectral Theory

The concept of breathers, i.e. time-periodic, spatially localized excitations, has been introduced in the context of the Sine-Gordon equation, which, however, seems to be the only (constant coefficient) nonlinear wave equation to support such solutions. In this sense, breathers have been considered a rare phenomenon. Surprisingly, a nonlinear wave equation with spatially periodic step potentials has been found recently to support breathers (Blank et al. 2011) by using a combination of spatial dynamics, center manifold reduction and bifurcation theory. Via inverse spectral theory, we aim towards characterizing a larger class of potentials that allow breathers. The research is motivated by the quest of using photonic crystals as optical storage.

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MS57

Multi-dimensional Stability of Travelling Waves through Rectangular Lattices

We consider general reaction diffusion systems posed on rectangular lattices in two or more spatial dimensions. We show that travelling wave solutions to such systems that propagate in rational directions are nonlinearly stable under small perturbations. We employ recently developed techniques involving point-wise Green's functions estimates for functional differential equations of mixed type (MFDEs), allowing our results to be applied even in situations where comparison principles are not available.

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MS57

Macroscopic Analysis of Traveling Waves in Microscopic Traffic Models

The traffic jam dynamics of a microscopic model is analyzed on a macroscopic level, i.e., for characteristic low-dimensional quantities, using an implicit equation-free approach. These methods are used to analyze the qualitative system behaviour by coarse bifurcation diagrams. The transitions from free flow to different traffic jam regimes, i.e., traveling waves on the ring road, are investigated, including one pulse and two pulse solutions.

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MS58

Melnikov Theory for Planar Hybrid Systems: Invariant Cones in Piecewise Linear Systems

We extend the Melnikov theory to a class of two-zonal planar hybrid piecewise smooth systems. In these systems, each zone of differentiability is separated by a straight line. When an orbit reaches the separation line then a reset map applies before entering the orbit in the other zone. By using Melnikov functions we analyze the existence of limit cycles. The results will be applied to the study of invariant cones in 3D piecewise linear systems.

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MS58

On the Splitting of Heteroclinic Manifolds in Coupled Systems with Impacts

In this work we consider two coupled impact systems obtained by a generalization of the model of the rocking block. After introducing a general perturbation, which includes both the coupling and an external periodic forcing, we extend Melnikov's method to this type of system to provide conditions for the persistence of heteroclinic manifolds. We also study properties regarding the energy accumulated along trajectories located in these manifolds.

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MS58

Application of the Subharmonic Melnikov Method to Piecewise Smooth Systems

We extend a refined version of the subharmonic Melnikov method to piecewise-smooth systems and demonstrate the theory for bi- and trilinear oscillators. Fundamental results for approximating solutions of piecewise-smooth systems by those of smooth systems are given and used to obtain the main result. Special attention is paid to degenerate resonance behavior, and analytical results are illustrated by numerical ones. Further results on perturbation approaches for piecewise-smooth systems will also be announced.

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MS59

Memory Effects of Inertial Particles in Chaotic Advection

We study the effect of the history force in the von Kármán flow, a paradigmatic model flow of chaotic advection. We find strong qualitative changes in the dynamics induced by the history force. Attractors are typically suppressed and more generally we find a weaker tendency for accumulation and for caustics formation. Furthermore the Lyapunov exponent increases with the history force and the escape rates are strongly altered.

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MS59

The Influence of the History Force on the Motion of Inertial Particles in Chaotic Advection: Gravi-

tational Effects and Horizontal Diffusion

In this work we analyze the effect of the Basset force on the sedimentation of inertial particles in a two-dimensional convection flow. When the memory effects are neglected, the system's dynamics exhibits periodic, quasi-periodic and chaotic attractors. With the history force we find that the attractors and their basins of attraction are drastically altered. We also highlight the strong influence of memory on the horizontal transport and vertical trapping of the particles.

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MS59

Memory Effects in Chaotic Advection and Snapshot Attractors

The presence of the history force in the Maxey-Riley equations makes the equation of motion to be an integro-differential equation. Viewed from the usual phase space of inertial particles, the dynamics is non-autonomous. After a short overview of recent results, we concentrate on the problem of how, say, periodic attractors can emerge in such systems. In the general theory of driven, time-dependent dissipative systems, an emerging tool is that of the so-called snapshot (or pullback) attractors. Such an attractor is the instantaneous location, in the phase space, of the elements of an ensemble of trajectories initiated in the remote past. To any single snapshot attractor there belongs a unique natural distribution that typically changes with time. This concept has been proven to be useful in climate models. We claim it to be also applicable to the problem of particle advection with history force. In the traditional single particle picture, a periodic attractor is reached after a power-law decay, while the convergence to the (still slowly moving) snapshot attractor is exponentially fast.

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MS60

Randomized Algorithms for Very Large-Scale Linear Algebra

Low-rank matrix approximations, such as partial spectral decompositions, play a central role in data analysis and scientific computing. The talk will describe a set of recently developed randomized algorithms for computing such approximations. These techniques exploit modern computational architectures more fully than classical methods and open the possibility of dealing with truly massive matrices. The algorithms described are supported by a rigorous mathematical analysis that exploits recent work in random matrix theory.

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MS60

The Dynamic Mode Decomposition: Extensions and Variations

Dynamic mode decomposition (DMD) represents an effective means for capturing the essential features of numerically or experimentally generated flow fields. We will discuss various extensions of and variations on the standard algorithms to promote sparsity by combining tools and ideas from linear algebra, convex optimization and compressive sensing. Several examples of flow fields resulting from simulations and experiments are used to illustrate the effctiveness of the developed method.

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MS60

Data-driven Modeling Approach for Olfaction Dynamics

In this talk I will introduce a data-driven approach for the combination of dynamical systems and data-reduction for neural networks. The approach is particularly relevant to neurobiological networks that underlie sensory systems, e.g., olfaction, for which neural activity is recorded while actual sensory modality is being processed. Specifically, we will show how to construct the network wiring, i.e., connectivity and dynamics, from the data via a reduced model.

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MS60

Dynamic Mode Decomposition with Sub-Nyquist-Rate Data Samples

Dynamic mode decomposition (DMD) is an increasingly popular tool for identifying oscillatory structures in fluid flows. However, it requires time-resolved data, which are often impossible to capture experimentally. We present a new algorithm that can identify temporally oscillatory structures from sub-Nyquist rate data. This is accomplished using compressed sensing, taking advantage of the sparsity observed in many flows. As a proof of concept, we apply our method to experimental data from a bluff body wake.

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MS61

Energy Exchanges in Embedded Granular Media

We discuss experimentally energy exchange phenomena in coupled granular chains embedded in poly-di-methyl-siloxane (PDMS) matrix. Specifically, we consider two rows of chains embedded in PDMS matrix and show that in spite of the fact that applied impulse is provided to one chain, the resulting pulse gets partially transferred to neighboring chain and energy distributes among the granular network. Based on the experimental measurements we validate a theoretical model and then use it for predictive design.

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MS61

Long Lived Solitary Waves in a 1D Granular Chain

Kinetic energy fluctuations of a non-dissipative 1D granular chain held between reflecting walls with various precompressions are investigated. The dynamics is explored for a weakly precompressed chain which admits only solitary waves that break into secondary waves under wall collisions, for a strongly precompressed chain which exhibits acoustic waves, and for intermediate precompression. The last case accommodates a nearly stable solitary wave that travels unaffected through the acoustic waves for extremely long times.

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MS61

Nonlinear Wave Propagation in the Arrays of Coupled Granular Chains

Dynamics of granular scalar models comprising the array of the arbitrary number of weakly coupled granular chains subject to on-site perturbations is considered. Analytical procedure depicting the transmission of strongly nonlinear, localized pulses through the granular array is developed. Results of analytical model and numerical simulations are found to be in a spectacular correspondence. Effect of on-site perturbations on the primary pulse transmission and redirection in the general scalar model is discussed.

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MS61

Existence of Bell-shaped Traveling Waves in Monomer Chains with Precompression

In a series of joint works with P. Kevrekidis, we show the existence and bell-shapedness of traveling waves for monomer chains. The novelty is the bell-shapedness of the waves, which is achieved by recasting as an equivalent constrained maximization problem, where we constraint over the unit spheres of certain Orlicz spaces. We will also mention some open problems (and possible approaches) like uniqueness and stability of these waves.

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MS62

Modeling Early Events in HIV Infection

In order to prevent and/or control infections it is necessary to understand their early-time dynamics. However this is precisely the phase of HIV about which the least is known. To investigate the initial stages of HIV within-host we have developed multi-type, continuous-time branching process models. We will present these models and discuss predictions pertinent to clinical factors associated with HIV such as per-exposure risk of infection and post-exposure time to infection detection.

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MS62

SIV Infection Dynamics in Macaques After Interruption of Intensified Treatment

HIV infection is well controlled by anti-retroviral drug therapy (ART) but virus persists and viremia returns upon treatment cessation. Recent studies on SIV infected monkeys showed a complete suppression of viral load during intensified ART. After treatment stopped, occasional viral blips occur but the viral load always returns to undetectable levels. We used models based on continuous-time branching processes to study the viral blips and make inferences about the re-activation dynamics of latently infected cells.

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MS62

A Branching Process Model of Prion Dynamics

Prions are infectious agents composed of misfolded proteins, responsible for illnesses such as mad cow disease in cattle and Creutzfeldt-Jakob disease in humans. We create a branching process model for yeast cells to describe how prions grow inside the cell and how they are transmitted from mother to daughter cell. We compare our model predictions to laboratory data and use it to estimate unknown parameters.

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MS62

Brisk Introduction to Branching Processes with a Model of Gene Expression

I will provide a very brief overview of what branching processes are and what they are useful for modelling. I will then discuss one novel application to the phenomenon of

gene expression with diffusion in the cellular environment. The latter is joint work with David Cottrell and Peter Swain.

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MS63

Fatigue Accumulation Under Chaotic Loading is Slower than Under Statistically and Spectrally Similar Stochastic Excitation

New fatigue testing apparatus was used to show different rates of fatigue damage accumulation under chaotic and stochastic loading, even when both excitations possess same spectral and statistical signatures. Furthermore, the conventional rainfall method considerably overestimates damage in case of chaotic forcing. Important nonlinear loading characteristics, which can explain the observed discrepancies, are identified and suggested to be included as loading parameters in new fatigue models.

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MS63

Localized Spikes and Flats on the Surface of Magnetic Liquids

An experimental model for formation of spatially localized states in dissipative systems is a layer of viscous magnetic liquid subjected to a magnetic field oriented normally to the fluid surface. When the field passes a critical threshold, a hexagonal pattern of liquid spikes emerges. Localized spikes and flats were generated and studied experimentally and numerically. In contrast to spikes, the location of flats is arrested by the hexagonal pattern.

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MS63

Bifurcation Analysis in a Mechanical Impact Oscillator Experiment

We use control-based continuation to obtain one-parameter bifurcation diagrams (e.g. frequency response) directly from an experiment of a periodically forced impact oscillator. Branches of periodic solutions, including unstable ones, are traced by applying a feedback control and using a predictor-corrector type path-following algorithm. The experimental findings are reproduced by a piecewise-linear model. It is smoothed to determine its bifurcation structure and the effect of the smoothening is investigated.

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MS63

Control of Nonlinear Lateral Dynamics in a Rotor-Stator System

In this combined experimental and numerical effort, a rotor contained within a stator is studied. An excitation input with high frequency content is superimposed on the motor rotation input provided to the rotor-stator system to examine how the lateral motions of the rotor can be steered among different solutions of the system, which include forward whirling solutions without rotor contact and forward and backward whirling solutions with contact.

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MS64

Collective Effects and Cascading Dynamics for Systems Defined on Complex Networks

Dynamical systems defined on networks have applications in many scientific fields. In particular, it is important to understand when networks exhibit synchronous or other types of coherent collective behaviors. Other questions include whether such coherent behavior is stable with respect to random perturbation, or what the detailed structure of this behavior is as it evolves. We will examine several prototypical models of networked dynamical systems and present a mixture of results that range from rigorous theorems for abstract models to quantitative comparisons of models and data.

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MS64

Reliable and Unreliable Behavior in Balanced Spik-

ing Networks

This talk concerns the reliability of networks of excitable neurons driven by sustained, fluctuating stimuli. Reliability here means that a signal elicits essentially identical responses upon repeated presentations, regardless of the network's initial condition; it is of interest in computational neuroscience because the degree to which a network is reliable constrains its ability to encode information in temporal spike patterns. Using a combination of qualitative theoretical ideas and numerical simulations, we have studied the dynamics of networks of excitable neurons with balanced excitatory and inhibitory connections. I will report our main findings, including the coexistence of unreliable and reliable dynamics in time and within the network, and (time permitting) how the correlation structure of the stimulus and intrinsic network dynamics together affect the reliability of a network. Qualitative explanations are proposed for the phenomena observed.

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MS64

Spike-based Coding in Chaotic Neural Networks

Large, randomly coupled networks of excitatory and inhibitory neurons are ubiquitous in neuroscience, and are known to autonomously produce chaotic dynamics. This produces an obvious threat to the reliability of network responses: if the same signal is presented many times with different initial conditions, there is no guarantee that the system will entrain to the signal in a repeatable way. However, we find that intermittent periods of highly reliable spiking nevertheless occur in the networks at hand. We give a geometrical explanation, and discuss the consequences for encoding and decoding of model sensory signals.

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MS64

Maximized Reliability Despite Maximized Variability in Sensory Cortex

An identical sensory stimulus presented many times does not typically evoke identical responses among neurons in sensory cortex. It is commonly thought that such variability of response is detrimental to reliable encoding of sensory information. Studying rat cortex slice cultures, we demonstrate that variability need not come at the cost of reliability. Pharmacologically tuning excitability of the cortical network we found that maximum reliability and variability emerge together under the same conditions at criticality.

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MS65

Defibrillation Mechanisms on a One-dimensional Ring of Cardiac Tissue

In this paper we compare quantitatively the efficiency of three different defibrillation protocols commonly used in commercial defibrillators. We have built a simplified one-dimensional model of cardiac tissue using the bidomain formulation that is the standard model for describing cardiac tissue. With this model, we have shown that biphasic defibrillators are significantly more efficient (about 25 percents) than the corresponding monophasic defibrillators. We identify that the increase in efficiency of the biphasic defibrillators is rooted in the higher proportion of excited tissue at high electric fields.

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MS65

Mechanisms of Ventricular Arrhythmias

Complex behavior in the heart often is associated with electrical abnormalities called arrhythmias that lead to compromised mechanical function. Such complexity includes dynamics typical of excitable and oscillatory systems, including period-2 (and higher-order) behavior along with single and multiple spiral or scroll waves. In many cases, dynamical instabilities either produce or exacerbate arrhythmias. In this talk, we use mathematical modeling and numerical simulation to elucidate mechanisms that can initiate and maintain cardiac arrhythmias.

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MS65

Cardiac Arrhythmia Prediction Using a 1D Dynamical Model

A nonlinear mathematical model of a cardiac fiber has been developed to gain improved understanding of the role of premature beats in the formation of ventricular fibrillation (VF), a lethal cardiac arrhythmia. The model predictions have been compared with *in vitro* data from canine right ventricles, confirming that the model is able to determine which sequences of premature beats are more likely to produce VF.

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MS65

Spiral Wave Generation and Instabilities in Cardiac Systems with Pacemaker-obstacle Interactions

We performed experiments on annular domains of cardiac monolayers with embedded pacemakers composed of ventricular cells from 8-day-old embryonic chick hearts. We tracked the wave propagation using an intracellular calcium dye and a CCD camera. The monolayers with wider annular domains generated more complex behaviour, including reentrant wave dynamics. Numerical simulations using a simplified FitzHugh-Nagumo model coupled in space provided insight into the dynamics.

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MS66

Mathematical Models of Crime and Energy Use in Urban Societies

Abstract not available at time of publication.

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MS66

Rate Effects on the Growth of Centres

Much of the mathematical modelling of urban systems revolves around the use spatial interaction models, derived from information theory and entropy-maximisation techniques and embedded in dynamic difference equations. This class of models have wide reaching applications: from trade and migration flows to the spread of riots and understanding the spatio-temporal patterns of burglaries. When framed in the context of a retail system, the dynamics of centre growth poses an interesting mathematical problem, with bifurications and phase changes, which may be analysed analytically. In this contribution, we present some analysis of the continuous retail model and corresponding discrete version, which yields insights into the effect of space on the system, and an understanding of why certain retail centers are more successful than others.

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MS66

What can Dynamical Systems Tell Us About Urban Energy Systems?

Cities account for over two-thirds of the world's primary energy consumption and 71% of global energy-related greenhouse gas emissions. To understand and improve the performance of urban energy systems, a range of modelling techniques have been used but dynamical systems methods are not widely employed. This paper will consider why this might be the case and suggest specific applications where dynamical systems offer the greatest potential.

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MS66

Mathematics of Crime

This lecture uses crime as a case study for using applied mathematical techniques in a social science application and covers a variety of mathematical methods that are applicable to such problems. We will review recent work on agent based models, methods in linear and nonlinear partial differential equations, variational methods for inverse problems and statistical point process models. From an application standpoint we will look at problems in residential burglaries and gang crimes. Examples will consider both "bottom up' and "top down' approaches to understanding the mathematics of crime, and how the two approaches could converge to a unifying theory. We will cover specific examples where urban geography plays an important role in the models.

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MS67

Periodic Waves in Fire-diffuse-fire Model of Calcium Dynamics in Cardiac Cells

Calcium dynamics plays an important role in intracellular communication in living cells. The fire-diffuse-fire model, which accounts for the effects of diffusion, absorption, and localized release of calcium, has been successfully used to model the initiation, propagation and failure of calcium waves and other spatio-temporal patterning of intracellular calcium. Previous theoretical studies were usually performed under the assumption of a linear absorption mechanism. In this talk I will present a simple approach for studying periodic traveling waves in one-dimensional fire-diffuse-fire models with an arbitrary absorption mechanism. I will then describe dynamics of such waves and discuss their stability and robustness.

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MS67

A Simple Criterion of Transverse Linear Instability for Nonlinear Waves

Transverse stability refers to the stability of a nonlinear wave which is homogeneous in one spatial direction with respect to non-homogeneous perturbations. Relying upon a spatial dynamics formulation in which the time-like variable is the spatial direction in which the wave is homogeneous, we give a sufficient condition for transverse linear instability. We apply this criterion to solitary and periodic gravity-capillary water waves.

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MS67

Nonlinear Schrodinger Models and PT-Symmetry: Living at the Interface between Hamiltonian and Dissipative

This talk concerns a theoretical analysis of some aspects of a theme that has received particular attention recently, namely parity-time (PT) symmetric media. Such media have recently been realized in nonlinear optics, where they often feature a cubic nonlinearity. In this talk, we will see how this special PT-symmetric interface between the underlying Hamiltonian problem and the presence of the gain/loss leads to interesting modifications of the system's bifurcations, to the emergence of new, so-called ghost states and to rather unexpected dynamical implications in both one and two dimensions.

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MS67

Stability of Traveling Waves on Vortex Filaments

We develop a general framework for studying the stability of solutions of the Vortex Filament Equation (VFE), based on the correspondence between the VFE and the nonlinear Schrödinger (NLS) equation provided by the Hasimoto map. This method is used to investigate the (linear and orbital) stability of periodic and soliton solutions. In the periodic case, we show that the solutions associated to cnoidal wave solutions of the NLS are stable only in the case where they take the form of an unknotted torus knot.

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MS68

Of Slugs and Snakes: Moving Localized Structures in Fluid Flows

In this talk I will describe the origin and properties of moving spatially localized convection found in different doubly diffusive systems. Two systems will be described in detail: binary fluid convection in a horizontal layer and natural doubly-diffusive convection in a vertically extended cavity. Although the motion of these structures is generally sluggish their collisions may lead to new types of dynamical behavior. The numerical results will be related to the phenomenon of homoclinic snaking in spatially reversible systems. The talk will be based on ongoing work with A. Alonso, O. Batiste, C. Beaume, A. Bergeon and I. Mercader.

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MS68

Unstable Solitons in Inhomogeneous Nonlinear Schrodinger Equations

I will discuss the (in)stability of solitons arising in models used to create a Bose-Einstein Condensate. I will outline how the Maslov index can be used to establish the instability of standing waves to inhomogeneous NLS equations. Instability will be established by simple observations of the initial soliton's orbit in the phase plane. This technique can be used to show instabilities in excited states, asymmetric states, gap solitons, and solitons on an nonzero background.

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MS68

Nonlocal Interactions and Localized Patterns

Localized patterns may occur in bistable systems, or from interactions with large-scale modes, or due to nonlocal interactions. This work explores the third of these mechanisms, which has received relatively little attention. Nonlocal equations with an integral convolution term arise naturally in many applications, including neural field modeling and predator-prey systems. We derive amplitude equations for such systems that can themselves be pattern-forming, leading to a ”patterns on patterns” structure or strongly localized states.

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MS68

Oscillons Near Hopf Bifurcations of Planar Reac-

tion Diffusion Equations

Oscillons are planar, spatially localized, temporally oscillating, radially symmetric structures. They have been observed in various experimental contexts, including fluid systems, granular systems, and chemical systems. Oscillons often arise near forced Hopf bifurcations, which are modeled mathematically with the forced complex Ginzburg-Landau (FCGL) equation. We present a proof of the existence of oscillons in the forced planar complex Ginzburg-Landau equation through a geometric blow-up analysis. Our analysis is complemented by a numerical continuation study of oscillons in the forced Ginzburg-Landau equation using Matlab and AUTO.

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MS69
Fluctuations and Equipartition in the Dynamics of Granular Ratchets

We examine the motion of a macroscopic wedge-shaped particle (constrained to only move along the x-axis) encountering dissipative collisions with granular gas particles. Based on a general stochastic model, we derive the full PDF of the wedge's motion. Contrary to what is observed for a Maxwell-Boltzmann gas, vanishingly small perturbations to the gas velocity PDF (e.g. via shaking) result in a steady-state drift velocity independent of wedge mass in the limit of a massive particle.

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MS69
Symmetry Breaking Induced Rotating Spirals in Agitated Wet Granular Matter

Pattern formation of a thin layer of vertically agitated wet granular matter is investigated experimentally. Due to the strong cohesion arising from the capillary bridges formed between adjacent particles, agitated wet granular matter exhibits a different scenario as its dry counter-part. Rotating spirals with three arms, which correspond to the kinks between regions with different colliding phases, are the dominating pattern. This preferred number of arms are found to be related to the period tripling of the agitated granular layer, which breaks the spatiotemporal symmetry and drives the rotation. As symmetry is retained in a narrow regime of the control parameter, period doubling pattern with frozen wave fronts arise. The phase diagram of patterns with breaking and non-breaking symmetries, as well as the shape and rotating speed of spirals will be addressed.

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MS69
Momentum Transfer in Non-equilibrium Steady States

An anisotropic and inelastic Brownian object can show steady nonequilibrium motion in an equilibrium ideal gas. Despite many adhoc calculations, the essential mechanism of this motion was only recently understood using the concept of momentum transfer deficit due to dissipation [Fruleux et al. Phys Rev Let.(2012)]. By this concept, many hetherto unrelated phenomena, like adiabatic piston or Brownian ratchet are also shown to be variants of a class of nonequilibrium steady states.

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MS69
A Granular Ratchet: Spontaneous Symmetry Breaking and Fluctuation Theorems in a Granular Gas

We
experimentally construct a ratchet of the Smoluchowski-Feynman type, consisting of four vanes that rotate freely in a vibrofluidized granular gas. We show that a steady state fluctuation relation holds for the work injected to the system, and that its entropy production satisfies a detailed fluctuation theorem. Surprisingly, the above relations are satisfied even when a convection roll has developed with a strong coupling between the motion of the vanes and the granular gas.

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MS70
Exact Solution to Estimation Problems in Scalar Conservation Laws and Hamilton-Jacobi PDEs. Applications to Transportation Engineering

In this talk, we investigate scalar conservation laws (or equivalently Hamilton Jacobi equation) with concave flux, in which initial, boundary and internal conditions are uncertain. Using the properties of the Lax-Hopf solution, we write the problem of reconstructing the intitial, boundary and internal conditions as mixed integer convex programming. The resulting framework is very flexible, and can compute solutions to various problems associated with transportation engineering: estimation, boundary control, privacy analysis, cybersecurity.

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MS70

Set-Valued Iteration Schemes for the Computation of Invariant Sets

Dynamically interesting invariant sets of dynamical systems are typically approximated either by geometric construction or by fixed-point type iteration. We approach this problem in a Banach space setting which allows to employ Newton-type iterations that do not feature typical drawbacks of the aforementioned methods. Limitations to the applicability initially arising from the technical setup can be overcome using a covering approach that represents invariant sets as (subsets of) unions of convex sets.

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MS70

Deterministic Numerical Continuation for Stochastic Dynamical Systems

Continuation methods for deterministic dynamical systems have been one of the most successful numerical tools in applied dynamical systems theory. We show how to extend these ideas to metastable equilibrium points of stochastic differential equations by combining results from probability, dynamical systems, numerical analysis, optimization and control theory. The algorithm naturally augments classical deterministic continuation and provides ellipsoidal confidence neighborhoods and distances between.

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MS70

Robust Optimal Control Problems: Extending Differential Approaches via Sets

In "robust" control problem, two types of controls occur and, the user can choose only one of them whereas the other one is not known exactly (i.e. some uncertainty). This talk focuses on the analytical situation when the latter perturbations have an unknown or uncertain strategy. It leads to non-standard (set-valued) initial value problems for states and controls. Finally we discuss the existence of solutions and their computability in principle.

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MS71

Flow Map Composition for Non-autonomous Dynamical Systems

The flow map of a dynamical system plays a major role in the computation of finite-time Lyapunov exponents, the Perron-Frobenius operator, and in uncertainty quantification using generalized polynomial chaos. However, the flow map calculation is expensive, both in computation time and memory requirement. In this talk, we continue to develop the theory of flow map composition, whereby long-time flow maps are constructed as the composition of multiple short-time flow maps. In addition, spectral interpolation is introduced to dramatically reduce the memory requirement of storing intermediate flow maps. A careful error analysis demonstrates the benefit of short-time compositions. Long-time flow maps are characterized by significant stretching and folding of trajectories, whereas short-time intermediate flow maps have less distortion and are more accurately represented by low-order basis functions. These ideas are illustrated on numerical examples.

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MS71

Coherent Structure Identification Using Flow Map Composition and Spectral Interpolation

We propose an efficient method for computing the propagation of a probability density function through the long-time flow map associated with an uncertain velocity field. Uncertain initial conditions and parameters are both addressed. We employ spectral representations for short-time flow maps, and construct long-time flow maps by composing them. The long-time flow map is used to compute stochastic quantities, which are shown to be correlated to coherent structures in the velocity field.

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MS71

Koopman Mode Analysis of Networks

Spectral analysis of a dynamical system's associated Koopman operator has proven fruitful in a number of areas. The so-called Koopman Mode analysis focuses on the point spectrum (especially the eigenvalues on the unit circle), providing a "skeleton" of the dynamics, with little attention given to the continuous part of the spectrum. This talk focuses on constructing the operators spectral measure directly from data allowing the analysis of the continuous spectrum.

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MS71

Coherent Sets from Data: Bifurcations, Braiding, and Predicting Critical Transitions

We discuss some results regarding identification of coherent sets, regions with long residence time, using a transfer operator approach, which are appropriate for systems of arbitrary time dependence defined by data, e.g., fluid flows. A topological analysis based on spatiotemporal braiding of coherent sets might be possible for analyzing chaos in such systems. Furthermore, by considering changes in the transfer operator modes, prediction of dramatic changes in system behavior may be possible.

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MS72

Mixed-mode Oscillations in the

Belouzov-Zhabotinsky Reaction

In stirred reactors, the Belousov-Zhabotinsky reaction displays mixed mode oscillations in which small and large amplitude oscillations alternate with one another. This lecture will describe studies of a six dimensional vector field formulated by Gyorgyi and Field as a model of the BZ reaction which fits empirical data well. Extending results in the thesis of Chris Scheper, we use geometric singular perturbation theory to analyze mixed mode oscillations in this model.

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MS72

Canard Cycles in Aircraft Ground Manoeuvres

We show that the sudden loss of lateral stability of a midsize passenger aircraft turning on the ground is due to a canard explosion.

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MS72

Spike-adding Mechanisms in Transient Bursts

Dynamical systems tools are designed to explain the long-term bahaviour of a system, that is, what happens after transients have died out. In many applications, however, it is more important to understand the transient rather than asymptotic behaviour. In this talk we employ standard tools from dynamical systems in order to analyse transient bursting behaviour. To illustrate these ideas, we use the example of an excitable cell model that is subject to a brief perturbation.

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MS72

Canard- and Hopf-induced Mixed-mode Oscillations in Pituitary Cells

It has been shown that large conductance potassium (BK) current tends to promote bursting in pituitary cells. This requires fast activation of the BK current, otherwise it is inhibitory to bursting. In this work, we analyze a pituitary cell model to answer the question of why BK activation must be fast to promote bursting. In particular, we show that the bursting can arise from either canard dynamics or slow passage through a dynamic Hopf bifurcation.

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MS73

Iterated Birth and Death Markov Branching Processes as a Model of Irradiated Cancer Cell Survival

We solve, under realistic assumptions, the following problem in radiation biology and oncology: finding the distribution of the number of tumor cells surviving fractionated radiation. Based on birth and death Markov branching process model of tumor cell population kinetics we find an explicit formula for the distribution in question and identify two of its limiting forms: the Poisson distribution and the generalized Poisson distribution. We also estimate the rate of convergence to the Poisson distribution.

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MS73

Multiscale Stochastic Reaction-diffusion Algorithms Combining Markov Chain Models with SPDEs

In this talk, I will introduce a multiscale algorithm for stochastic simulation of reaction-diffusion processes. The algorithm is applicable to systems which include regions with a few molecules and regions with a large number of molecules. A domain of interest is divided into two subsets where continuous-time Markov chain models and stochastic partial differential equations (SPDEs) can be respectively used. Several examples with simulation results will be shown. This is a joint work with Radek Erban at the University of Oxford.

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MS73

Multistage Carcinogenesis and Cancer Evolution as a Branching Process

Stochastic models of multistage carcinogenesis, cancer evolution at the cellular level, have played an important role in the analysis of cancer epidemiology data since the 1950s. By being biologically-based, multistage models can be used to test hypothesis about carcinogens mechanisms of action and to gauge their effects on cancer risk. In this talk I will show how to analyze multistage carcinogenesis models as continuous branching processes and the advantages of doing so versus alternative approaches.

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MS73

HPV and Cervical Cancer: A Stochastic Model at Tissue Level

Infection with the Human Papilloma Virus (HPV) is a prerequisite for cervical cancer. While $\sim 80\%$ of women get infected during their lifetime, most clear the virus within 2 years. If the infection persists, it can lead to malignant cancer. Various aspects of the carcinogenesis remain poorly understood at the cellular level. We develop a stochastic model of the cervical epithelium, coupling the dynamics of HPV infection to a multi-stage model of cancer evolution.

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MS74

Uncertainty Quantification and Decisions in Markovian Dynamics

Abstract not available at time of publication.

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MS74

Linking Diffusion Maps with Coarse-graining Complex System Dynamics

Abstract not available at time of publication.

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MS74

Patch Dynamics for Macroscale Modelling of Diffusion in Heterogeneous Media

Abstract not available at time of publication.

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MS74

Accurate Bifurcation Diagrams of an Agent-based Sociological Model Using Variance-reduced Jacobian-vector Products

Abstract not available at time of publication.

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MS75

Mesoscopic Structure and Social Aspects of Human Mobility

The individual movements of large numbers of people are important in many contexts, from urban planning to disease spreading. Datasets that capture human mobility are now available and many interesting features have been discovered, including the ultra-slow spatial growth of individual mobility. However, the detailed substructures and spatiotemporal flows of mobility the sets and sequences of visited locations have not been well studied. I'll discuss an empirical project where we found that individual mobility is dominated by small groups of frequently visited, dynamically close locations, forming primary habitats capturing typical daily activity, along with subsidiary habitats representing additional travel. These habitats do not correspond to typical contexts such as home or work. The temporal evolution of mobility within habitats, which constitutes most motion, is universal across habitats and exhibits scaling patterns both distinct from all previous observations and unpredicted by current models. The delay to enter subsidiary habitats is a primary factor in the spatiotemporal growth of human travel. Interestingly, habitats correlate with non-mobility dynamics such as communication activity, implying that habitats may influence processes such as information spreading and revealing new connections between human mobility and social networks.

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MS75

The English Language has a Self-similar, Positively-biased Emotional Spectrum

We show that the emotional content of individual English words exhibits a spectrum with a strong positive bias, largely independent of word usage frequency. Our findings suggest a deep linguistic encoding of the pro-social, cooperative nature of people, and hold broadly across four diverse large-scale text corpora: Twitter, the New York Times, Google Books, and music lyrics. Our Mechani-

cal Turk measurements for over 10,000 words statistically agree with but greatly expand upon previous, limited studies.

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MS75

Unraveling Daily Human Mobility Motifs

We uncover daily mobility patterns and identify the underlying mechanism responsible for the observed behavior. By using the concept of motifs from network theory, we show that despite the existence of millions of possible networks, only a few networks are present, following simple rules. Only 17 networks, called here motifs, are sufficient to capture up to 90% of the population in datasets obtained from both surveys and anonymized mobile phone data for different countries.

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MS75

Revealing the Character of Cities Through Data and Hedonometrics

We investigate how geographical location influences individual happiness, using a novel algorithm applied to word frequencies collected from Twitter messages. We examine differences in word usage between US cities, and using census data explain how happiness relates to underlying physical and social factors in those cities. Furthermore, we attempt to categorize cities in a data-driven way based on differences in word use and demographics.

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MS76

Using Neural Mass Models and Bifurcation Theory to Understand Transitions to Pathological Oscillations in Neural Systems

Neural mass models (NMMs) are employed as a means of capturing the bulk properties of interacting populations of neurons. The response of each population is governed by a differential equation. The equations are coupled together according to the schematic structure of the model and solved numerically. Bifurcation analysis can then be used to understand the range of solutions and the transitions between them. We examined a NMM of cortical tissue to better understand focal-onset epilepsy.

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MS76

Use of Mesoscale Models to Understand Data on Sleep and Seizures, and to Investigate Options for Seizure Control

A method is presented for probabilistically tracking the evolution of measured electroencephalogram data in the sleep parameter space of a mean-field cortical model. This algorithm is then applied to track the parameter evolution of seizures.
Extending the seizure applications, the effect on seizure dynamics of a control algorithm using a charge balanced optogenetics actuator is studied. Optogenetics enable optical stimulation of neurons with high spatial and temporal resolution.

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MS76

Mean Field Models of the EEG: Physiological Relevance and Mathematical Challenges

We will give a brief overview of a number of important mean field approaches to modelling brain activity that have been applied with varying degrees of fidelity to articulating the genesis of rhythmic electroencephalographic activity in health and disease. This brief survey will conclude with a discussion of the mathematical challenges, particularly the simulation, bifurcation analysis and parameter estimation, that these theories will need to negotiate in order to progress as neurobiologically effective explanatory frameworks.

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MS76

Bifurcation and Pattern Formation in a Mean-field Model of the Electroencephalogram

We study a model of the electrical potentials generated by excitatory and inhibitory neuron populations in the cortex. The model takes the form of a system of semilinear, hyperbolic PDEs, that allow for oscillatory solutions and travelling waves. We implemented the model in the open-source software PETSc, which allows for the continuation of equilibria and periodic orbits, and re-analyzed results by Bojak & Liley on the onset of self-organised 40Hz oscillations near a Hopf-Turing bifurcation.

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MS77

On the Maxwell-Bloch Equations with Non-zero Boundary Conditions

The initial-boundary value problem for the Maxwell-Bloch equations with non-zero fields at infinity is considered. The inverse scattering transform is formulated and is used to investigate the behavior of the solutions.

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MS77

Light Propagation in Lambda-configuration Metamaterials with Mixed Positive and Negative Refractive Index

We study numerically the propagation of two-color light pulses through a metamaterial doped with active atoms such that the carrier frequencies of the pulses are in resonance with two atomic transitions in the Λ configuration and that one color propagates in the regime of positive refraction and the other in the regime of negative refraction. In such a metamaterial, one resonant color of light propagates with positive and the other with negative group velocity. We investigate nonlinear interaction of these forward- and backward-propagating waves, and find self-trapped waves, counter-propagating radiation waves, and hot spots of medium excitation.

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MS77

Dynamics of Light Propagating through Active Optical Media

The Maxwell-Bloch equations describe resonant interaction between light and active optical media, whose many mechanisms are captured by their lossless limit. They include random polarization switching in randomly prepared media and light pulses slowed down to a fraction of the speed of light, solvable by the inverse-scattering transform. A non-integrable variation of the Maxwell-Bloch equations describes propagation of light through meta-materials with negative and positive refractive indices for two resonant frequencies of the light pulses.

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MS77

On the Coupled Maxwell-Bloch Equations with Inhomogeneous Broadening for a 3-level System

The initial value problem (IVP) for the propagation of a pulse through a resonant 3-level optical medium can be solved by Inverse Scattering. While the scattering problem is the same as for the coupled NLS, the time evolution depends on asymptotic values of the material polarizability envelopes and is highly nontrivial. This talk will address the solution of the IVP for the coupled Maxwell-Bloch equations with inhomogeneous broadening for generic preparation of the medium.

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MS78

Hydrodynamic Mean-?eld Solutions of 1D Exclusion Processes with Spatially Varying Hopping Rates

Abstract not available at time of publication.

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MS78

Novel Features in an Accelerated Exclusion Process Towards Modeling Transcription

Inspired by the cooperative speed-up observed in transcribing RNA polymerases, we introduce distance-dependent interactions in an accelerated exclusion process (AEP). Each particle moves to the neighboring site if vacant. Additionally, if reaching another cluster of particles, it can kick up the frontmost particle in that cluster. The steady state of AEP shows a discontinuous transition, from being homogeneous (with augmented currents) to phase-segregated. More surprisingly, the current-density relation in the phase-segregated state is simply $J = 1-\rho$, indicating the particles (or holes) are moving at unit velocity despite the inclusion of long-range interactions.

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MS78

Traffic Flow Model for Bio-Polymerization Processes

Bio-polymerization processes like transcription and translation are central to a proper function of a cell. The speed at which the bio-polymer grows is affected both by number of pauses of elongation machinery, as well their numbers due to crowding effects. In order to quantify these effects in fast transcribing ribosome genes, we rigorously show that a classical traffic flow model is a limit of mean occupancy ODE model. We compare the simulation of this model to a stochastic model and evaluate the combined effect of the polymerase density and the existence of pauses on transcription rate of ribosomal genes.

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MS78

Random Hydrolysis Controls the Dynamic Instability in Microtubules

One of the most fascinating phenomena associated with cytoskeleton proteins is dynamic instability in microtubules, when these biopolymers can be found in growing or shrinking dynamic phases. Despite multiple efforts, mechanisms of this phenomenon are still not well understood. Here we present a microscopic stochastic model of dynamic instability which explicitly takes into account all relevant biochemical processes. It provides a comprehensive description of the dynamic instability of microtubules. Our theoretical results are supported by Monte Carlo simulations, and they also agree with all available experimental observations.

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MS79

Lamprey Locomotion Driven by Non-linear Muscle Mechanics and Work-dependent Deactivation

The swimming behavior observed in lampreys is the result of the balance of forces from activated muscle, from the response of different tissues of the body and from reactions of the surrounding fluid environment. Here we examine some of the effects of nonlinear muscle mechanics and neural activation on the forces generated along the body of the organism. Implications of the force generation pattern on swimming efficiency and performance of the organism are discussed.

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MS79

Optimal Open- and Closed-loop Control of Anguilliform Swimming

We study optimal control of an existing model of anquilliform swimming developed by McMillen and Holmes in which the body is approximated by a finite number of linked segments. We minimize a cost function that penalizes both positive and negative work. We consider both the open-loop problem in which muscle torques are specified and the closed-loop problem in which muscle torques depend on the motion of the body perturbed by noise.

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MS79

Lamprey Swimming, a Hydrodynamic Approach

We use a robotic lamprey to investigate the wake structure during anguilliform swimming. 11 servomotors produce a traveling wave along the lamprey body. The waveform is based on kinematic studies of living lamprey. PIV measurements show that a 2P structure dominates the wake. The phase-averaged surface pressure distribution along the centerline of the robot increases toward the tail, indicating that thrust is produced mainly at the tail. The phase relationship between these signals is also examined.

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MS79

Strategies for Swimming: Explorations on the Behaviour of a Neuro-musculo-mechanical Model of the Lamprey

Fish swim by generating waves of muscle activation that pass down the body toward the tail. Such activation produces traveling waves of lateral curvature, which develop forward thrust from the surrounding water. Increased swimming speed is brought about by increasing both the frequency of the waves and the strength of muscle activation. We use a combined model of the body in which a recently developed model for the muscle forces is employed, and coupled with forces due to the surrounding fluid. We show that over a range of ratios between the wave speeds of activation and curvature, the ratio that is observed experimentally in the lamprey gives rise in the model to the maximum forward speed. This was true over a wide range of model parameters.

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MS80

Stationary Co-dimension 1 Structures in the Functionalized Cahn-Hilliard Model

The functionalized Cahn-Hilliard equation appeared recently in the study of polymer-electrolyte membranes. It generates an intriguing variety of evolving thin structures. Here, we focus on simple stationary structures and their bifurcations: flat plates and spherical/cylindrical shells. The existence problem corresponds to constructing homoclinic solutions in a perturbed integrable Hamiltonian system. The stability is established by a careful analysis of a (projected) 4th-order operator in which two potential destabilization mechanisms - meandering and pearling - must be controlled.

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MS80

Stability of Multi-Bump, Blowup Solutions of the Ginzburg-Landau Equation with Respect to Non-Radially Symmetric Perturbations

In this talk we study, the stability of radially symmetric blowup solutions of the Ginzburg-Landau equation with respect to radially symmetric and non-radially symmetric perturbations. 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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MS80

Stability of Multiple Solutions in a Convection-diffusion-reaction PDE

In this talk we will discuss the stability of non-unique steady-state solutions of a time-dependent convection-diffusion-reaction PDE. Its stationary version can be recognized as an extended Bratu-model with damping. Depending on the form of the reaction term, we can identify zero, one, two, or even infinitely many steady-states. Stability analysis of the evolutionary PDE shows that only one of these solutions can be stable.

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MS80

Unstable Spots in a FitzHugh-Nagumo System

In this talk, I will look at several destabilizing scenarios for planar localized structures such as spots and stripes in a generalized FitzHugh-Nagumo equation. We are especially interested in the bifurcation of a stationary spot into a travelling spot. Using formal analysis and the numerical continuation package AUTO-07p, we determine the

location of this pitchfork bifurcation, its criticality and the shape and speed of the bifurcating traveling spot. This is joint work with B. Sandstede.

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MS81

A Novel Model for Collective Behavior in Groups of Predators

In this work, we present a novel model of a multi-agent system inspired by the phenomenon of bat swarming. The model is unique in the coupling between agents, interaction modalities, and communication mechanisms. We define an order parameter based on navigation and foraging success to explore the emergence of collective behavior.

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MS81

Evolution of Networks of Multi-agent Systems on Low-dimensional Manifolds

In this work, we use a nonlinear dimensionality-reduction technique called Isomap to infer the complexity of a networked multi-agent system. Using image streams of interacting-particle models as input to the Isomap algorithm, the dimensionality of the resulting submanifold is used to determine the degree of alignment between agents. We further exploit local linearity of the input high-dimensional manifold to detect phase transitions in collective motion. Finally, we validate this approach on real datasets comprising raw videos of zebrafish schools.

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MS81

Dynamics of Delocalized Consensus Formation

Many systems in Science and Engineering need to process information collectively, with examples ranging from neural networks, to biological swarms, and decentralized sensor nets. In this talk I present a series of analytically tractable network models of decission dynamics that are used to identify beneficial and detrimental factors in collective decission-making. In particular, I will show that already very simple models make predictions that can be verified in experiments with humans and animals.

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MS81

Computation from Adaptive Synchronization

It is generally accepted that the brain transmit and process information by means of synchronization. For instance, neural assemblies are known to organize their dynamics in a balance between synchronization and desynchronization, and modifications of such balance have been associated with a number of neurological illnesses, including schizophrenia and Alzheimers disease. Yet, how to conciliate computation and synchronization, when the latter can be seen as a destruction of information, is still an open problem. Here, we present a framework for the spontaneous emergence of computation from adaptive synchronization of networked dynamical systems. The fundamentals are nonlinear elements, interacting in a directed graph via a coupling that adapts itself to the synchronization level between two input signals. We demonstrate how these units can emulate different Boolean logics, and perform any computational task in a Turing sense, each specific operation being associated with a given network's motif.

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MS82

Attractors Near Grazing-sliding Bifurcations

We will present a method of analysis of grazing-sliding bifurcation scenarios, that may lead to the birth of multiple attractors from a single attractor in three dimensional Filippov type flows, by appropriate reduction to one-dimensional discontinuous maps. Three, qualitatively different, scenarios will be presented. A constructed example of a Filippov type flow, displaying the analysed cases, will be shown. We will then verify the presence of attractors, using the model example, numerically.

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MS82

Bifurcation Analysis of an Intermittent Control Model During Human Quiet Stance: A Possible Mechanism of Postural Sway

Ground reaction force during human quiet stance is known to be modulated with the cardiac cycle through hemodynamics, inducing a tiny periodic disturbance torque to the ankle joint. Can it be a major source of perturbation inducing postural sway? Here we consider postural sway dynamics of an inverted pendulum with an intermittent control strategy, and show that, based on a bifurcation analysis, the model with the hemodynamic perturbation can exhibit human-like postural sway.

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MS82

Dynamics Near Incomplete Chattering

The dynamics of mechanical models with impact is considered. In particular, the dynamics for trajectories that are close to the border between complete and incomplete chattering is studied. In the single degree of freedom situation, a limit mapping is derived as the border is approached, that apart from scaling only depends on the coefficient of restitution. The multi-degree of freedom case is also discussed.

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MS82

Transient Dynamics in Impacting Systems

It is well known that mechanical systems with impacts can undergo chattering, a large number or even an infinite number of impacts in finite time. There are successful attempts at trying to explain the local behaviour of chattering but global analysis is still somewhat missing. Here we will discuss the global dynamics of an impact oscillator that can undergo chattering through analysis of the transient dynamics as the position of the impacting surface is varied.

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MS83

A Deterministic Perspective on Stochastic Thermodynamics: Local Equilibrium and Information Theory

Stochastic thermodynamics (ST) extends equilibrium thermodynamics to treat nonequilibrium processes on much smaller, so-called mesoscopic scales. Its consistency relies on local equilibrium (LE). The most prominent results of ST are nonequilibrium fluctuation relations (cf. Rondoni's talk). However, LE is a strong assumption which does not always apply. This is the case for systems without a clear separation of scales (cf. Lucarini's talk) or strongly dissipative systems (cf. Swift's talk). In my talk, I will present a deterministic approach to ST and discuss routes towards a dynamical picture of LE.

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MS83

Statistical Physics of the Climate System

The investigation of the climate system is one of the grand challenges of contemporary science. Such a problem is gaining more and more relevance as exoplanets are being discovered at an accelerating rate and rather exotic atmospheric circulations are being conjectured, due to the vast variety of possible astronomical and astrophysical configurations. In this contribution we will discuss how nonequilibrium statistical mechanics allows framing in a rigorous and efficient way classical problems of climate science such as the understanding of the climatic response to forcings of general nature and the parametrization of unresolved processes.

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MS83

Gravity-Wave Detectors and Nonequilibrium Statistical Physics of Very Cold Systems

The detection of gravitational waves requires exceedingly accurate measurement tools, capable of recording microscopic fluctuations in macroscopic objects. Recently, these tools have been found to operate in non-equilibrium conditions, thus allowing direct tests of the non-equilibrium fluctuation relations developed in the past two decades. We will review the relevant well established results, and we will present novel analysis concerning response and nonequilibrium temperature relations.

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MS83

Phase Coexistence and Surface Tension in Vibrated Granular Fluids

We describe experiments and simulations carried out to investigate phase separation in a vibrated, dry granular system. The dynamics is found to be controlled by curvature driven diffusion, which suggests the presence of an effective surface tension. We find behaviour consistent with Laplace's equation and detailed measurements of the pressure tensor in the interfacial region show that the surface tension results predominantly from an anisotropy in the kinetic energy part alone.

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MS84

Bayesian Data Assimilation with Optimal Maps

We develop a novel, map-based schemes to sequential data assimilation, i.e., nonlinear filtering and smoothing. One scheme involves pushing forward a fixed reference measure to each filtered state distribution, while an alternative scheme computes maps that push forward the filtering distribution from one stage to the other. The main advantage is that the map approach inherently avoids issues of sample impoverishment, since it explicitly represents the posterior as the pushforward of a reference measure, rather than with a particular set of samples. The computational complexity of our algorithm is comparable to state-of-the-art particle filters. We demonstrate the efficiency and accuracy of the map approach via data assimilation in several canonical dynamical models, e.g., the Lorenz-63 and Lorenz-96 systems.

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MS84

Estimating Global Electric and Magnetic Fields in Plasma Experiments and Particle-in-Cell Codes in the presence of noise for the Purpose of Predicting Incipient Magnetic Reconnection

Diagnosing magnetic reconnection from experimental data, from particle-in-cell (PIC) simulations, or from space observations involves making measurements, which are easily obtained in PIC data, sparse in experiments and very sparse in observations. The latter two measurements have high noise levels and the PIC data has inherent PIC noise. We have developed methods of estimating the electric and magnetic fields and associated global structures such as stable and unstable manifolds to diagnose reconnection and incipient reconnection.

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MS84

Propagating Uncertainty About Gas EOS to Performance Bounds for an Ideal Gun

For any strongly connected directed graph, a particular set of branching probabilities maximizes the entropy rate of the resulting Markov process. Calculating those probabilities can yield probability measures for constrained sets of functions. Curiously, the calculation is equivalent to one of Shannon's early Information Theory results. I motivate the problem by the challenge of characterizing uncertainty about the performance of a gas driven gun and compare that to the application Shannon addressed.

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MS84

Coarse-graining Emergent Behavior from Complex Models

Mathematical models are often extremely complex and involve many unknown parameters; however, the collective behavior of the system is often surprisingly comprehensible. We consider the manifold of all possible predictions in data space and find that it is typically bounded with a hierarchy of widths. Long directions describe emergent behavior while narrow directions correspond to irrelevant details. Approximating the model manifold by its boundary coarse-grains away the microscopic details producing models of emergent behavior.

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MS85

Surfactant-induced Gradients in the Three-dimensional Belousov-Zhabotinsky Reaction

Experimentally, scroll wave dynamics is often studied by optical tomography in the Belousov-Zhabotinsky reaction, which produces CO_2 as an undesired product. Addition of small concentrations of a surfactant to the reaction medium suppresses or retards bubble formation. We show that in closed reactors even these low concentrations of surfactants are sufficient to generate vertical gradients of excitability. In reactors open to the atmosphere such gradients can be avoided. The gradients induce a twist on vertically oriented scroll waves, while a twist is absent in scroll waves in a gradient-free medium. These findings are reproduced by a numerical study, using an extended Oregonator that accounts for CO_2 production and for its advection against the direction of gravity.

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MS85

Geometrically Constrained Wave Propagation in Excitable Media

It is well-known that domain size may strongly influence dynamics and stability of travelling excitation waves. I report on theoretical and experimental results about scroll ring evolution constrained to thin layers with no-flux conditions imposed at the boundaries. Results include boundary-induced suppression of negative line-tension instability accompanied by formation of stable autonomous pacemakers. Experiments were performed in thin transparent layers of the Belousov-Zhabotinsky reaction.

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MS85

Twists of Opposite Handedness on a Scroll Wave

The interaction of a gradient of excitability and a scroll wave of the Belousov-Zhabotinsky reaction oriented (almost) perpendicular to the vertical gradient is studied. Filaments with a component parallel to the gradient twist, whereas scrolls with U-shaped filaments develop twists from both ends of the filaments. These filaments display a pair of twists of opposite handedness, which are separated by a nodal plane where the filament remained untwisted. The experimental findings were reproduced by numerical simulations.

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MS86

Stability Analysis of Flock Rings for 2nd Order Models in Swarming

In this work we consider second order models in swarming in which individuals interact pairwise with a power-law repulsive-attractive potentials. We study the stability for flock ring solutions and we show how the stability of these solutions is related to the stability of a first order model. In unstable situations it is also possible to observe formation of clusters and fat rings.

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MS86

Instability and Bifurcation in a Trend Depending Price Formation Model

A model for the formation of prices proposed by Lasry-Lions presents the evolution of such prices as a motion of a free boundary in a nonlinear parabolic problem. Its analysis has received a lot of attention: the dynamics show a smooth evolution into a stable time-independent price. Inspired by the older work by Guidotti-Merino on the appearance of stable oscillations in a thermal control problem, we modify the model in order to produce a Hopf bifurcation and existence of stable periodic solutions.

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MS86

Computing Stationary States of Kinetic Swarming Models

We consider a second-order self-propelled interacting particle system, which has been frequently used to model complex behavior of swarms such as fish schools or birds flocks. We present recent advances in the explicit computation of particular solutions of the associated kinetic equation, such as flocks and rotating mills. For so-called Quasi-Morse potentials, such density profiles can be expressed in terms of a linear combination of special functions (in 2D and 3D).

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MS86

Smoothing Transformations and Wealth Distributions

We discuss Kac-like kinetic equations modeling wealth distribution in simplified economies. Our models are derived from "microscopic" descriptions, in which wealth is exchanged between agents in binary trades. Unlike the kinetic energy in the original Kac equation, wealth is conserved only in the statistical mean. Extending McKean's probabilistic approach, we identify the Pareto-Index of the stationary state and the rate of convergence to equilibrium in terms of the model parameters.

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MS87

Modeling the Host Response to Inhalation Anthrax

Bacillus anthracis, the causative agent of anthrax, can exist in the form of highly robust spores, thus making it a potential bio-terror threat. Once inhaled, the spores can germinate into vegetative bacteria capable of quick replication, leading to progressive disease and death. This presentation discusses ongoing work on the development of mathematical models that explore the host response to inhalation anthrax and provide insight into the mechanisms that drive the risk of disease.

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MS87

Innate Immune Response in Healthy and Immunocompromised Host

The innate immune response to bacterial infection in a tissue compartment is modeled using an axiomatic approach, resulting in a three dimensional ODE system that describes the dynamics of bacteria, neutrophils and G-CSF (the neutrophils growth factor) in the site of infection. The modeling provide insights into the importance of killing mechanisms other then the neutrophils. Moreover, we suggest an interplay between the concentrations of macrophages in the tissue and neutrophil concentration in the blood.

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MS87

Systems Biology of the Pulmonary Infection Process in Humans

We have developed the capability to non-invasively acquire aerosolized droplets of alveolar lining fluid (AALF) from the human lung. The droplets can contain pathogens and pathogen secreted ligands. The droplets also contain biomolecules from the host airway. Using AALF time series we have begun to investigated two avenues. Our primary interest is to predict which patients will progress to develop pneumonia in the 72 hours prior to the manifestation of clinical symptoms. Our secondary interest is to develop a sound analytic framework from which we can regress early treatment gains.

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MS88

Clock-Driven Intermittent Controller and Model Based Predicitve Controller for Human Balancing Models

Stabilizability of unstable equilibria in the presence of reflex delay is investigated, such as stick balancing at the fingertip or postural sway during quiet standing. Two types of control concepts are investigated with respect to the critical reflex delay, for which stable balancing is possible: (1) the act-and-wait controller is a special version of clock-driven intermittent controllers; (2) the finite spectrum assignment approach is a kind of model based predictive feedback controller.

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MS88

Intermittent Open Loop Control in Humans: Can the Hypothesis be Tested?

Intermittent open loop control, otherwise known as serial ballistic control, has been proposed repeatedly during the last 60 years as a paradigm for human motor control. In the absence of rigorous, model based investigation and key experimental tests, this question has remained open. Here we present recent model based experimental results supporting the case that sustained human control is serial ballistic in nature and we consider explanations of why serial ballistic control is relevant.

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MS88

Evidence for Continuous Versus Intermittent Control Mechanisms Contributing to Control of Human Upright Stance

Controversy exists regarding whether human balance control is regulated using a continuous feedback mechanism versus intermittent control mechanism. Several recent studies present experimental results that purport to demonstrate the contribution of intermittent control. We show that all these experimental results are in good agreement with a simple continuous feedback model that has been used before to describe spontaneous sway properties of healthy young and elderly subjects as well as responses to various external perturbations.

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MS88

An Intermittent Control of a Double Inverted Pendulum: Roles of Hip Motions Examined with Human Postural Sway

Human upright quiet standing is stabilized by neural feedback control with a relatively large transfer delay. To better understand the neural strategy for stabilization, we considered dynamics of a double inverted pendulum model with an intermittent feedback controller. In-phase and anti-phase coordination between hip and ankle joints in the model was compared with those in human. We then discuss roles played by hip joint motion during human quiet stance.

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MS89

Modeling Stochastic Neural Dynamics: Approaches and Mathematical Issues

This talk will provide an overview of several approaches to studying stochastic dynamics of neuronal networks, highlighting and comparing approaches that will appear in other talks of the minisymposium while placing these in a broader context. Issues discussed will include choices of random graph models, when a random graph is unnecessary or inappropriate, and models for stochastic processes on the nodes. A particular focus will be on mathematical approaches to analyzing the network dynamics.

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MS89

Interaction of Biochemical and Neural Networks in the Brain

The standard electrophysiological perspective is that the brain consists of networks of neurons that influence each other through the biochemistry of neurotransmitter synthesis, release, and reuptake, viewing biochemistry as simply a means of neuron-to-neuron communication. However, many groups of neurons distantly release diffusing neurotransmitters that alter target biochemistry: the electrophysiology is the means by which the neurons project biochemical changes over long distances. The dynamics of interacting biochemical and electrophysiological networks provide interesting mathematical challenges.

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MS89

Optimal Reduction of Complexity for Ornstein-Uhlenbeck Processes on Random Graphs

Extending Schmandt and Galan's stochastic shielding approximation, we consider the optimal complexity reducing mapping from a stochastic process on a graph to an approximate process on a smaller sample space, as determined by the choice of a particular measurement functional on the graph. We quantify the error introduced by the approximation and provide an analytical justification for the method. We focus on the case of ion channel state partitioning into conducting versus nonconducting states.

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MS89

Jigsaw Percolation: Which Networks Can Solve a Puzzle?

Jigsaw percolation is a process with the following dynamics: groups of individuals merge if they are directly connected on an underlying social network, and if they have complementary information, i.e. compatible "puzzle pieces' which are connected via an auxiliary network. We analyze the probability of a total population merger, where a puzzle network is given and the social network is an Erdos-Renyi random network with given edge probability p.

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MS90

Subdiffusive Fractional Equations with Space-dependent Anomalous Exponents

We show that subdiffusive fractional equations are not structurally stable with respect to spatial perturbations to the anomalous exponent. To rectify this problem we propose the inclusion of the random death process into the random walk scheme from which we arrive at the modified fractional master equation. We analyze the asymptotic behavior of this equation, both analytically and by Monte Carlo simulation, and apply it to the problem of morphogen gradient formation.

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MS90

Propagation of Fronts in Subdiffusive Media

We consider two kinds of fronts in systems with subdiffusion, reaction fronts and fronts of phase transitions. For the analysis of reaction fronts, we use exactly solvable models with piecewise linear reaction functions. For fronts between stable states, a drastic difference from the case of normal diffusion is revealed. Exact solutions corresponding to propagating phase transition fronts are also found, and their transverse instability is investigated.

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MS90

Models and Tests for Anomalous Diffusion in Crowded Environment

Many experiments on the motion of particles in crowded environments hint towards anomalous diffusion, mostly subdiffusion. The nature of this subdiffusion can be quite diverse, and therefore needs for description within theoretical models based on different physical assumptions. The difference between time-inhomogeneous, non-ergodic models and ergodic ones is deeply rooted in the thermodynamics of the corresponding processes, and it can be done either by running a test for ergodicity or a one for time homogeneity. The distinction within the ergodic class can be based on specific tests of homogeneity of filling of the space by the corresponding trajectory and will be discussed in some detail based on analytical and numerical examples.

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MS90

Weakly Nonlinear Analysis of the Superdiffusive Brusselator Model near a Codimension-two Turing-Hopf Bifurcation Point

A weakly nonlinear analysis is performed near a codimension-two Turing-Hopf point of the superdiffusive Brusselator model in one spatial dimension. Two coupled amplitude equations describing the slow time evolution of Turing and Hopf modes are derived. The dependence of stability criteria of pure Turing, pure Hopf, and mixed mode solutions to long-wave perturbations on the anomalous diffusion exponents is discussed and compared to regular diffusion.

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MS91

Nonautonomous Control of Invariant Manifolds

It is well-known that the temporal evolution of stable and unstable manifolds play a significant role in transport in nonautonomous dynamical systems. As a first step towards understanding how to control such manifolds, this talk addresses the control problem of determining the nonautonomous velocity perturbation in two dimensions required to ensure that a one-dimensional heteroclinic manifold splits into stable and unstable manifolds whose primary segments lie along *specified* time-varying curves in space.

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MS91

A Stable Principle Manifold of a Separable Attractor of the Nonautonomous Chaotic Beam System

An elastic beam subject to moving contact loads models external forcing of fluids in internal ship tanks. The modeling PDE has chaotic solutions with an attractor with a decomposable form that identifies dimensionality reduction that encapsulates a Cartesian product, of a principle manifold corresponding to spatial regularity against a temporal low-dimensional chaotic attractor at a fixed site on the beam. The principle manifold serves to translate complex low-dimensional information at one site to other sites.

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MS91

Finite-Size Lyapunov Exponents (FSLE) and Lagrangian Coherent Structures

Finite-Size Lyapunov Exponents (FSLE) have proven to be effective indicators of hyperbolic Lagrangian Coherent Structures (LCS) in dynamical systems. However, computing FSLE involves integration of different trajectories over different time intervals, thus an exact mathematical connection between FSLE and LCS has been unknown. Here we establish such a connection, which turns FSLE from a heuristic indicator into a rigorous LCS detection tool under certain conditions. We illustrate our results on simple unsteady flow examples.

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MS91

Invariant Manifolds in Non-autonomous Equations

Economic models often lead to deep mathematical problems. For example, classical solutions of economic growth models induce implicit, non-autonomous differential equations, that are supplemented by *transversality* conditions. From a certain perspective, it is possible to relate the solutions of these equations to the existence of stable manifolds. Time dependence arises whenever models include discount factors. We explore the existence of invariant manifolds in this context and its relation to non-autonomous Hamilton-Jacobi problems.

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MS92

Plankton Bloom Front Meets Chain of Vortices in a Flow

Plankton blooms, particularly harmful algal blooms, can be described by excitable systems. We study the impact of a laminar one-dimensional flow as well as chain of vortices on diffusion fronts which develop from a phytoplankton-zooplankton system. We discuss the emergence of different plankton patterns depending on the different growth rates of the species, the relation between the front velocity, the mean flow velocity and the strength of the vortices.

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MS92

A Chemical Front in the Faraday Flow

We investigate the transport in a turbulent quasi twodimensional laboratory flow induced by capillary Faraday waves on a thin fluid layer. In experiments with an excitable autocatalytic chemical reaction in this flow, propagating chemical waves with a highly wrinkled front have been observed. These observations demand for a detailed study of the underlying advective transport. We first characterize the vortex patterns in the flow in the Eulerian frame and relate them to the geometric pattern of the Faraday waves. In a second part, we compute Lagrangian coherent structures (LCS) that determine the spatiotemporal mixing patterns. Simultaneous experimental measurement of the velocity fields and the chemical concentration allow for a superposition of the LCS onto the concentration field. This reveals that the LCS shape the advancing reaction fronts.

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MS92

Pinning and Invariant Barriers in Advection-reaction-diffusion Systems

Invariant manifolds are important barriers to passive tracers in 2D time-independent and time-periodic flows. Although these manifolds are no longer defined for time-aperiodic flows, the past decade of research has demonstrated the significance of finite-time-lyapunov-exponents (FTLE) and lagrangian coherent structures (LCS). Recently barriers to front-propagation in (time-independent and time-periodic) fluid flows have been identified - so called burning invariant manifolds (BIMs). We define an analog of the FTLE for front-propagation in time-aperiodic flows using a dimension reduction. This type of analysis may find application in the analysis of oceanic plankton blooms, turbulent combustion, and industrial chemistry.

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MS92

Experimental Studies of Barriers to Front Propagation in Vortex-dominated Flows

We present experiments on the behavior of propagating reaction fronts in laminar fluid flows. This is an issue with applications to a wide range of systems including combustion dynamics in flows with chaotic advection, microfluidic chemical reactors, and blooms of phytoplankton and algae in the oceans. To analyze and predict the behavior of the fronts, we generalize tools developed to describe passive mixing. In particular, the concept of an invariant manifold is expanded to account for reactive burning. "Burning invariant manifolds" (BIMs) are defined in a three-dimensional phase space. When projected into two spatial dimensions, these BIMs provide barriers that retard the motion of reaction fronts. Unlike invariant manifolds for passive transport, however, the BIMs are barriers for front propagation in one direction only. These ideas are tested and illustrated experimentally in a chain of alternating vortices and an extended, spatially-random pattern of vortices.

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MS93

Transport and Flow in Complex Networks: Cascading Overload Failures in Networks with Distributed Flows

In complex information or infrastructure networks, even small localized disruptions can give rise to congestion, large-scale correlated failures, or cascades, – a critical vulnerability of these systems. Here, we study cascades of overload failures for distributed flows in spatial and non-spatial random graphs, and in empirical networks (internet and power grid). We review and investigate a few recently proposed schemes to mitigate such failures (e.g., preemptive node/edge removal, edge weighting, and assigning excess capacities).

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MS93

Walking and Searching in Time-Varying Networks

We study random walks in time varying networks considering the regime of time-scale mixing. We derive analytically the stationary state and the mean first passage time of such processes. The findings show striking differences with respect to the well-known results obtained in quenched and annealed networks, emphasizing the effects of dynamical connectivity patterns in the definition of proper strategies for search, retrieval and diffusion processes in time-varying networks.

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MS93

Predicting Traffic Changes in the Wake of Geo-Localized Damages in Large-Scale Transportation Networks

Traffic flows obey a path-cost minimization principle, generating a heterogeneous use of network paths. Validated on a US highway transportation data-set we present a novel method for computing network flows using the radiation law [F. Simini et.al., Nature 484, 96 (2012)] and a range-limited, weighted betweenness centrality measure [M. Ercsey-Ravasz et.al. PhysRevE 85, 066103 (2012)]. We then use this method to quantify the non-local effects of geo-localized damages in the US highway transportation network.

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MS93

Power Grid Vulnerability to Geographically Correlated Failures

We consider line outages in the power grid, which are caused by a natural disaster or a large-scale attack. We present a model of such geographically correlated failures, investigate its properties, and show that it differs from models used to analyze cascades in the power grid. We show how to identify the most vulnerable locations in the grid and perform extensive numerical experiments with grid data to investigate the various effects of geographically correlated outages.

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MS94

Population Dynamics and Preferential Segregation

It is well-know that particles segregate in turbulent flows. If, however particles of different Stokes number react with each other, segregation of particles into different spatial regions may have a dramatic effect on population dynamics. We present first results on this topic by qualitative analysis and simple 2D numerical modeling.

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MS94

Interaction of Droplets and Turbulence in Rayleigh-Benard Convection

Responses of a droplet ensemble during an entrainment and mixing process at the edge of a cloud are investigated by means of three-dimensional direct numerical simulations. We combine the Eulerian description of the turbulent velocity, temperature and vapor content fields with a Lagrangian ensemble of cloud water droplets which are advected in the flow and shrink or grow in correspondence with the supersaturation at their position.

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MS94
Revisiting the Scaling Analysis of Irreversible Aggregation Dynamics

The analysis of the size distribution of droplets condensing on a substrate is a test ground for scaling theories. Surprisingly, a faithful description of its evolution must explicitly address microscopic nucleation and growth mechanisms of the droplets. In view of this we discuss here, how this breaking of universality relates to other systems with vastly polydisperse droplet size distributions, as they will be discussed in subsequent talks.

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MS94
Understanding Rainfall: Collisional Versus Non-collisional Mechanisms for Droplet Growth

I shall discuss the possible mechanisms for the growth of microscopic water droplets in clouds into rain drops. Collisional mechanisms are not effective in a critical range of droplet sizes. Two non-collisional routes for droplet growth will be considered: these are Ostwald ripening, and a new theory for growth due to fluctuations in supersaturation termed 'convective ripening'. Both mechanisms can be illuminated by experiments. I shall discuss experiments by Juergen Vollmer and co-workers on a 'test-tube' model for rainfall in a convectively stable atmosphere, which are nicely explained by invoking Ostwald ripening.

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MS95
Bifurcation Phenomena in a 2D Discontinuous Map

The physical situations that give rise to discontinuous maps are discussed and their 2D normal forms are explored. The character of the normal form depends on the derivatives of the map functions with respect to the parameters. Earlier work explored the bifurcations in this system under some assumptions. Here we report some results on the most general case of 2D discontinuous map.

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MS95
Multistability and Arithmetically Period-adding Bifurcations in Piecewise Smooth Dynamical Systems

Multistability, as characterized by the coexistence of multiple attractors, is common in nonlinear dynamical systems. In such a case, starting the system from a different initial condition can result in a completely different final or asymptotic state. The behavior thus has implications to fundamental issues such as repeatability in experimental science. Existing works on multistability in nonlinear dynamics focus mostly on smooth systems. A typical scenario for multistability to arise is when a Hamiltonian system becomes weakly dissipative so that a large number of KolmogorovArnoldMoser (KAM) islands become sinks, or stable periodic attractors. There has also been an interest in nonsmooth dynamical systems. For example, piecewise smooth systems have been known to arise commonly in physical and engineering contexts such as impact oscillators and switching circuits. Previous works have shown that nonsmooth dynamical systems can exhibit bifurcations that have no counterparts in smooth systems. The aim of this paper is to explore general phenomena associated with multistability in nonsmooth dynamical systems. We shall use a generic class of piecewise smooth maps that are representative of nonsmooth dynamical systems. By focusing on the weakly dissipative regime near the Hamiltonian limit, we find that multistability can arise as a result of various saddle-node bifurcations. A striking phenomenon is that, as a parameter characterizing the amount of the dissipation is decreased, the periods of the stable periodic attractors created at the sequence of saddle-node bifurcations follow an arithmetic order. We call such bifurcations arithmetically period-adding bifurcations. We provide physical analyses, numerical computations, and mathematical proofs to establish the occurrence of these bifurcations. Our work reveals that multistability can be common in nonsmooth dynamical systems, and its characteristics can be quite different from those in smooth dynamical systems.

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MS95
Codimension Two Border Collision Bifurcations in Piecewise Monotone Discontinuous Maps

We consider the bifurcation structures which originate from the intersection point of two border collision bifurcation curves. The classification of possible structures can be done by using the first return map in a suitable interval around the discontinuity point. This first return map is continuous at the codimension-2 point and the possible bifurcation structures depend on the shape of its branches (increasing or decreasing). Additionally, the connection to the Lorenz-like flows is emphasized.

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MS95
Bifurcation Structure in a Piecewise Smooth Map with Two Kink Points

We consider a family of one-dimensional piecewise smooth maps with two kink points. The map comes from an economic application. The bifurcation structure of the parameter space is studied. Using the skew tent map as a normal form for border collision bifurcations (BCB) we define the types of attractors which appear due the BCB of the fixed

point. Peculiarities of the bifurcation structure related to the horizontal branch of the map are described.

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MS96

Marine Bioinvasion in the Network of Global Shipping Connections

Transportation networks play a crucial role for the spread of invasive species. Here, we combine the network of worldwide cargo ship movements with environmental conditions and biogeography, to develop a model for marine bioinvasion. We classify marine ecoregions according to their total invasion risk and the diversity of their invasion sources. Our predictions agree with observations in the field and reveal that invasion risks are highest for intermediate geographic distances. Our findings suggest that network-based invasion models facilitate the development of targeted mitigation strategies.

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MS96

Successful Strategies for Competing Networks

We investigate competition between networks and how to design optimal strategies for the connection between them. Specifically, we consider two networks interacting through connector links and competing for centrality. We show how each network can improve the outcome of this competitive interaction by carefully selecting the type of connector links or reorganizing its internal structure. We also introduce a competition parameter, which quantifies which network is taking advantage of the other in real situations.

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MS96

Extreme Vulnerability of Network of Networks

Network science focused on studying a single isolated network that does not interact with other networks. In reality, many real-networks interact and depend on each other. I will present an analytical framework for the cascading failures, critical threshold and the giant component of a network of networks. Such systems have many novel features that are not present in classical network theory. Moreover, interdependent networks embedded in space are significantly more vulnerable compared to random networks.

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MS96

Network of Networks and the Climate System

We introduce a novel graph-theoretical framework for studying the interaction between subnetworks within a network of networks which allows us to quantify the structural role of single vertices or whole subnetworks concerning the interaction of subnetworks on local, mesoscopic and global scales. Applying this to climate data uncovers interesting features of the atmospheres vertical stratification, to identify interrelations of Indian and East Asian Summer Monsoon or to detect paleo-climatic variability transitions related to human evolution.

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MS96

Synchronization in Populations of Chemical Oscillators: Quorum Sensing, Phase Clusters and Chimeras

We have studied large, heterogeneous populations of discrete chemical oscillators (100,000) to characterize two different types of density-dependent transitions to synchronized oscillatory behavior. For different chemical exchange rates between the oscillators and the surrounding solution, we find with increasing oscillator number density (1) the gradual Kuramoto synchronization or (2) the sudden quorum sensing switching on. We also describe the formation of phase clusters and chimera states and their relation to other synchronization states. M. R. Tinsley, S. Nkomo, and K. Showalter, Nature Physics 8, 662 (2012).

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MS97

Modeling the Response of Coastal Ecosystems to Nutrient Loading, Climate Change, and Shellfish Aquaculture

Aquatic simulation models have emerged in recent decades as critical tools for the heuristic study of ecosystem structure and function. These models are also increasingly being used to inform management decisions on a variety of issues, particularly the effects of nitrogen abatement on the cultural eutrophication of estuaries. These two goals (research and management) often present contrasting requirements for model resolution, parameterization, and accuracy. The trend in both areas has been towards increasingly complex and highly resolved models. Limitations of these models, however, include their long run times, extensive time and resources required for model development, lack of user-friendliness, and large number of state variables and parameters which can be difficult to constrain, especially in systems without adequate data for verification of both state concentrations and rate processes. A growing body of literature is calling for development of simple and intermediate-complexity models as alternatives to these complex approaches, and new approaches are being developed for use in parallel with more complex models in a move towards ensemble predictions much like weather and hurricane forecasts. I will present results from a variety of simple and intermediate-complexity modeling approaches in U.S. East coast estuaries with a focus on predicting system response to changes in anthropogenic nutrient loading, ongoing climate change, expansion of shellfish aquaculture, and shellfish restoration. In addition to generating heuristic understanding, these models are being used to develop management recommendations and restoration alternatives, and are being deployed online for direct use by managers, educators, and other stakeholders.

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MS97

Size- and Stage-structured Population Model to Assess the Growth-mediated Effect of Environmental Conditions on Population Dynamics

Population abundance fluctuates over time. The fluctuation is caused by changes in survival and/or reproductive rates (vital rates). Determining how vital rates fluctuate and how they in turn affect population abundance is one of the main objectives of population biology. One of my current research focuses on investigating the effects of environmental conditions on population dynamics of white shrimp in the Gulf of Mexico. Previous studies have demonstrated that environmental conditions in an estuary affect individual growth of post-larval and marsh-stage juvenile shrimp. From a field experimental study, age-size relationship was determined. In addition, shrimps were sampled in situ to determine their size distribution. From these two data sets, size-specific instantaneous mortality of young shrimp was estimated. Then, a size- and stage-structured population model was used to assess the effects of variable individual growth rates on annual population growth rate. The result shows that the finite annual population growth rate can range from 0.4 to 1.1 based on the observed range of individual growth rate. Finally, the implication of the result on transient and asymptotic yield is discussed.

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MS97

Nonlinear Effects in Size-structured Models of Zooplankton Communities

There exist many challenges, both biological and modeling, inherent in marine ecosystems. The talks in this mini-symposium cover a wide-range of topics, from shellfish to phytoplankton. This introductory talk will introduce the topics that will be covered throughout this mini-symposium and some of the common modeling strategies that will be employed. Many of the overarching questions will be discussed, such as the effect of nutrient availability and climate change on population dynamics. The final part of the talk will explore some of these themes in a specific size-structured model of zooplankton communities.

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MS97

The Response of a Size-structured Plankton Community to Environmental Variability

The influence of fluctuating environmental conditions on plankton community structure is investigated in an idealized model for size-dependent phytoplankton-zooplankton interactions. When the model is forced with periodic nutrient pulses, the phytoplankton total abundance and size distribution are both controlled by the allometric relationships describing growth and grazing and by the amplitude and frequency of pulses. Results are compared to observed relationship between total chlorophyll and the relative abundance of small/large phytoplankton cells.

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MS98

Time-delayed Switching Control of Structures with Uncertainties

Models of balance with on-off control have attracted recent attention, in mechanics, robotics, and biology. We consider the influence of noise in these on-off systems through canonical models of balance, considering different noise sources in the setting of act-and-wait control, and contrast with randomness in feedback (state-dependent) control. Conditions for noise-sustained transients, typically undesirable in balance, are provided using numerical and analytical approaches.

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MS98

Oscillators with Large Delay

Differential equations with a large delay in one of their arguments show features reminiscent of spatially extended systems. Eigenvalues of equilibria and periodic orbits tend to form bands, for which one can derive easily computable formulas. This permits us to draw conclusions for a system with given coefficients but increasing delay. For example, one can find criteria, which ensure the co-existence of large numbers of stable periodic orbits for large delays.

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MS98

Dynamic Contact Problems Modeled by Delayed Oscillators

Dynamic contact problems are in the forefront of mechanical engineering research due to the expensive laboratory experiments and high-performance computing used at industrial R&D level. These multi-scale problems can successfully be transformed to delayed oscillators; this opens way to their analytical study needed for model validation and for testing numerical codes. Rolling of elastic wheels and cutting of metals are discussed as relevant examples leading to non-autonomous delay-differential equations like the delayed Mathieu equation paradigm.

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MS98

Irregular Motion Caused by State-dependent Delay

For $\frac{\pi}{2} < \alpha < \frac{5\pi}{2}$ the simple linear equation

$$x'(t) = -\alpha x(t-1) \qquad \in \mathbf{R}$$

has only non-real characteristic values, 2 in the right halfplane and the others in the left halfplane. We construct a state-dependent delay

$$d_U : C \supset U \to (0,2)$$

with $d_U(\phi) = 1$ for ϕ close to $0 \in C = C([-2,0],\mathbf{R})$ in such a way that the equation

$$x'(t) = -\alpha x(t - d_U(x_t))$$

has a homoclinic solution $x = h$,

$$h(t) \to 0 \quad \text{as} \quad |t| \to \infty, 0 \neq h_t = h(t+\cdot) \in C^1 = C^1([-2,0],\mathbf{R}).$$

The flowline

$$\begin{aligned} \mathbf{R} \ni t \mapsto h_t \quad &\in \quad X \\ &= \quad \{\phi \in U \cap C^1 : \phi'(0) = -\alpha\phi(-d_U(\phi))\} \end{aligned}$$

is a minimal intersection of the stable and unstable manifolds at equilibrium in the solution manifold X. This should imply chaotic motion close to the homoclinic loop.

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MS98

Delayed Control of Self-excited Vibrations in Elastic Structures

Flutter is an aeroelastic self-excited oscillation of aircraft wing with high frequency and large amplitude; it can cause a loss of structural integrity in wings. As active control has become a major method for flutter suppression of aircraft wings, it results in some new problems induced by the time delay in the controllers and filters. Both the negative and positive effects of the time delay on the flutter suppression of aircraft wings are discussed in this talk, but the positive effect is emphasized.

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MS99

Zonal Jets and Meridional Transport Barriers in Planetary Atmospheres

Theoretical results relating to KAM theory have led to the expectation that associated with zonal (west–east) jet streams in planetary atmospheres should be barriers which inhibit meridional (south–north) transport. Evidence will be provided for this expectation based on the analysis of: 1) winds produced by an idealized model of Jupiter's weather layer; and 2) winds produced by a comprehensive model of the Earth's stratosphere. This will follow a review of the relevant KAM theory results.

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MS99

Periodic Orbits and Transition to Chaos in Many-degrees-of-freedom, Mean-field Hamiltonian Systems

A study of transition to chaos in many-degrees-of-freedom systems is presented in the context of mean-field-coupled symplectic maps. The coupling is motivated by weakly nonlinear descriptions of plasmas and fluids. We focus on reversible twist and nontwist systems, and use continuation methods to compute symmetric periodic orbits with given rotation vectors. Preliminary ideas are presented on approximation of N-dimensional tori by periodic orbits, and the transition to chaos due to the destruction of the tori.

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MS99

Singularity Theory for Non-twist KAM Tori: A Methodology

We present a novel methodology to find a classify non-twist KAM tori in degenerate Hamiltonian systems.The classification of KAM tori which is based on Singularity Theory. The results are presented in an a posteriori format that let us to deal with far from integrable Hamiltonian systems. Remarkably, the proofs lead to numerical algorithms for computing non-twist KAM tori. This talk aims to illustrate the main ideas of our approach, including some numerical examples.

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MS99

Breakup of Invariant Tori of Volume Preserving Maps

KAM theory predicts that Diophantine, two-tori of 3D volume-preserving maps are robust. Though a torus with fixed rotation vector is fragile, robustness pertains to one-parameter families. We show that the breakup threshold can be predicted using an extension of Greene's residue criterion. Another of Greene's conjectures is that noble circles are locally most robust. We study the 3D analogue by investigating the robustness of tori with rotation vectors from cubic fields.

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MS99

Numerical Extension of the Center-stable and Center-unstable Manifolds of the Collinear Libration Points of the Spatial, Circular Restricted Three-body Problem

Results will be presented on the computation of the families of 2-dimensional invariant tori around the collinear equilibrium points of the restricted three-body problem, that span most of the center manifolds of these points. The linear approximation of their stable and unstable manifolds will also be covered. The different families of tori involved will be extended up to their natural termination or the computational limit of the numerical methodology used, that will also be discussed.

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MS100

Geometric Methods Applied to Non-holonomic Mechanics

In this talk we discuss some of the geometry behind the theory of nonholonomic systems. In particular we discuss when measure is preserved in various systems and the nature of the ensuing dynamics. We also discuss analogies of such systems with certain optical systems.

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MS100

Integrability and Quantization: A Geometric Approach

Abstract not available at time of publication.

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MS100

Geometry of the Three Body Problem

Abstract not available at time of publication.

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MS100

Geometric Mechanics of Elastic Rods in Contact

One of the most challenging and basic problems in elastic rod dynamics is a description of rods in contact that prevents any unphysical self-intersections. Most previous works addressed this issue through the introduction of short-range potentials. We study the dynamics of elastic rods with perfect rolling contact which is physically relevant for rods with rough surface. Such dynamics cannot be described by the introduction of any kind of potential. We show that, surprisingly, the presence of rolling contact in rod dynamics leads to highly complex behavior even for evolution of small disturbances.

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MS101

Measure Solutions for Some Models in Population Dynamics

We give a direct proof of well-posedness of solutions to general selection-mutation and structured population models with measures as initial data. This is motivated by the fact that some stationary states of these models are measures and not L^1 functions, so the measures are a more natural space to study their dynamics. Our techniques are based on distances between measures appearing in optimal transport and common arguments involving Picard iterations. These tools provide a simplification of previous approaches and are applicable or adaptable to a wide variety of models in population dynamics.

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MS101

Kinetic Models for Opinion Formation

We discuss nonlinear kinetic models for opinion formation. The evolution is described by systems of Boltzmann-like equations. We show that at suitably large times, in presence of a large number of interactions in each of which individuals change their opinions/positions only little, the nonlinear systems of Boltzmann-type equations are well-approximated by systems of Fokker-Planck type equations, which admit different, non-trivial steady states.

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MS101

Flocking Dynamics and Mean-field Limit in the Cucker-Smale-type Model with Topological Interactions

Motivated by recent observations of real biological systems, we introduce a Cucker-Smale-type model with interaction between agents depending on their topological distance, measured in units of agents' separation. We study the conditions leading to asymptotic flocking, i.e., finding a velocity consensus. Moreover, introducing the concept of topological distance in continuum descriptions, we show how to pass to the mean-field limit, recovering kinetic and hydrodynamic descriptions.

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MS101

Mathematical Modeling and Simulation of Pedestrian Motion

We present different modeling approaches for the motion of large pedestrian crowds and their efficient numerical simulation. We start on the microscopic level and discuss the transition to the corresponding meso- and macroscopic models. Here we focus on the particular interactions between pedestrians and other specific modeling aspects, like motion in congested areas. Pedestrian crowds show a complex dynamical behavior, which can be observed in the mathematical models. These equations are in general nonlinear and require flexible and efficient discretization techniques like discontinuous Galerkin methods. We illustrate this versatile behavior with numerical simulations.

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MS102

Mathematical and Statistical Modeling of Human Lymphocyte Proliferation with CFSE Data

Partial differential equation (PDE) models are presented to describe lymphocyte dynamics in a CFSE proliferation assay. Previously poorly understood physical mechanisms accounting for dye dilution by division, auto fluorescence and label decay are included. The new models provide quantitative techniques that are useful for the comparison of CFSE proliferation assay data across different data sets and experimental conditions. Variability and uncertainty in data and modeling are discussed.

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MS102

The Interaction of Antibiotic Drug Combinations is Dynamic: the Genomic and Theoretical Basis of Rapid Synergy Loss in Edible E.coli

When antibiotic efficacy & multi-drug antibiotic interactions are measured in standard pharmacological procedures, their inhibitory effect is usually measured over one day especially in academic studies. This is too short if we are to understand how drug efficacy changes over time because of evolution to treatment. The use of intensive procedures like "colony counting" produce data based on cell yield at 24h & not on growth rate measures throughout the 24h period. So we evaluated drug interactions on a continuous basis, observing hundreds of generations in experiments lasting days. Studies like this readily reveal evolutionary dynamics and highlight the dynamically unstable drug interactions. For example, the drug pair erythromycin & doxycycline kill synergistically over a ¡24-hour period & antagonise over longer periods. We show, using mathematical models & whole-genome analyses that rapid gene duplication of several drug-resistance operons is responsible for synergy loss.

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MS102

Ensemble Modeling of Immune Response to Influenza A Virus Infection

Human body responds to influenza infection by initiating a spectrum of immune responses, ranging from innate to adaptive cellular and antibody, which are regulated by an intricate network of signaling interactions that have not yet been completely characterized. In the talk I will outline a series of models that provide qualitative and quantitative prediction of the time course of the disease, aid in understanding of the mechanisms of the immune response, and have been utilized in the study the effects of an antiviral drug treatment. Our latest effort has been focused on ensemble models that reflect the uncertainty about parameter values, data sparseness, and the likely variation of the disease outcome across a population exposed to IAV. The technique is useful when the model contains many unknown parameters, such as reaction rate constants of biochemical processes, which are poorly constrained and their direct measurement in vivo is not feasible.

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MS102

Optimal Self-Sacrifice Facilitates Pathogen Invasion of the Gut

The interior lining of the human intestine is inhabited by populations of commensal microbiota, which provide defense against invasive bacteria. Surprisingly, *Salmonella Typhimurium* gains an environmental advantage over the commensals by provoking the hosts inflammatory defenses. Two hypotheses have been proposed to explain how *S. Typhimurium* gains this advantage: the food hypothesis and differential killing hypothesis. We develop and analyze a model for how these effects interact to determine optimal strategies for the Salmonella population.

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MS103

Networks from the Bottom Up

Using a statistical physics exact formulation of transfer of information from measurements to a model, we show how to complete Hodgkin-Huxley models of individual neurons through estimation of fixed parameters and unobserved states. The application of this to models of neurons in the avian song system will be presented.

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MS103

Scale-invariant Brain Dynamics: Theory Versus Experiments

The idea that the brain as a dynamical system fluctuates around a critical point received compelling support when *neuronal avalanches* were experimentally observed, their distributions of size and duration being compatible with power laws [Beggs & Plenz, *J. Neurosci.* **23** 11167 (2003)]. Since then, other signatures of scale-invariant brain dynamics were obtained in a variety of experimental setups. While models have been able to reproduce some of these features, many challenges remain and will be reviewed.

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MS103

How Synaptic Potentiation Balances Plasticity and Stability Within An *In Vitro* Network of Neurons

Long-term potentiation (LTP) is widely believed to be the physiological basis of learning and memory. Mechanisms underlying LTP have been studied extensively at the monosynaptic level, but the effects of LTP on larger scale networks of neurons remain poorly understood. We chemically induce LTP in a cultured network of hippocampal neurons and show that after synaptic potentiation, a network of *in vitro* hippocampal neurons returns to a homeostatic state after widespread increases in firing.

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MS103

Using Dynamical Information from One Node to Estimate the States and Parameters of Small Networks of Coupled Neuronal Oscillators

We consider small dynamical networks of coupled oscillators for which the network topology is unknown. Using partial knowledge of the oscillators' dynamics we estimate the coupling and state of each node. We focus on the case where the state time evolution from only one oscillator is available. We propose an adaptive strategy that uses synchronization between the true network and a replica network to estimate these features and apply it to small neuronal networks.

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MS104

Stochastic Switching and Alternating Activity Bouts Resulting from Reciprocal Inhibition and Applications to Sleep-Wake Cycling

'Sleep-active' and 'wake-active' neurons in the brains of mammals are thought to inhibit each other resulting both in discrete states of sleep and wake and switching between the two states. New behavioral data sheds light on the underlying neurophysiology. In infants, both sleep and wake bout durations have an exponential distribution with independent regulation of bout means. This suggests stochastic switching in a bistable system, and so we modeled this system as a pair of coupled, mutually inhibitory neurons receiving noisy driving currents. We examined bout durations of the two neurons, switching mechanisms, and dependence on system parameters. Regardless of parameter choices, we found that bout durations of a neuron are always exponentially distributed. Furthermore, bout switches were found to be primarily a consequence of release from inhibition rather than escape via excitation, and we found that inhibition allows independent control over bout lengths of the two neurons.

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MS104

Mutually Inhibiting Two Cluster Model for Sleep-

Wake Transitions

Sleep and wake states are governed by competitive interactions between neuronal networks, resulting in a power law distribution of wake bout durations. We modeled two mutually-inhibiting random graphs where each neuron can be in an excited, basal or inhibited state and fire according to a poisson process. Dynamics of the stochastic mean field equations for population of each state neuron is investigated to understand possible mechanisms of the power law behavior of bout durations.

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MS104

Characterizing Bistability in Stochastic Processes on Modular Neural Networks

Many real-world networks, including neuronal networks, exhibit modularity: their nodes can be partitioned into subsets with few links between, but many within. For a stochastic process on a network with two mutually inhibiting modules, we expect to observe bistability – alternating time intervals where each cluster is highly activated. In this talk we establish quantitative links between these vague notions of "bistability' and "modularity', as they relate to sleep-wake cycling dynamics.

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MS105

Experimental Study of Electrothermal 3D Mixing using 3D MicroPIV

In lab-on-chips, micro-mixing is a keystep to perform fast and reproducible reactions. For the last thirty years, dynamical system community has demonstrated that chaotic mixing must involve at least 3 dimensions. Yet, microfluidic research community has scarcely studied 3D mixing. Meanwhile, electrokinetics has emerged as an elegant way to drive vortices. By overlapping vortices in 3 dimensions, we present an original time dependent (3D+1) micro-mixer. Flows periodically stretch and fold, inducing chaotic advection, which is characterized by 3D μPIV.

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MS105

Chaotic Fluid Mixing for AC Electrothermal Flows by Blinking Vortices

We present an experimental and theoretical study of AC electrothermal chaotic mixing using blinking of asymmetric 2D and 3D electrothermal vortices. Electrothermal flows are modelled by finite element method using COMSOL software based on an enhanced electrothermal model. We use the mix-variance coefficient (MVC) and mix-norm on experimental particle detection data and numerical trajectory simulations to evaluate mixing at different scales including the layering of fluid interfaces by the flow, a key-point for efficient mixing. The blinking vortices method greatly improve mixing efficiency. The effect of blinking frequency and particle size is studied. Theoretical, experimental and simulation results of the mixing process will be presented.

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MS105

Creation and Manipulation of Lagrangian Flow Structures in 3D ACEO Micro-flows

Flow forcing by AC electro-osmosis (ACEO) is a promising technique for the actuation of micro-flows. Its utilization to date mainly concerns pumping and mixing. However, emerging micro-fluidic applications often demand multiple functionalities within one device. This is typically achieved via complex system designs. The present study explores first ways by which this may be accomplished in a standard micro-channel via systematic creation and manipulation of 3D Lagrangian flow structures using ACEO.

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MS105

Understanding Chaotic Mixing and Reversal Using Linear Flow Models

It has long been known that convective diffusive irreversibility in reversing Stokes flows can be used to separate solutes based on diffusion. We consider a reversal

process in Stokes flows in the presence of weak diffusion using chaotic and non-chaotic flows. We seek to understand the distinct effects that chaotic flows have on the loss of reversibility relative to non-chaotic flows using rate-independent observables. I will present results from numerical simulation for comparison of the two classes of Stokes flows. Using linear flows as models, I will show that the decay of reversibility presents universal properties. In nonlinear flows, I will show that this breaks down due to the distribution of strain rates. In the limit of infinitesimal diffusivity, chaotic flows exhibit qualitatively distinct behavior with complete loss of sensitivity to the level of noise. Finally, I will discuss the relevance of the study of convective diffusive irreversibility in reversing flows to mixing.

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MS106

Elongated Swimming Particles in a Chaotic Advecting Flow

We investigate the dynamics of self-propelled, point-like particles advected in a two-dimensional chaotic flow. Swimming is modeled as a combination of fixed intrinsic speed and stochastic terms in translational and rotational equations of motion. Interaction of active particles with the dynamical structures of flow leads to macroscopic effects on particle transport. We work with both spherical and ellipsoidal swimmers and compare the two cases. We show that elongated swimmers with high speed get attracted to the unstable manifolds of hyperbolic fixed points; and their transport is enhanced relative to swimming spheres.

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MS106

Burning Manifolds in the Wake of a Cylinder

Passive chaotic advection in open flows, like in the flow around a cylindrical obstacle, is governed by an invariant chaotic set. The long-time trajectories cover the unstable manifold of the chaotic set, while its stable manifold separates the trajectories of different long-time behaviour. When an active process associated with front propagation takes place in such flows, a possible approach to model the front motion concerns the particles on the front as fluid elements having an orientation besides their position. Their motion can then be investigated as a low order dynamical system, in the spirit of burning manifolds that serve as transport barriers in such "chemical flows". Now we aim at investigating the behaviour of this extended dynamical system, taking the orientation of the front as an independent variable. We expect to gather information on how the location of the burning manifold depends on the initial front angle and velocity.

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MS106

Front Propagation in Fluid Flows: A Swimmer's Perspective

This talk considers the generalization of passive advective transport to "active" media, specifically to media that support some kind of front propagation: for example, the expansion of chemical reaction fronts in microfluidic mixers or plankton blooms in large-scale oceanic flows. A low-dimensional nonlinear dynamics model, in which the front element can be viewed as a "swimmer" in the flow, is used to predict the existence–and to explain the properties–of robust, one-sided barriers to front propagation. We call these barriers burning invariant manifolds (BIMs). BIMs play a central role in guiding the propagating fronts through the medium, determining the patterns formed by the fronts, and in determining the average propagation speeds. We compare our theory to table-top experiments in magneto-hydrodynamically driven flows, and we highlight the role of BIMs for experimental phenomena, such as the mode-locking and pinning of reaction fronts.

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MS106

Navigating the Lagrangian Flow Map – Globally Optimal Feedback Control of Underpowered Vehicles in Time-varying Flow Fields

The optimal feedback control problem of interest takes the form of a time-varying HJB PDE. The solution of this PDE – the "value function' – is the optimal cost-to-go as a function of space and time. In the simplest case, the vehicle speed is fixed, the value function depends solely on the position of the vehicle at the fixed final time (making it constant along optimal trajectories), and the optimal control is simply to steer down the gradient of the value function. Solving for the value function is difficult because it is neither C^1 nor C^0, due to the presence of locally optimal trajectories and the small vehicle speed, respectively. Nevertheless, we compute the value function backwards in time using a Godunov, semi-Lagrangian finite difference scheme. Moreover, we explain the relationship between the optimal control and the Lagrangian structure of the flow itself, observing the flow's mapping of optimal trajectories from 3D space-time to the 2D time slice of interest.

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MS107

Time Delay and Symmetries in Antigenic Networks

In the studies of host-pathogen interactions, an important role is played by the structure of antigenic variants associated with a pathogen, as well as the properties of immune response. Using a model of antigenic variation in malaria, we illustrate how the methods of equivariant bifurcation theory can be used to analyse symmetry properties of antigenic networks and draw insightful conclusions about possible dynamical behaviours. Particular attention is paid to the role played by immune delay.

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MS107

Time Delays and Clustering in Neural Networks

We study the existence and stability of cluster states in a network of inherently oscillatory neurons with time delayed, all-to-all coupling. Cluster states are periodic solutions where the network splits into groups. Neurons within a group are synchronized, while neurons in different groups are phase-locked with a fixed phase difference. We reduce the system of delay differential equations to a phase model where the time delay enters as a phase shift and use this phase model to show how the time delay affects the stability of various symmetric cluster states. Analytical results are compared with numerical bifurcation studies of the full system of delay differential equations.

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MS107

Designing Connected Vehicle Systems with Time Delays

Arising wireless communication technologies allow us establish interactions between distant vehicles. Incorporating such information in nonlinear vehicle controllers may extinguish nonlinear congestion waves triggered by human drivers. On the other hand, these connections usually include long delays which makes the design very challenging. In this talk we investigate the dynamics of connected vehicle systems at the linear and nonlinear level and lay out an experimental setup that allows one to test the designed algorithms.

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MS107

Spatio-temporal Patterns in Lattices of Delay-coupled Systems

In our recent publications [Phys. Rev. Lett. 107 (2011) 228102, Chaos 21 (2011) 047511] we show how spatio-temporal spiking patterns can be created in a ring of unidirectionally delay-coupled neurons. This talk reports about a higher-dimensional extension of this technique. In particular, arbitrary stable two-dimensional patterns can be created by a lattice of unidirectionally coupled neurons with periodic boundary conditions (torus) with appropriately adjusted time delays.

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MS108

Synchronizing Frequency Selective Maps

In cognitive radio, it is frequently desirable to avoid interfering with other transmitters by removing certain frequencies from a signal to be transmitted. I show here that it is possible to design chaotic maps in which certain frequencies are absent, and that these maps may be self-synchronized. The synchronized maps are resistant to interference within the excluded frequency bands.

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MS108

Chaotic Signals for Digital Communications

In this paper we present a system-level overview of the Chaos modem prototype that we have developed. Our Chaos modulation provides a BER lower than an uncoded BPSK and at the same time a bandwidth efficiency equal to that of BPSK with equivalent spreading. Improved LPI/LPD and AJ characteristics are also provided by our Chaos packets. Results on a communications video link developed on our FPGA Chaos hardware platform with A/D and D/A converters will be presented.

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MS108

Harnessing Chaos for Digital Communications

Chaotic signals have offered promise for secure communications for more than two decades, yet have faced challenges in terms of synchronization, computational precision, and modulation efficiency. Recent work at the Harris Corporation has harnessed the core chaotic processes via 'digital chaos' in both FPGA and DSP implementations to efficiently achieve the desired goals of secure chaotic communication systems within the bounds of practical software-defined hardware platforms.

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MS108

On the BER Performance of a Class of Chaotic Spreading Functions

This paper aims to analyze the performance of a particular class of chaotic digital communication systems that uses a slice of a discrete-time chaotic function as the spreading sequence. Using the cubic map as the spreading function of choice, this paper investigates the temporal and statistical properties of the cubic map, and then derives an expression for the bit error rate probability for this class of systems. A similar analysis is performed for a digital communication system that uses a psuedorandom binary sequence as the spreading code. A comparision between the two systems shows that the latter possesses a lower probability of bit error at the expense of being easier to detect as compared to the chaotic digital communication system.

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MS109

Data Assimilation for Two Model Problems: Targeted Observations and Parameter Estimation

We explore novel data assimilation (DA) techniques for two model problems, one forecasting the propagation of a front and the other a toy chaotic system. Using the local ensemble transform Kalman filter (LETKF) DA method, we demonstrate LETKF with targeted observations based on largest ensemble variance is *skillful* in outperforming LETKF with randomly located observations. We also apply the hybrid ensemble Kalman filter parameter estimation method LETKF+sEnKF to further improve state estimation skill.

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MS109

Lagrangian Data Assimilation for Point-Vortex Systems

Assimilating Lagrangian data (e.g. those from ocean drifters) into point-vortex models to estimate the unobserved vortex centres is a challenging filtering problem due to nonlinear features of Lagrangian drifters that can fail the standard Kalman filter and its variants. Therefore, we adopt the particle filtering approach to assimilate information from different launching positions of tracers for various point vortex systems. The results will gain our understanding to the optimal launching positions to predict/track large-scale eddies.

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MS109

A Hybrid Ensemble Kalman/Particle Filter for Lagrangian Data Assimilation

Lagrangian data assimilation involves using observations of the positions of passive drifters in a flow in order to obtain a probability distribution on the underlying Eulerian flow field. Several data assimilation schemes have been studied in the context of geophysical fluid flows, but many of these have disadvantages. In this talk I will give an overview of Lagrangian data assimilation and present results from a new hybrid filter scheme applied to the shallow water equations.

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MS109

Estimating Parameters in Stochastic Systems: A Variational Bayesian Approach

Data assimilation can often be seen from a Bayesian perspective, however most operational implementations introduce approximations based on a very small number of samples (ensemble Kalman filter) to perform a statistical linearization of the system model, or seek an approximate mode of the posterior distribution (4DVAR). In statistics, alternative approaches are based on Monte Carlo sampling using particle filters or path sampling, neither of which is likely to scale well enough to be applied to realistic models in the near future. This work introduces a new approach to data assimilation based on a variational treatment of the posterior distribution over paths.

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MS110

The Influence of Local Interactions Between Plants and their Natural Enemies on Plant Diversity

Seedling patterns resulting from plant mortality due to seed predators and pathogens are hypothesized to play a key role in maintaining plant diversity, while limited seed dispersal may contribute to species coexistence. I investigate how different patterns of dispersal and plant mortality affect seedling spatial patterns, and how these patterns relate to plant coexistence using spatially explicit stochastic models that incorporate the multiple spatial and temporal scales over which these processes occur.

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MS110

Stochastic Automaton Model for Ant Foraging and Territorial Competition

We simulate cellular automaton with a set of individual-based rules to reproduce spatiotemporal dynamics arising from local interactions of ants in colony. Ants deposit diffusible chemical pheromone that modifies local environment for succeeding passages. Individual ants, then, respond to conspecific/heterospecific pheromone gradients, for example, by altering their direction of motion, or switching tasks. We describe ant's movement by reinforced random walk, and use game-theoretic framework for modeling territorial conflicts. We study patterns (foraging trails, territoriality, etc.) emerging from 'microscopic' interactions of individual ants. We derive macroscopic PDEs by considering continuum limits of the mechanistic microscopic dynamics, and compare the two models.

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MS110

Trail Formation Based on Directed Pheromone Deposition

Ants are able to build trail networks on a very large scale. The trails are based on the deposition of small amount of chemicals called pheromones. In this talk, we introduce an Individual-Based Model to describe the formation of these networks. The novelty of the model is to consider deposited pheromones as small pieces of trails that each ant can follow. Numerically, we observe the emergence of large and flexible networks. We analyze how the trail patterns depend on the strength of the ant-pheromones interaction and show the existence of a phase transition. Finally, we introduce the kinetic and macroscopic limit of the model.

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MS110

Derivation of Coarse-Grained Models of Bi-Directional Pedestrian Traffic From Stochastic Microscopic Dynamics

Microscopic rules for pedestrian traffic in a narrow street or corridor are discussed and the corresponding stochastic system modeling the pedestrian bi-directional flow is introduced. Mesoscopic and macroscopic PDE models for the pedestrian density are derived. The macroscopic PDE model is a system of conservation laws which can change type depending on the strength of interaction between the pedestrian flows and initial conditions. Behavior of the stochastic and the coarse-grained models is compared numerically for several different regimes and initial conditions. Finally, nonlinear diffusive corrections to the PDE model are derived systematically. Numerical simulations show that the diffusive terms can play a crucial role when the conservative coarse-grain PDE model becomes non-hyperbolic.

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MS111

The Wiggling Trajectories of Bacteria

Many motile bacteria display wiggling trajectories, which correspond to helical swimming paths. We observe and quantify the helical wiggling trajectories of Bacillus subtilis and show that flagellar bundles with fixed orientation relative to the cell body are unlikely to produce wiggling trajectories with pitch larger than 4 μm. On the other hand, multiple rigid bundles with fixed orientation, similar to those recently observed experimentally, are able to produce wiggling trajectories with large pitches.

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MS111

Cellular Dynamics Involved in Immune Reactions During Healing Processes

We propose a partial differential equation model adapted from the principles of wound healing studies and analyze it to gain insights regarding the dynamics of immune cells/proteins following the insertion of a foreign body. Specifically we look at the multiple roles of macrophages and the conditions for stabilizing/destabilizing the equilibrium state. Furthermore, we investigate the impact of mesenchymal stem cells on the stability and the transient behavior of the system.

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MS111
Pairwise Interaction in Micro-swimming

A key observation in experiments and numerical simulations of suspensions of micro-swimmers is that 'pushing' organisms have a stronger tendency toward alignment compared to 'pulling' organisms. It is impossible to characterize the above phenomena without making reference to two-point statistics of the system such as orintational correlations of pairs of swimmers. It is therefore natural to seek an understanding of the behavior of an isolated pair of swimmers as a first step to understanding these systems. Such an analysis leads to a two way diffusion problem. Proper boundary conditions as well as approximate solution methods for this problem will be discussed. Subsequently the pairwise solution will be used to try to characterize the behavior of a multi-body suspension.

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MS111
Multiscale and Hybrid Models of Bacterial Chemotaxis

Chemotaxis is the directed cell movement in response to external chemical signals. Bacterial chemotaxis is a critical process in bacterial infections and bioremediation. At the population level, bacterial chemotaxis has been modelled by macroscopic Patlak-Keller-Segel equations. However, these equations do not match recent experimental data in oscillatory signal fields. In this talk, I will present our recent progress in deriving PDE models of bacterial chemotaxis from descriptions of single-cell signalling and movement, and comparisons of PDE models with hybrid models that integrate more details of single cell signaling and movement. Through these results I will clarify the performance and applicability of PKS equations in modelling bacterial chemotaxis.

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MS112
A Time Since Last Infection-Dependent Epidemiological Model

The aim of this work is to propose a model for infectious agents with transmission rates that vary during the infectious period, and/or that can cause reinfection. Existence, positivity, regularity, continuity of the solutions, and analysis of the existence and stability of equilibria is conducted using strongly continuous nonlinear semigroups. The model exhibits interesting outcomes, including existence of multiple endemic equilibria, backward bifurcations, and endemic equilibria even in the absence of vital dynamics.

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MS112
Resistance to Larvicides in Mosquito Populations and How It Could Benefit Malaria Control

We model larviciding of mosquitoes taking into account the evolution of resistance to the larvicides, the evolutionary costs of resistance and the implications for malaria control. A possible malaria control strategy is to shorten this adult lifespan by larviciding with a potent larvicide to which mosquitoes become resistant. This novel strategy is studied using a mathematical model for the wild type and resistant mutants and by incorporating the malaria disease dynamics using an SEI type model with standard incidence that incorporates the latency period of the parasite in wild type and resistant mosquitoes.

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MS112
Mathematical Modeling of the HIV/AIDS Epidemic in Cuba

HIV is a pandemic which has accounted for more than 30 million deaths since 1981. The Caribbean nation of Cuba, where HIV/AIDS prevalence is reported to be less than 0.1%, has remained remarkably unscathed. The success in Cuba can be attributed to its extremely effective national program for the prevention and control of HIV/AIDS, initiated in 1983. In this talk, I will discuss the strategies that the Cuban government has taken to monitor and manage the HIV/AIDS epidemic. I will present a detailed qualitative analysis of the governing nonlinear system of differential equations and then provide a more general model that divides the undiagnosed HIV-infected class into two classes, one containing individuals who acquired the infection via sexual transmission, and the other containing individuals who acquired the infection via nonsexual transmission, which can serve as a model for other regions of the world in which transmission by nonsexual means plays a substantial role.

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MS112
Endemic Bubbles Generated by Delayed Behav-

ioral Response in Epidemic Models

Several models have been proposed to capture the phenomenon that individuals modify their behavior during an epidemic outbreak. This can be due to directly experiencing the rising number of infections, media coverage, or intervention policies. In this talk we show that a delayed activation of such a response can lead to some interesting dynamics. In the case of SIS type process, if the response is not too sharp, the system preserves global stability. However, for sharp delayed response, we can observe stability switches as the basic reproduction number is increasing. First, the stability is passed from the disease free equilibrium to an endemic equilibrium via transcritical bifurcation as usual, but a further increase of the reproduction number causes oscillations, which later disappear, forming a structure in the bifurcation diagram what we call endemic bubble.

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MS113

Computing Optimal Paths in Stochastic Dynamical Systems with Delay

Based on variational theory, we present a numerical method for computing optimal transition pathways in stochastic differential equations with delay. We compute the most probable transition path (represented as heteroclinic structures) resulting from the iterative solution of a two-point boundary value problem which minimizes the action in a corresponding deterministic Hamiltonian system. We apply it to continuous stochastic systems, such as noisy nonlinear oscillators, and large discrete systems, such as epidemic rare events.

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MS113

Interplay of Bistability, Noise, and Time-delay in Semiconductor Lasers: Complex Dynamics and Potential Applications

I present experimental, numerical, and analytical results on noise induced square-wave (SW) switching in lasers with time-delayed feedback/coupling. The SWs are optically induced and controlled by the delay, making them attractive for applications. Stable SWs occur for adequate parameter regions; outside these regions the SWs are transient towards the model steady-states. Due to delay-noise interactions, we show that noise can be exploited to increase the duration of the SW transient.

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MS113

Synchronization of Degrade and Fire Oscillators by a Common Diffusible Activator

Delayed feedback has successfully been used to describe a variety of biological oscillators, both natural and synthetic. A recent example is the application of a delayed negative feedback formalism (degrade and fire) to model a population of oscillators that are synchronized by a diffusible activating signal. We present analytical and computational results for the synchronization of an ensemble of degrade and fire oscillators which couple through a common delayed positive feedback signal.

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MS113

Statistical Multi-moment Bifurcations in Random Delay Coupled Swarms

We study randomly distributed time delay coupling on the dynamics of large systems of self-propelling particles. Bifurcation analysis reveals patterns with certain universal characteristics that depend on distinguished moments of the time delay distribution. We numerically and analytically show that complex bifurcating patterns depend on all of the moments of the delay distribution. Moreover, there is a noise intensity threshold that forces a transition of the swarm from a misaligned state into an aligned state.

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MS114

Leading from Within: New Leadership Models in Swarms

We report on efforts to analyze models of swarms with *covert leaders*. In three-zone swarming, individual behavior is driven by the position and orientation of neighboring individuals in each of three concentric zones, corresponding to repulsion, orientation and attraction respectively. The fundamental purpose of this research is to understand how leadership affects the underlying dynamics and information transfer within the swarm, and we discuss new stability boundaries for continuum models for swarming with leadership.

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MS114

A Nonlocal Continuum Model for Locust Phase Change and Swarming

The desert locust *Schistocerca gregaria* has two interconvertible phases, solitarious and gregarious. Solitarious (gregarious) individuals are repelled from (attracted to) others, and crowding biases change towards the gregarious phase. We construct a model of the interplay between phase change and spatial dynamics leading to locust aggregations. The model is a system of nonlinear, nonlocal advection-reaction equations. We derive instability conditions for the onset of a locust aggregation, characterized by collective transition to the gregarious phase. Via a model reduction to ODEs describing the bulk dynamics of the two phases, we calculate the proportion of the population that will gregarize. Numerical simulations reveal transiently traveling clumps of insects and hysteresis.

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MS114

Social Intelligence: How Grouping Leads to Effective Information Use in Mobile Animals

In this talk I will present some recent work on information and its use within swarming systems. I will outline some empirical results pertaining to information sharing in schooling fish. I will then present some reduced models based around simple coordination games, that capture the same qualitative features as the real systems, such as localized interaction, social influence, and rapid transitions to ordered states, but which allow some analytical treatment.

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MS114

Design and Prediction of Co-dimension One Pattern Formation of Non-local Collective Motion

In this talk we present recent results on pattern formation of objects modeled by particles which obey non-local collective motion laws. More specifically, we develop a nonlocal linear stability analysis for particles which aggregate uniformly on a $d-1$ sphere. Remarkably, linear theory accurately characterizes patterns in the ground states from the instabilities in the pairwise potential. This aspect of the theory allows us to design specified potentials which assemble into targeted patterns.

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MS115

Efficient Computation of Invariant Tori in Volume Preserving Maps

Volume preserving maps naturally arise in the study of incompressible fluid flows. Codimension one invariant tori play a fundamental role in the dynamics of these maps as they form boundaries to transport within the system. In this talk I will present a quasi-Newton scheme to compute the invariant tori of three-dimensional, volume-preserving maps. I will further show how this method can be used to predict the perturbation threshold for their destruction.

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MS115

Transport in a 3D + 1 Ocean

A central theoretical difficulty in ring dynamics is the lack of unambiguous phenomenological criteria for quantifying their formation. We study the separation of Eddy Franklin, formed during the DeepWater Horizon incident, with the data assimilating Naval Research Laboratory RELO model. A strong hyperbolic region with intersecting stable and unstable 2D material surfaces marked ring separation. The hyperbolicity developed simultaneously at all levels. Intersecting stable and unstable manifolds provides an easily diagnosed signal of ring separation.

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MS115

Finite-Time Transport in Aperiodic Volume-Preserving Flows

We present a new method for computing the volumes of lobes comprising finite-time transport between arbitrarilydefined regions in aperiodic volume-preserving flows. Compared to a standard volume integral approach, our method provides a reduction in dimension of the trajectory information necessary to compute these lobe volumes. We introduce the theory in 2D, and illustrate its application by computing transport within a simple model of a 3D aperiodic rotating Hills vortex.

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MS115

Dynamical Systems Analysis of a Three-dimensional Time-dependent Ekman-driven Fluid Flow

Techniques from the dynamical systems theory are applied to study a 3-dimensional time-dependent fluid flow in a rotating cylinder. The circulation in this system is driven by a stress imposed at the upper surface. The motion in a radially symmetric steady background state is regular (non-chaotic), whereas the perturbed asymmetric time-dependent flow is characterized by the presence of both regular and chaotic fluid parcel trajectories, with regular regions acting as transport barriers. This is consistent with an extension of the KAM theorem. Chaotic motion arises as a result of resonances, and a formula for the resonance widths is derived. A simple kinematic model is used to study the geometry of barriers, manifolds, resonances, and other objects that provide a template for chaotic stirring in this flow. A high-resolution spectral element model is then used to check the validity of our results in realistic settings and to explore different parameter regimes.

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MS116

Observability-based Sensor Placement for Biological and Bio-inspired Systems

The focus of the work in this project is the exploration of the coupling of control and sensing in nonlinear dynamical systems. These methods are being developed with a focus on tracking of position and strength of vortices behind a pitching and heaving airfoil, strain sensor distribution in deformable insect wings for agile flight, and relative locations of sensors and actuators in engineered and biological systems.

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MS116

Designing Dynamics for Cooperative Learning by Multiple Agents

We consider the problem of designing distributed dynamics capable of learning an unknown vector from intermittent, noisy measurements made by multiple agents subject to time-varying communication restrictions. We propose a simple individual agent dynamic and study performance of the interconnected system. Our main results bound the learning speed of these dynamics in terms of combinatorial measures of the time-varying graph sequence, which encodes the restricted communication among the agents.

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MS116

Distributed Control and Optimization for Spatiotemporal Sampling

This talk will present two approaches for optimization of spatiotemporal sampling with multiple vehicles. First, coordinated trajectories for sampling a parametrized flowfield are optimized using the empirical observability gramian from nonlinear observability. Second, sampling trajectories are designed for nonstationary fields in which the spatial and temporal statistics may vary in space and time. In both approaches, we use tools from nonlinear control, specifically Lyapunov-based control, to design decentralized algorithms for stabilization of multi-vehicle sampling formations.

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MS116

Distributed Control of Mobile Sensing Resource Distribution in Flows

We consider distributed control policies to enable a team of homogeneous agents to maintain a desired spatial distribution in a geophysical flow environment. Stability properties of the ensemble dynamics of the distributed control policies are presented in the presence of uncertainty. Since realistic quasi-geostrophic ocean models exhibit double-gyre flow solutions, we use a wind-driven multi-gyre flow model to verify the proposed distributed control strategy and compare our control strategy with a baseline deterministic strategy.

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MS117

Symmetries and Compositionality for Control in Complex Cyber-Physical Systems

This talk considers control of symmetric systems, which are systems, typically cyber-physical systems, which are comprised of many diffeomorphically-related components that are interconnected in a regular manner. Specifically, we consider a set of generators, X, and an associated group, G. Two components are interconnected if $g_1 = sg_2$ with $s \in X$ and $g_1, g_2 \in G$. Two different systems, G_1 and G_2, are defined as equivalent if they have the same generators and identical component dynamics (they will be different if they have different relations).

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MS117

Incorporating Uncertainties in Dynamics and Observations for the Prediction Problems in Geophysical Systems

Abstract not available at time of publication.

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MS117

Mixing with Natural Convection

The mixing properties of a natural convective flow inside a cubic box with time-dependent temperatures on the vertical walls are explored. We identify the symmetry planes, periodic lines and invariant surfaces for the corresponding Stokes problem following the methodology of Clercx and colleagues. Using Poincar maps, elliptic and hyperbolic segments of the periodic lines are found. The topological changes introduced on the invariant surfaces due to a nonlinear perturbation, are briefly discussed.

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MS117

Nonlinear Effects of Electrostatics in Industrial Processes

Electrical charging of agitated grains is an archetypal example of a many-body system far from equilibrium that exhibits highly organized - and enormously powerful - collective behaviors such as multi-million volt lightning in sandstorms. In this talk, we present a simple yet predictive model for the charging of granular materials in collisional flows based on straightforward dynamical systems reasoning. We confirm the models predictions using discrete element simulations and a tabletop granular experiment.

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MS118

Entire Solutions for Lattice Differential Equations with Obstacles

We construct entire solutions for scalar bistable lattice differential equations with obstacles in more than one spatial dimension. The method of proof is based on comparison principles. The anisotropy in the lattice complicates the construction of super-solutions as compared with the PDE case.

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MS118

Positive Stationary Solutions and Spreading Speeds of KPP Equations in Locally Spatially Inhomogeneous Media

This paper mainly explores spatial spread and front propagation dynamics of KPP evolution equations with random or nonlocal or discrete dispersal in unbounded inhomogeneous and random media and reveals such an important biological scenario: the localized spatial in-homogeneity of the media does not prevent the population to persist and to spread, moreover, it neither slows down nor speeds up the spatial spread of the population. This is joint work with Dr. Wenxian Shen.

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MS118

Transition Fronts in Lattice Differential Equations

The purpose of this talk is two-fold. First we will provide an overview of the talks in both Part I and Part II of this minisymposium. Second we consider transition fronts for lattice differential equations in the presence of obstacles. Our interest is in both bistable and monostable dynamics. This is joint work with M. Brucal-Hallare, A. Hoffman, H.J. Hupkes, and A. Zhang.

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MS119

Information Geometry and its Application in Space Tracking

Information geometry seeks to study the geometric structure of probability density function spaces. It is particularly useful when the uncertain system subject to study is neither Cartesian nor Gaussian. These features render

Cartesian and Gaussian classical approaches to uncertainty propagation ineffective. An example of such systems is tracking of space objects that satisfy Hamiltonian dynamics. This talk investigates the relationship between Hamiltonian dynamics-based uncertainty propagation and that dictated by the geodesic equation from information geometry.

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MS119

Symplectic Constraints with Applications to Spacecraft Navigation

We begin with an overview of symplectic constraints in Hamiltonian dynamical systems. We then discuss new results on the evolution of time-dependent symplectic cross-sections found in tube invariants of normally hyperbolic invariant manifolds, such as the libration points in the classic three-body problem. Finally, we discuss how these results might be applied to interplanetary space-mission design.

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MS119

Symplectic Semiclassical Wave Packet Dynamics

I will talk about the geometry and dynamics of semiclassical wave packets, which provide a description of the transition regime from quantum to classical mechanics. I will show how to formulate semiclassical mechanics from the symplectic-geometric point of view by exploiting the geometric structure of quantum mechanics; this approach effectively "strips away" quantum effects from quantum mechanics and incorporates them into the classical description of mechanics.

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MS119

Mapping Probability Distributions Nonlinearly in Symplectic Dynamical Systems

The dynamical evolution of probability distributions in symplectic dynamical systems are studied, with an emphasis on systems mapped by Hamiltonian Dynamics. Fundamental conservation laws and constraints for symplectic systems are expressed in tangible ways for probability distributions, these include Liouvilles Theorem, Gromovs Non-Squeezing Theorem, and the Integral Invariants of Poincare-Cartan. These connections lead to implications and applications for the prediction of deterministic systems with uncertain initial conditions.

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MS120

Diffusion-mapped Delay Coordinates for Time Scale Separation

An under-appreciated fact about attractor reconstruction is that the induced geometry of time-delay coordinates increasingly biases the reconstruction toward the stable directions as delays are added. This bias can be exploited, using the diffusion maps approach to dimension reduction, to extract dynamics on desired time scales from high-dimensional observed data. We discuss the technique and its application to video data from experiments.

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MS120

Diffusion Maps as Invariant Functions of Dynamical Systems

We apply diffusion maps to obtain a representation of the ergodic quotient of a dynamical system. The ergodic quotient is the joint image set of all flow-invariant functions, numerically approximated by averages of Fourier harmonics along trajectories. The dominant elements of the diffusion map act as flow-invariant functions whose level-sets are invariant regions of homogeneous dynamics, e.g., resembling integrable systems. We discuss the potential to use diffusion geometry in obtaining a model-free bifurcation analysis.

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MS120

Diffusion Embeddings of Parameterized Difference Equations

In this talk I will present some results on how one can use diffusion maps to embed parameterized difference equations. As the parameters of the difference equation are changed, the geometry of the system changes as well. In joint work with Ronald Coifman and Roy Lederman, we use a single low dimensional embedding space to track changes in the intrinsic geometry of the system as the parameters are changed.

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Ronald Coifman

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MS120

Diffusion Maps for Model Reduction of Dynamics with Symmetries

In the first part of this talk we will review the diffusion maps framework for non-linear dimensionality reduction of data. We then introduce vector diffusion maps, which is a recent generalization of diffusion maps that is based on vector fields instead of scalar functions, and is particularly useful for data with underlying symmetries, with and without dynamics.

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MS121

Cascades in Interdependent Networks

Abstract not available at time of publication.

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MS121

Approximation Methods for Dynamics on Networks

I will briefly review several analytical approaches for dynamics on networks, with a special focus on cascade dynamics.

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MS121

Limited Imitation Social Contagion as a Model of Fashions

We study binary state contagion dynamics on a social network where nodes act in response to the average state of their neighborhood. We model the competing tendencies of imitation and non-conformity by incorporating an off-threshold into standard threshold models of behavior. In this way, we attempt to capture important aspects of fashions and general societal trends. Allowing varying amounts of stochasticity in both the network and node responses, we find different outcomes in the random and deterministic versions of the model. In the limit of a large, dense network, however, these dynamics coincide. The dynamical behavior of the system ranges from steady state to chaotic depending on network connectivity and update synchronicity. We construct a mean-field theory for general random networks. In the undirected case, the mean-field theory predicts that the dynamics on the network are a smoothed version of the average node response dynamics. We compare our theory to extensive simulations on Poisson random graphs with node responses that average to the chaotic tent map.

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MS121

Dynamics on Modular Networks with Heterogeneous Correlations

Abstract not available at time of publication.

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MS122

A Framework for Approximate Reduced Models of Multiscale Systems with Nonlinear and Multiplicative Coupling

We develop a new framework for approximate reduced models of multiscale processes. This framework approximates the parameterized coupling terms in a reduced model through their first-order Taylor expansion, which, in turn, is computed via the Fluctuation-Dissipation theorem. We demonstrate computationally that this framework is suitable for multiscale systems with nonlinear and multiplicative coupling.

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MS122

Local Learning of Stochastic Dynamical Systems

In Chemistry and Biology many people are interested in simulating how a system of molecules interacts over a large period of time. In order to obtain a long path of the molecules in the system, the standard method is to compute all the forces between all the atoms at each time step and move forward in time. Unfortunately this dynamical system is very stiff, and so we have to take very small time steps (on the order of 10^{-15} s). I will outline a procedure that uses machine learning techniques to automatically learn a SDE that well represents the dynamics of the system. The SDE we learn will no longer depend upon doing expensive force field computations and can take larger time steps.

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MS122

Dimension Reduction in Systems with Moderate

Separation of Time Scales

We develop effective stochastic models for moderately separated "slow-fast" systems by eliminating non-essential fast modes. Two approaches of the stochastic mode-reduction strategy are presented. One is to reduce the dimension of the original full system through a slow manifold, the other is homogenization. We present some examples and numerical simulations motivated by the shallow-water equation.

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MS122
Dynamics of Nanomagnets with Spin-transfer Torques

Driving nanomagnets by spin-polarized currents offers exciting prospects in magnetoelectronics, but the response of the magnets to such currents remains poorly understood. We show that an averaged equation describing the diffusion of energy on a graph captures the low-damping dynamics of these systems, and agrees with experimental observations. We then extend this averaging technique to spatially extended systems described by stochastic partial differential equations.

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MS123
Modeling Age and Size Based Division of Labor in Fire Ant Workers

The size of single-queen, or monogyne colonies of fire ant may contain as many as a quarter million of workers of various sizes. Worker polymorphism in the fire ant (Solenopsis invicta) is common and there is a correlation between the body size/age and tasks of workers. Young workers tend to spend more time within the nest by feeding or grooming larvae/queen. As workers get older, their duties shift from the brood-tending to foraging which is the most dangerous job of worker ants. Since the size of colony is the primary factor to determine the survival of the queen, if the foragers are selected from all workers at random without regard to age, it would lower the average lifespan of workers. Therefore, more resources must be invested toward worker production. This means a reduction in sexual alate production. In this project, we construct models to examine how the physical and temporal castes of workers affect the colony size compared to a colony of random-age foragers.

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MS123
Disease Spread on Long Distance Travel Networks

Recent epidemics like the SARS outbreak and the 2009 pandemic influenza A(H1N1) highlighted the role of the global human transportation network played in the worldwide spread of infectious diseases. We introduce an SIR-based model to describe the temporal evolution of an epidemic in regions connected by long distance travel, such as intercontinental flights. Literature study of revealed on-board transmission of influenza in flights even with a duration of less than 8 hours, hence we include the possibility of transmission of the disease during travel. We obtain that an age structured model where age is the time elapsed since the start of the travel leads to a nonlinear system of functional differential equations. We determine some fundamental properties of the model and the reproduction number. We parametrize the model and use real demographic and air traffic data for specific regions. We validate our approach fitting the model to the first wave of the 2009 influenza pandemic.

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MS123
Age of Maturity and Threshold Phenomena in Age Dependent Populations

We consider an age structured population model having the special feature that the age of maturity of an individual at a given time depends on the history of the age of maturity, and the history of the population density, at that time. This is manifested as a threshold condition for the resource consumption of the immature population. Using this as motivation, we are led to a more general situation which takes the form of an abstract algebraic delay-differential system. We discuss the progress made on this project. This is work is the result of a collaboration with Dr. Felicia Magpantay and Dr. Jianhong Wu.

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MS123
Disease Permeability of a Dynamic Social Network

In this study, we investigate the capacity of a newly introduced infectious disease to destabilize a social contact process, and drive that process to a new steady state. Initially, we estimate a set of social contact parameters at the dyad level using empirical data from a well-studied herbivore. We then validate rule performance in recapturing empirically observed higher-order network properties through simulation of dynamic networks. Next, we examine the interacting effects of transmission probability, virulence, and infectious period on the efficiency with which a disease spreads through a dynamic (and evolving) social contact network. Finally, we assess the capacity of the introduced disease to push the social contact process to a new steady state.

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MS124

Synchronization of Small Networks of Electrochemical Oscillators on Macro- and Microscale

Experimental results are presented in which the dynamical features of 2-20 electrochemical oscillating units are characterized as the network properties of coupling between units are tuned. In a macroscopic design the coupling is induced by cross-resistances between electrodes; in the lab-on-chip design the coupling is inherent determined by the geometry of the cell. The effects of network topology on identical synchronization, clustering, and formation of chimera states are investigated.

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MS124

Realization of Chimera States in a Network of Mechanical Oscillators

Chimeras are counterintuitive states where a population of identical oscillators splits into two parts, with one synchronizing and the other oscillating incoherently. While many theoretical studies have been performed, the origin and role of chimeras in nature and technology has remained elusive. We present the first purely mechanical realization of chimeras and show that chimeras emerge naturally in a competition of two antagonistic synchronization patterns, and analyze a model and its bifurcation scenarios in detail.

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MS124

Quasiperiodic Dynamics in Ensemble of Nonlinearly Coupled Electronic Oscillators

We perform experiments with 72 electronic limit-cycle oscillators with global nonlinear coupling. With increase of coupling we observe a desynchronization transition to a quasiperiodic state. In this state the mean field is, however, non-zero, but the mean field frequency is larger than frequencies of all oscillators. We analyze effects of common periodic forcing of the ensemble and demonstrate regimes when the mean field is entrained by the force whereas the oscillators are not.

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MS124

Collective Dynamics of Self Propelled Droplet Populations

Self propelled particles (SPPs) typically carry their own energy and are not propelled simply by the thermal buffeting due to the environment. As non-equilibrium entities, they are not restricted to classical equilibrium constrains. We developed microscale self-propelled droplets which can be produced in large numbers and with high monodispersity, allowing us to perform experiments on large ensembles of such SPPs. We will discuss their non-equilibrium statistical mechanics and collective dynamics such as flocking and rectification.

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MS125

Predator-prey Interactions Using Particle Models

We discuss an aggregation model of predator-prey interactions. In the absence of predators, prey are represented by a particle system for which the steady state consists of a swarm of uniform density. Adding a predator introduces interesting dynamics into the system. We give some analytical results concerning the shape of the resulting swarm and stability of the predator-prey interactions. Joint work with Yuxin Chen.

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MS125

Inferring Individual Rules Through the Dynamics of Phase Transitions in Collective Motion

Connecting observations of collective motion in animal

groups to individual-based models usually involves averaging over time and space to obtain a clear signal from each for comparison. However, many dynamic processes require the temporal component to be maintained in order for models to shed light on the process. Here, I study the evolution of order from disordered states in both models, and in actual observations of collective motion in an aquatic duck, to (a.) determine signatures of the transition, and (b.) determine what model components and parameters reproduce properties of the transition. We find evidence reinforcing previous observations on relative magnitudes of interaction forces in this biological system.

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MS125

Field Experiments and Tracking of Animal Groups in 3d

The key to comprehend the mechanisms of collective animal motion is to obtain quantitative empirical data of individual trajectories of group members. We present new results both for flocks of starlings and swarms of midges recorded in the field using a stereographic camera system and tracked in the 3dimensional space using a built in home algorithm. In this talk I will describe our experimental setup and show main results of the tracking algorithm.

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MS125

Emergent Dynamics of Laboratory Insect Swarms

Emergent collective behavior, in flocks, swarms, schools, or crowds, is exhibited throughout the animal kingdom. Many models have been developed to describe swarming and flocking behavior using systems of self-propelled particles obeying simple rules or interacting via various potentials. Little empirical data, however, exists for real biological systems that could be used to benchmark these models. To fill this gap, we report measurements of laboratory swarms of flying *Chironomus riparius* midges, using stereoimaging and particle tracking techniques to record three-dimensional trajectories for all the individuals in the swarm. We present a statistical characterization of the emergent behavior of the swarms, as well as a characterization of the small-scale interactions.

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MS126

Probabilistic Source Regions and the Role of Lagrangian Coherent Structures

For many applications, particle back-trajectories are essential. Recent results show that a new interpretation of the FTLE field can explain the varied origin of particles sampled sequentially at a geographically fixed location. By including subgrid turbulence, a stochastic process, the notion of probabilistic source regions emerge. A related important notion is the persistent barrier, connected to instantaneous saddle points of the Eulerian field, which may lead to the most diverse samples in terms of origins.

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MS126

The Ecology of Mixing

Detailed understanding of biophysical transport in coastal upwelling systems is critical for effective ecosystem management. Using an ocean model of the California Current system, we discuss kinematics of patchiness generation for buoyant Lagrangian particles (plankton). Particle aggregation is strongly controlled by coherent structures and particularly eddy merging. We review and compare metrics to quantify patchiness (or mixedness) of this biophysical flow, including variance based and fractal metrics, which give surprisingly similar results for this system.

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MS126

Grand Lagrangian Deployment (glad): Dispersion Characteristics in the Northern Gulf of Mexico

Initial dispersion, residence time, and advective pathway results obtained from the nearly simultaneous deployment of some 300 surface drifters in the vicinity of the DeSoto Canyon are reported. The goal of the GLAD experiment was to characterize, with unprecedented statistical significance, multi-point and multi-scale dispersion properties of the flow in the region of the Deepwater Horizon spill site including demarcation of the advective pathways between the Canyon and larger-scale flow features in the Gulf. For the initial time period considered, relative dispersion is found to be controlled by local dynamics. Very limited exchange, either across-shelf or with nearby mesoscale features, was observed.

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MS126

Trajectory Complexity Methods and Lagrangian Coherent Structures in 3D Fluid Flows

We consider methods for identifying Lagrangian coherent structures (LCS) in both 2D and 3D geophysical fluid flows using individual trajectory complexities. Particulary two complexity methods - the correlation dimension and ergodicity defect - are discussed in the context of several examples. The theoretical and practical advantages and disadvantages of the complexity methods in comparison to other standard methods is also discussed.

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MS127

Functional Relevance of Activity Propagation in V1

Combining optical imaging of voltage-sensitive dye in awake behaving monkey with appropriate denoising and signal processing methods, we prove the existence of activity propagation at single-trial level. Such propagations generate dynamic lateral interactions within cartographic representations that have strong functional implications. For instance, interactions between feedforward waves of activity and lateral interactions can be at the origin of context-dependent dynamic input normalization linked to the emergence of global mesoscopic signal.

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MS127

Complex Oscillatory Patterns in a Neuronal Network with Adaptation and Lateral Inhibition

Recent studies of a firing rate model for two mutually inhibitory neuronal populations show the existence of several dynamical regimes, including mixed-mode oscillations. We extend these results to a spatially distributed network characterized by local excitatory and long-range inhibitory connections and firing rate neuronal adaptation. We show that intricate spatio-temporal patterns derived from the mixed-mode solutions seen in the reduced model can occur in certain parameter regimes.

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MS127

Spatially Coherent Dynamics in a Pair of Interacting Neural Field Layers

Given the ubiquity of interconnected regions in the brain, we present a model for a pair of interacting neural field layers which could represent two different reciprocally connected layers of brain tissue, brain regions, or pools of neurons within the same layer. We study the existence and stability of stationary solutions and explore bifurcations to stationary and spatially-coherent oscillatory solutions in neural fields with excitation and inhibition, including effects of adaptation and inhomogeneous inputs.

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MS127

Waves in Random Neural Media

While travelling waves in homogeneous neural media are relatively well-studied, little work has been done on spatially and/or temporally heterogeneous media. I will show some recent results in this direction obtained using numerical techniques developed for the study of stochastic partial differential equations.

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MS128

Controlling Collective Behavior

A key problem is how to apply a efficient control strategies so that a network dynamics is exploited to obtain a desired ordered collective behavior. In this talk, we address this issue and also present an adaptive decentralized pinning control technique that impose a desired dynamics to the network. We also assess the interplay between the synchronization state stability and the controller action to achieve the desired controlled dynamics.

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MS128

Do the Functional Networks Reveal the Structural Organization?

Experimental results typically do not access the network structure, which is then inferred by the node dynamics. From the dynamics one constructs a network of functional relations, termed functional network. A fundamental question towards the understanding of complex systems concerns the relation between functional and structural network. We show that the functional network can drastically differ from the topological network. We uncover the mechanism for this abrupt change between functional and structural networks.

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MS128

Dynamics of Synchronous Neurons

Neural synchronization is of interest in the stages of sleeping, seizures, Parkinsons disease, depression, and more. Here we (1) describe neuron model equations based on the Huber and Braun (HB) work, (2) show their wide range firing regimes, (3) discuss how these neurons develop patterns of synchronous behavior, and (4) extend the model to the multi-compartment case applied to the crab stomatogastric neural system.

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MS128

How to Select Neighbors for Robust Consensus

Network topology plays a critical role in collective behaviour, influencing the outcome, speed and robustness of group decision-making. We gain insight into the effects of a directed communication network on robustness of consensus to noise by extending the notion of effective resistance from undirected graphs. This allows us to relate structural features of the directed graph to the group robustness and derive rules by which individuals can change their neighbours to improve performance.

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MS129

Turing Patterns for Nonlocal Diffusive Systems

Many physical and biological processes occur with long-range interaction, giving rise to nonlocal in space operator equations. These operators are diffusive-like but are bounded rather than unbounded as is the case of the diffusion operator. We study systems which include such nonlocal operators and show that Turing instabilities also occur, producing patterned stable states.

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MS129

Solitary Waves in the FPU Chain: A New Exact Solution

We consider solitary wave solutions in the Fermi-Pasta-Ulam problem with piecewise linear nearest-neighbor interactions. We show that in this case the problem reduces to a Fredholm integral equation of the second kind, which can be solved explicitly using the Wiener-Hopf method. Taking advantage of the availability of an exact solution, we test the limits of applicability of the simplest quasicontinuum approximations of the discrete problem. We show that in agreement with the results of Friesecke and Matthies (2002), atomic-scale localization occurs in the high-energy limit. Numerical simulations suggest stability of the obtained solutions above a certain velocity threshold.

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MS129

Traveling Wave Solutions with Mixed Dispersal for Spatially Periodic Fisher-KPP Equations

Traveling wave solutions to a spatially periodic nonlocal/random mixed dispersal equation with KPP nonlinearity are studied. By constructions of super/sub solutions and comparison principle, we establish the existence of traveling wave solutions with all propagating speeds greater than or equal to the spreading speed in every direction. For speeds greater than the spreading speed, we further investigate their uniqueness and stability.

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MS130

Topological Changes in Chaotic Invariant Sets

In this talk we reveal the existence of a new codimension-1 curve that involves a topological change in the structure of the chaotic invariant sets (attractors and saddles) in generic dissipative systems with Shilnikov saddle-foci. This curve is related to some spiral-like structures that appear in the biparameter phase plane. We show how this curve configures the spiral structure (via the doubly-superstable points) originated by the existence of Shilnikov homoclinics and how it separates two regions with different kind of chaotic attractors or chaotic saddles. Inside each region, the topological structure is the same for both, chaotic attractors and saddles.

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MS130

Global Study of 2D Dissipative Diffeomorphisms with a Homoclinic Figure-eight

We consider 2D diffeomorphisms having a homoclinic figure-eight to a dissipative saddle. We study the rich dynamics that they exhibit under a periodic forcing. Generically the manifolds split and undulate giving rise to a large bifurcation diagram. Many tools to study it and to detect the (co)existent attractors will be presented. The qualitative description of the global dynamics in a fundamental domain is complemented with the analysis of a return model that provides quantitative data.

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MS130

Symbolic Tools for Deterministic Chaos

Computational technique based on the symbolic description utilizing kneading invariants is proposed for explorations of parametric chaos in three exemplary systems with the Lorenz attractor: the iconic Lorenz equations from hydrodynamics, the Shimizu-Morioka model - a normal model from mathematics, and a laser model from nonlinear optics. The technique allows for uncovering the stunning complexity and universality of the patterns discovered in the bi-parametric scans of the given models and detects their centers organizing a plethora of spiral structures codimension two T(erminal)-points and separating saddles in intrinsically fractal regions corresponding to complex chaotic dynamics.

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MS131

A Practical Mathematical Model of Intermittent Androgen Suppression for Prostate Cancer

Prostate cancer is an ideal target for preparing mathematical tools to treat diseases because there is a commonly used tumor marker and a good but temporarily effective hormone therapy. In this talk, we summarize the recent advancements of mathematical modeling of prostate cancer. Our special focus is on robustly personalizing a treatment schedule of intermittent androgen suppression. Some general mathematical problems that should be considered in the future will be also discussed.

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MS131

A Model of Personalized Androgen Ablation Therapy for Metastatic Prostate Cancer

Metastatic prostate cancer is treated with continuous androgen ablation. However, this approach eventually fails due to progression to a castration-resistant state. Here, we present a biochemically-motivated model of prostate cancer growth that incorporates a number of personalized parameters. The model is used to retrospectively analyze patient case histories in order to: (i) investigate the benefits of continuous versus intermittent androgen ablation; and (ii) to evaluate the potential of these parameters as biomarkers for significant disease.

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MS131

Immunotherapy with Androgen Deprivation Therapy May Stabilize Prostate Cancer

A mathematical model of advanced prostate cancer treatment is developed to examine the combined effects of androgen deprivation therapy and immunotherapy. The model presented in this paper examines the efficacy of dendritic cell vaccines when used with continuous or intermittent androgen deprivation therapy schedules. Numerical simulations of the model suggest that immunotherapy can successfully stabilize prostate cancer growth using either continuous or intermittent androgen deprivation.

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MS131

The Evolution of Androgen-receptor Expression in Prostate Cancer

In previous research we investigated natural selection acting on androgen receptor expression in prostate cancer using a multi-scale model. This model outlined conditions under which aggressive, hormone-resistant tumors arise. Here we extend the model by generalizing its strategy space to allow androgen expression to vary continuously. We analyze the extended model using adaptive dynamics. The results of this extended model are used to refine the predictions of the original investigation.

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MS132

Evolution Systems on Time-dependent Domains: Study of Dynamics, Stability, and Coarsening

In this talk we discuss the key differences in the stability picture between extended systems on time-fixed and time-dependent spatial domains. As a paradigm, we use the complex Swift-Hohenberg equation to study dynamic pattern formation and evolution on time-dependent spatial domains. In particular, we discuss the effects of a time-dependent domain on the stability of spatially homogeneous and spatial periodic base states as well as on pattern coarsening.

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MS132

Front Motion, Pinning and Depinning in One and Two Spatial Dimensions

The 1:1 forced complex Ginzburg-Landau equation exhibits bistability between spatially homogeneous equilibria and thus admits traveling fronts in both one and two dimensions. When one equilibrium becomes Turing unstable, the front can be pinned to Turing patterns (e.g. rolls and hexagons) bifurcating from this equilibrium. Depinning processes outside the parameter interval of pinning involve stretching of the pattern wavelength accompanied by creation or destruction of cells at a preferred distance from the front.

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MS132

Linear Stability of Time-dependent Flows

We present a general theory and two examples for the linear stability of non-autonomous systems and present two example of its use. The technique essentially identifies the spectral radius of the propagator of the linear operator as the appropriate measure for the amplification of initial perturbations by the linearized dynamics. The technique connects and generalizes the classical modal stability theory using eigenvalues and the non-modal approaches using optimal growth of energy.

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MS132

Dynamic Bifurcations and Melting-boundary Convection

This talk focuses on a simple physically motivated model of time-dependent changes in stability. The talk presents a model for weakly nonlinear thermal convection in a fluid layer with a melting top boundary. This leads to the derivation of a new set of non-autonomous envelope equations as a dynamic generalization to the well-known Ginzburg-Landau equation. However, because of the interaction of two destabilizing mechanisms (convection and morphological dynamics), this new system possesses a number of interesting properties not found in systems close to a traditional dynamic bifurcation. The presentation will highlight some of the properties of this system both analytically and numerically; specifically, we'll find the robust "locking in' of spatially complex patterns, and show this is a general feature of systems of this nature.

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MS133

How Do Cells Detect the Frequency of Pulsatile Chemical Signals?

A hallmark of the endocrine system is pulsatile hormone secretion. Target cells often respond to pulsatile hormones differentially depending on pulse frequency. To distinguish responses to pulse frequency from responses to changing hormone dose, we consider the frequency response of target cells to a family of dose normalized input signals. We show that simple nonlinear feedforward systems can show increasing, decreasing, or non-monotonic frequency responses to pulsatile signals with constant mean dose.

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MS133

(Exploiting the) Fast and Slow Time Scales in Cellular Signalling

Oscillations and bursts act as signals in many cell types, including those involved in neuronal firing and cell secretion. A key feature of the dynamics in there cells is that some physiological processes evolve much faster than others. We can take advantage of this separation in timescales to analyse models using geometric singular perturbation techniques. These techniques allow us to explain 'transient' responses as well as long-term dynamics by identifying canards and invariant manifolds that organise the phasespace.

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MS133

Population Spiking Dynamics and Signal Processing in Vasopressin Neurons

The magnocellular vasopressin neurons of the hypothalamus act to maintain osmotic pressure by regulating kidney function. Experiments show a robust linear relationship between osmotic pressure and vasopressin hormone secretion despite the very non-linear properties of spike generation and stimulus-secretion coupling in the vasopressin neurons. Here we simulate the spiking and secretion mechanisms, and use a population model to examine how cell heterogeneity interacts with the spiking and secretion properties to produce a linear population response.

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MS133

Modeling the Glucagon Secreting Alpha Cell

While pancreatic β-cells release insulin in response to high glucose levels, α-cells release glucagon when blood glucose is low. Both insulin and glucagon work together to maintain glucose homeostasis. While the mechanisms leading to insulin secretion are fairly well understood, how glucagon secretion is suppressed at high glucose levels is still debated. We developed a mathematical model of the α-cell and investigated intrinsic mechanisms that lead to the suppression of glucagon secretion.

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MS134

Heterogeneity and Correlation Transfer in Noise-Driven Oscillators

We consider the ability of two uncoupled heterogeneous oscillators to synchronize when driven with colored partially correlated noise. We derive equations for the stationary density of the phase difference assuming small noise and find two surprising results :

1. at low correlations it is possible for pairs of heterogeneous oscillators to synchronize better than a pair of homogeneous oscillators;
2. if the oscillators have different frequencies, there is a nonzero time scale of the noise that maximizes synchrony

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MS134

Infering Phase Dynamics from Observations of Os-

cillatory Networks

It is described, how the interconnections in a network of coupled oscillators can be detected from the processing of the observed multivariate time series. The procedure suggested leads to invariant description in terms of phases, independent on the obseravbles and embeding used, and delivers phase equations in the form used in theory. The method is illustrated with the analysis of experimental data.

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MS134

Geometry of Irregular Oscillations and Applications

Phase of irregular oscillations in nonlinear and non-equilibrium systems becomes arbitrary with fluctuations in amplitude. The problem amounts to correctly identifying those system states that are in the same phase. For limit-cycle oscillators, states are identified by hypersurfaces called isochrones. We propose a generalization of isochrones for an application to irregular oscillations. The dynamics of the resultant phase is on average decoupled of the amplitude dynamics. The approach is illustrated by applications to pulmonary respiration.

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MS134

Bifurcations of Bursting Polyrhythms in 3-Cell Central Pattern Generators

We identify and describe the principal bifurcations of bursting rhythms in multifunctional central pattern generators (CPG) composed of three neurons connected by fast inhibitory or excitatory synapses. We develop a set of computational tools that reduce high-order dynamics in biologically relevant CPG models to low-dimensional return mappings that measure the phase lags between cells. We examine bifurcations of fixed points and invariant curves in such mappings as coupling properties of inhibitory and excitatory synapses are varied. These bifurcations correspond to changes in the availability of the network's phase locked rhythmic activities such as periodic and aperiodic bursting patterns. As such, our findings provide a systematic basis for understanding plausible biophysical mechanisms for the regulation of, and switching between, motor patterns generated by various animals.

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MS135

Sensory Encoding Mechanisms in Neuronal Dynamics

In sensory systems, it has been widely observed that receptor cells outnumber the neurons in the immediate downstream layer by several orders of magnitude. Thus, a natural question to ask is how much information is lost because of this reduction? We answer this question using compressed sensing theory as a tool for quantifying information retention in an idealized retinal model. Via numerical simulations and mathematical analysis, we demonstrate several necessary conditions for data compression.

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MS135

Low-dimensional Descriptions of Neural Networks

Biological neural circuits display both spontaneous asynchronous activity, and complex, yet ordered activity while actively responding to input. When can model neural networks demonstrate both regimes? Recently, researchers have demonstrated this capability in large, recurrently connected neural networks, or "liquid state machines", with chaotic activity. We study the transition to chaos in a family of such networks, and use principal orthogonal decomposition techniques to provide a low-dimensional description of network activity. We find that key characteristics of this transition depend critically on whether a fundamental neurobiological constraint — that most neurons are either excitatory *or* inhibitory — is satisfied.

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MS135

Information Transmission in Discrete Feedforward Networks

We study the emergence of neutral stability and rate propagation in stochastic feedforward networks. Spectral properties of a mean-field approximation can reveal when complex dynamics and high levels of information transmission co-occur in these networks. A key issue is robustness to connection parameters, which can be improved by adding biological factors such as noise and inhibition. We further examine how biophysically motivated learning rules can control network connectivity to improve information transmission.

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MS135

Wave Patterns in an Excitable Neuronal Network

This talk describes a study of spiral- and target-like waves traveling in a two-dimensional network of integrate-and-fire neurons with close-neighbor coupling. Individual neurons are driven by Poisson spike trains. Waves begin as a target or a spiral, and evolve into a straight "zebra"-like grating. The wavelength and wave speed of the patterns were investigated, as were the temporal power spectra of the oscillations experienced by the individual neurons as waves were passing through them.

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MS136

Multistable Dynamics of Stochastically Switching Networks

We consider multistable dynamical networks whose connections switch stochastically according to a given rule. The stochastic switching can be a sequence of independent random vectors or a Markov vector process. We study dynamical properties of the multistable switching networks as a function of the switching frequency. We also analyze how the switching network topology of dynamical networks can enhance the performance of networks with static connections.

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MS136

On Convergence and Synchronization in Piecewise Smooth Networks

Switching in complex networks can be undesired when the goal is to guarantee emergence of coordinated motion. Conversely, it can be usefully exploited to design distributed control laws for the emergence of desired coordinated behaviour. We consider hybrid-switched networks of dynamical systems and present new tools to study convergence of all agents towards the same evolution. We use these tools to develop novel switched strategies to control the emergence and properties of such coordinated behaviour.

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MS136

Neighborhood Gossip: Exploiting Structure in Moving Neighborhood Networks to Discover Global Environmental Variables

We consider a network of mobile agents that act as point environmental sensors, where agents communicate only locally. Suppose the network task is to approximately describe some enviromental state over the domain of movement, where typically global information is required (such as transport problems). We describe techniques to exploit the Moving Neighborhood Network structure and topology to resolve the function using local processing information.

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MS136

Information Transfer in Coupled Oscillator Networks: Uncertainty, Influence, and Effects of Blinking Channels

Causality inference is central in nonlinear time series analysis. A popular approach to infer causality between two processes is to measure the information transfer between them, a notion termed as transfer entropy. Using networks of coupled oscillators, we show that the presence of indirect interactions, common drivers, and blinking channels often results in erroneous identification of network connections. We overcome these limitations by developing an entropy reduction approach, whose effectiveness is tested against various networks.

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PP0

The Tranport Through Nontwist Barriers in a Model Describing Magnetic Field Lines in Tokamaks

We use a symplectic map to model magnetic field lines in tokamaks perturbed by ergodic magnetic limiter. Particularly, we are interested in the transport of trajectories under the influence of nonmonotonic safety factor profiles, leading to nontwist scenarios characterized by the presence of a robust invariant torus (shearless). In the present work we study a parameter space profile and the shearless breakup that marks the onset of the transport of trajectories towards the boundary.

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PP0

Dynamics of Short Desynchronization Episodes in

the Brain

While neural synchronization is widely observed in neuroscience, neural oscillations are rarely in perfect synchrony and go in and out of phase in time. We found that neural synchronization in different circuits of the brain follows qualitatively similar temporal pattern: desynchronization episodes are very short, but frequent. We explore the mechanisms responsible for these patterns in simple conductance-based models. We show that short desynchronizations may allow for higher levels of synchrony with weaker synaptic connections.

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PP0

Localized Pattern in Periodically Forced Systems

Oscillons, spatially localized oscillatory patterns, were discovered in the Faraday wave experiment in the 1990s. We reduce a simple model PDE [A.M.Rucklidge & M.Silber, SIADS 8 (2009) 298-347] with parametric forcing to the forced complex Ginzburg-Landau equation where it is known [J.Burke, A.Yochelis & E.Knobloch, SIADS 7 (2008) 651-711] that oscillons can be found, and are able to demonstrate a quantitative connection between the oscillons found numerically in the model PDE and those from the forced complex Ginzburg-Landau equation.

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PP0

The Swarm and the Mosquito: Information Transfer, Co-Operation and Decision Making in a Group

Mosquitoes form swarms which serve selected functions during mating behavior. Males fly together in a "coherent' group, which attracts the attention of nearby females. Communication between individuals is observed to rely on acoustic interaction; each mosquito dynamically adjusts its wing beat frequency in response to the sound of its neighbors. We present experimental data investigating the nature of these interactions, and discuss them in the broader context of swarm structure, dynamics and stability.

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PP0

Algorithm for Interval Linear Programming Involving Interval Constraints*

In real optimization, we always meet the criteria of useful outcomes increasing or expenses decreasing and demands of lower uncertainty. Therefore, we usually formulate an optimization problem under conditions of uncertainty. In this paper, a new method for solving linear programming problems with fuzzy parameters in the objective function and the constraints based on preference relations between intervals is investigated. To illustrate the efficiency of the proposed method, a numerical example is presented.

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PP0

Travelling Waves in a Fractional Fisher Equation Using the Homotopy Analysis Method

In this poster, the Homotopy Analysis Method (HAM), which is a powerful tool to solve nonlinear equations and originally proposed by Liao, is applied to traveling waves in the fractional Fisher equation. Different from traditional perturbation techniques, HAM does not rely on small parameters. HAM makes use of an auxiliary convergence parameter to provide an efficient way to determine the convergence region of the series. Numerical examples are given to support the idea.

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PP0

Mesoscale Symmetries Explain Dynamical Equivalence of Food Webs

A goal of complex system research is to identify dynamical implications of network structure, such as small motifs influencing the dynamics on the network as a whole. Here, we investigate ecological food webs, complex heterogeneous networks of interacting populations. We show that certain mesoscale symmetries imply the existence of localized dynamical modes. If unstable they cause dynamical instability regardless of the embedding network; if stable their removal results in a smaller but dynamically equivalent network.

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PP0

Investigating Physical Experiments with Control-

Based Continuation

We present a general method for systematically investigating the dynamics and bifurcations of a physical nonlinear experiment. In particular, we show how the odd-number limitation inherent in a popular non-invasive control scheme, (Pyragas) time-delayed feedback control, can be overcome for experiments with periodic forcing. To demonstrate the use of our non-invasive control, we trace out experimentally the resonance surface of a nonlinear oscillator near the onset of instability, around two saddle-node bifurcations (folds) and a cusp bifurcation.

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PP0

Analysis of Fluid Systems from the Optical Flow-Approximate Vector Fields

Analysis of fluid systems such as the ocean and atmosphere is important topics in current research. To analyze global dynamics of such systems, such as coherent pairs and transport barriers, the vector fields of the systems are required. In the absence of a prior model, multi-time step optical flow technique can be employed on remote data to determine the vector fields. In this work, the transport barriers for the Jupiters atmospheric data are explained.

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PP0

Spatiotemporal Dynamics of Alternans Nodes in Heterogeneous Cardiac Tissue

We study the behavior of electrical alternans, a period-2 cardiac rhythm resulting in beat-to-beat alternations in action potential duration (APD). In extended tissue, alternans may become spatially discordant, characterized by out-of-phase regions in APD alternation separated by nodes where APD remains constant from beat to beat. We investigate the effects that continuous and discontinous gradients ofelectrophysiological properties have on nodal formation, position and motion.

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PP0

Coarse-Graining of Bursting Dynamics

We have developed a numerical method that maps between the variables of a bursting neural network (for which the equations are known) and the variables of a simplified model (for which the equations are unknown). By simulating the neural network for short periods of time we can estimate the dynamics the simplified model should retain and gain a better understanding of the restrictions on the parameters domain for which the simplification is valid.

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PP0

Why People Walk in Circles?

People use their senses, most dominantly sight and hearing, to interpret geographical cues in order to navigate to a target location. How does the process work if no cues are present and the only information is the initial direction towards the target location? Experiments suggest that people are not capable of walking straight and form surprisingly small looped trajectories. The analysis of experimental data infers a parametric family of stochastic difference models with individual-based set of parameters reflecting the directional bias and other properties of individual's motion. We analyze the stochastic process in terms of the first exit time problem.

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PP0

Use of Quasi-Steady-State Assumptions in the Analysis of Biophysical Models

Many biological systems have the property that some processes evolve much faster than others. Mathematical models of such systems often possess different time scales. A common first step in the analysis of these models is to remove fast variables by making quasi-steady-state assumptions. Unfortunately, quasi-steady-state reduction can sometimes cause significant changes in dynamics. We discuss progress on establishing conditions under which quasi-steady-state reduction is mathematically justifiable and will not disrupt the dynamics of the model.

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PP0

Entrainment of Neuronal Models in Noise

We study properties of entrainment of stochastic neuronal models to periodically-modulated inputs. We consider spike phases as generated by a Markov chains on the circle, and analyze path-wise dynamic properties, such as stochastic periodicity (or phase-locking) and stochastic quasiperiodicity. We show how these properties are read off of the geometry of the spectrum of the transition operator in representative model examples, and investigate how the entrainment properties change with parameters.

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PP0

Calcium Dynamics in Airway Smooth Muscle Cells

Free cytoplasmic calcium ions in human airway smooth muscle cells are quite important in regulating the airway contraction that contributes to our normal breath. Experiments show in the present of agonist calcium changes in form of oscillations and propagates in waves.Here we construct a dynamical model to explore what leads to the oscillatory behavior, which is a way to understand how the calcium affects our breath and will be very useful to the research of pathology of asthma.

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PP0

Bifurcations in Bifurcations: a Dynamical Analysis of An Impacting T-Junction Flow

Fluid flows through pipe T-junctions appear commonly, for instance, in industrial systems and blood vessels. We consider a junction with square cross-section, where fluid splits to two side channels. A local bifurcation analysis—using numerical continuation on the Reynolds number Re—reveals a supercritical pitchfork bifurcation at $Re \approx 430$, beyond which the outflow pipes contain asymmetric counter-rotating vortices. A supercritical Hopf bifurcation next occurs at $Re \approx 540$.

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Regulation of Electrical Bursting in a Spatio-Temporal Model of a Gnrh Neuron

Gonadotropin-releasing hormone (GnRH) neurons are hypothalamic neurons that control the pulsatile release of GnRH that governs fertility and reproduction in mammals. The mechanisms underlying the pulsatile release of GnRH are not well understood. We construct a spatio-temporal model to understand how the soma and dendrite of the GnRH neuron interact to control bursting, which is initiated in a region approximately 100 micrometers away from the soma, but is controlled by the mechanisms in the soma.

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PP0

Acoustic Detection and Ranging Using Solvable Chaos

Acoustic experiments demonstrate a novel approach to detection and ranging that exploits the properties of a solvable chaotic oscillator. This nonlinear oscillator includes an ordinary differential equation and a discrete switching condition and provides the wideband transmitted waveform. The hybrid system admits an exact analytic solution as the linear convolution of binary symbols and a single basis function, which enables coherent reception using a simple analog matched filter and without need for digital sampling or signal processing. An audio frequency implementation of the transmitter and receiver is described, and successful acoustic detection and ranging measurements demonstrate the viability of the approach.

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PP0

The Lorenz System Near the Loss of the Foliation Condition

We study the Lorenz system in a parameter regime where the foliation condition fails, which means the reduction to a one-dimensional map is not possible. We consider a transition where the one-dimensional stable manifolds of two secondary equilibria undergo a sudden dramatic change. We explain the effect of this change on the two-dimensional stable manifold of the origin and its role in the loss of the foliation condition.

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PP0

Symmetry Breaking in Colliding Disk Systems

We develop an alternative collision rule to those developed in current work on hard disk systems (Dellago, Posch, et. al). The proposed collision rule leads to symmetry breaking and the invalidation of the conjugate pairing rule for Lyapunov exponents. Comparison of numerical results to those obtained using existing methods is discussed. The approach is considered as one way of taming chaos in problems of interacting systems with a high number of degrees of freedom.

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Spatially-Shifted Feedback Control of Turbulent Behavior in Advection Diffusion Systems

We present experimental and theoretical results related to the control of actively mode-locked lasers, using delayed feedback, a problem that is equivalent to the control of advection-diffusion systems with spatially shifted feedback. Tiny feedback levels (1e-8 in our experiment) lead to spectacular efficiencies, although the process is different from OGY-type control. This method is efficient when large transient growth is present in the system.

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PP0

Happiness and Movement on Twitter

Using status updates collected from Twitter's gardenhose feed, we explore population-level happiness. We employ a simple real time hedonometer that is effective on large quantities of text. Many Twitter users enable geo-location of their tweets. For these users, we explore the relationship between their location, average movement, and happiness.

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PP0

Random and Regular Dynamics of Stochastically Driven Neuronal Networks

Dynamical properties of Integrate-and-Fire neuronal networks with multiple time scales of excitatory and inhibitory neuronal conductances driven by random Poisson trains of external spikes will be discussed. Both the asynchronous regime in which the network spikes arrive at completely random times and the synchronous regime in which network spikes arrive within periodically repeating, well-separated time periods, even though individual neurons spike randomly will be presented.

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PP0

Formation of Localized Hot Spots of Criminal Activity in a Model Incorporating Non-Local Effects

A ubiquitous feature of crime is the spatially and temporally patterned hot spot or local region of high levels of criminal activity. Understanding the dynamics and mechanisms underlying the formation and dissipation of hot spots is of importance in modern policing. We analyze a spatially structured model of criminal activity that incorporates non-local interactions in the environment. We demonstrate conditions for the formation and stability of hot spots in a partial differential integral model.

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PP0

Stochastic Simulation of RNAP Elongation

Motion of a polymerase in a transcription process experiences multiple short pauses, which, together with high density of transcribing polymerases, may effect overall transcription rate. We developed a new algorithm to simulate one-dimensional Total Asymmetric Simple Exclusion Process (TASEP) with open boundaries where the hopping rates between neighboring sites are allowed to change both in space and time. Our implementation uses multiple runs of a discrete event simulator with each run having a time complexity $O(mn \log n)$ where m is the total number of simulated polymerases and n is the length of the DNA strand. We compare our algorithm to a classical algorithm of Boortz and Lebowitz which is being used for simulations of stationary distribution for TASEP with hopping rates that depend on space only.

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PP0

Traveling Waves in a Gasless Combustion Model with Heat Loss

We consider a model of gasless combustion with heat loss, where the heat loss from the system to the environment is formulated according to Newtons law of cooling. The pde system that describes evolution of the temperature and remaining fuel contains two small parameters, a diffusion coefficient for the fuel and a heat loss parameter. We use geometric singular perturbation theory to show existence of traveling waves in this system and then study their spectral and nonlinear stability.

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PP0

Bifurcation Analysis of a Civil Transport Aircraft's Upset Behaviour

Unintended and/or extreme dynamics outside the design flight envelope of an aircraft are referred to as upset behaviour. An upset can induce a loss-of-control accident — the leading cause of civil aviation fatalities — if the pilot does not respond correctly. We present a bifurcation analysis of the NASA generic airliner model that identifies attractors that correspond to various upset behaviour, including different types of spin.

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PP0

Approximate Deconvolution for Large-eddy Simulation (LES) on Adaptive Grids

LES and adaptive grids reduce the computational cost of turbulence modeling, but combining these techniques generates errors. Inaccuracies in subfilter models limit LES solution reliability at the grid scale, contaminating the interpolated solution at grid interfaces. The grid interface also reflects high wavenumber solution components. Approximate deconvolution can improve the grid scale solution. Results from isotropic turbulence advected past a grid interface show approximate deconvolution reduces interface perturbations and hastens convergence to the downstream solution.

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PP0

Interplay Between Energy-Market Dynamics and Physical Stability of a Smart Power Grid

A smart power grid is currently being envisioned for the future in which, among other features, users would be able to play the dual role of consumers as well as producers and traders of energy, thanks to emerging renewable energy production and energy storage technologies. As a complex dynamical system, any power grid is subject to physical instabilities. With existing grids, such instabilities tend to be caused by natural disasters, human errors, or weather-related peaks in energy demand. We analyze the impact, upon the stability of a smart grid, of the energy-market dynamics arising from users ability to buy from and sell energy to other users. The stability analysis of the resulting dynamical system is performed assuming different proposed models for this market of the future, and the corresponding stability regions in parameter space are identified. We test our theoretical findings by comparing them with data collected from some existing prototype systems.

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PP0

Using the Ensemble Kalman Filter to Track Links in Neuronal Networks

We demonstrate the use of the unscented Kalman filter for the detection and tracking of network links using time series data generated from a network of Hindmarsh-Rose neurons. We show the ability of the filter to identify the links when confronted with increasing amounts of noise as well as model error. Additionally, the filter is shown to have the ability to track non-stationary connections even when an incorrect assumption of their dynamics is assumed.

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PP0

Shock-Fronted Travelling Wave Solutions Arising in a Model of Tumour Invasion

Within mathematical biology there exists a class of advection-reaction-diffusion (ARD) models that support travelling wave solutions and demonstrate a possible transition from smooth to shock-fronted waves. We present results for one particular ARD model describing malignant tumour invasion. Numerical solutions indicate that both smooth and shock-fronted travelling wave solutions exist for this model. We verify the existence of these solutions using techniques from geometric singular perturbation and canard theory and provide results on stability.

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PP0

Observability of Nonlinear Dynamics of Elastic Flight Vehicle

In this paper, global observability analysis of nonlinear dynamics of a flexible supersonic flight vehicle based on rank condition method is presented. The observability algorithm under the input action is clarified and implemented. Singular value variations of flight vehicles observability space is used as a criteria expressed applicable definition for mathematical concept of observability in critical regions where singular values are near to zero. Mathematical relations between different types of observability for nonlinear dynamics is studied. Using SOSTOOLS and Yalmip, a novel method is presented to find continuous observable regions of variables. The average of condition numbers for observability space constructed at operational points of flight system states, is compared in rigid and elastic models of flight vehicles to exhibit the aeroelasticity effect on the observability of flight vehicle. Singular points created when dimension of observability space is reduced. An Algabraic nonlinear equation set is offered to find all local singular points of nonlinear dynamics.

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PP0

Delay Induced Dynamics of Adaptive Epidemic Models

An extension of an epidemiological susceptible-infected-susceptible (SIS) model on an adaptive network, featuring constant sojourn times in the infected state is investigated. Moment expansion, pair approximation and survival analysis are applied for mapping the high dimensional discrete model based on local rules onto a set of continuous macroscopic observables. The resulting nonlinear delay differential equations capturing the emergent level behavior of the model are analyzed; revealing complex dynamical behavior such as bistability, oscillations and bursting.

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PP0

Analysis of Size Structured Population Models in

Marine Ecosystems

We investigate size structured population models to describe specific aspects of marine ecosystems. The evolution of the density size distribution of a population as function of time and individual size is described by an integro-PDE. The biological questions which motivate our mathematical investigations are predator-prey cycles and coexistence of several species depending on e.g. resource level. We determine regions in parameter space with different qualitative behavior of the solution and present their biological interpretation.

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PP0

Characterization and Observations of Nonlinear Charged Particle Dynamics and Chaos in the Magnetotail

The use of nonlinear dynamics modeling and satellite measurements of an ion distribution function signature is used to infer the meso-scale structure of the magnetotail. Additionally, we discuss quantitative measurements of particle chaos in the magnetotail focusing on the Lyapunov exponent and the fractal structure of the basin boundary between forward and back-scattered particles. The resonance phenomena that produces the ion signature is also apparent in the Lyapunov exponent and the fractal dimensionality.

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PP0

Effects of Freeplay on the Dynamic Stability of An Aircraft Main Landing Gear

We study the occurrence of (unwanted) shimmy oscillations of a dual-wheel aircraft main landing gear, which is modelled with torsional, lateral, longitidunal and axial degrees of freedom, as well as freeplay in the torque-link. By means of a bifurcation study in dependence on forward velocity and loading force on the gear, we show that the occurence or not of shimmy oscillations depends very sensitively on the amount of freeplay.

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Computing Stability of Mosquito Motion

We use the rigid body simulation software TREP to create a computational model of a mosquito. Using quasi-steady assumptions for the wing aerodynamics, along with an imposed periodic wing motion drawn from measurements of mosquitoes, we perturb the wing motion and body initial conditions to find steadily translating states of the insect's body motion. We then examine the stability characteristics of these states, finding pitch and roll instabilities, along with a non-self adjoint structure to the Jacobian matrix.

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PP0

Synchronization of Hypernetworks: Dimensionality Reduction Through Simultaneous Block-Diagonalization of Matrices

We present a general framework to study stability of the synchronous solution for a hypernetwork of coupled dynamical systems. We are able to reduce the dimensionality of the problem by using simultaneous block-diagonalization of matrices. Under certain conditions, this technique may yield a substantial reduction of the dimensionality of very large systems. We apply our reduction technique to a number of different examples.

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PP0

2-θ Neuron Model for 3-Cell Inhibitory Central Pattern Generators

We examine bifurcations and stability of multi-patterns in 3-cell CPGs of inhibitory bursting neurons using 2-θ neuron models. Reducing the Hodgkin-Huxley models to 1D 2-θ models allows comprehensive analysis of the system. The model was tested for the transitions to specific robust bursting patterns as found in plausible Hodgkin-Huxley models and follow pattern formations with duty-cycle and asymmetric connections. Pattern detection and stability are determined using return maps for phase-lags on 2D tori.

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Interaction Between Aircraft Landing Gear Dynamics and Fuselage Modes

Cockpit vibrations experienced by pilots during aircraft take off and landing are thought to be caused by shimmy oscillations of the nose landing gear that feed into the fuselage. To test this hypothesis and to investigate the nature of the mutual interaction involved, a mathematical model is presented that couples the nose landing gear dynamics with horizontal and vertical modes of the fuselage.

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PP0

Distributive Zooplankton Digestion Delay on Planktonic Dynamic

A mathematical model is proposed to study of the distributive zooplankton digestion delay on planktonic dynamic. The model includes three state variables viz., nutrient concentration, phytoplankton biomass and zooplankton biomass. The release of toxic substance by phytoplankton species reduces the growth of zooplankton and this plays an important role in plankton dynamics. In this paper, we introduce a delay (time-lag) in the digestion of phytoplankton by zooplankton. The stability analysis of all the feasible equilibria are studied and the existence of Hopf-bifurcation for the interior equilibrium of the system is explored. From the above analysis, we observe that the supply rate of nutrient and delay parameter play important role in changing the dynamical behaviour of the underlying system. Further we have derived the explicit algorithm which determine the direction and the stability of Hopf-bifurcation solution. Finally numerical simulation is carried out to support the theoretical result.

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PP0

A Closed Npz Model With Delayed Nutrient Recycling

We consider a closed Nutrient-Phytoplankton-Zooplankton (NPZ) model that allows for a delay in the nutrient recycling. Mathematical properties that come from such a model are discussed, as well as their biological implications. Biomass is conserved in the system in a way that relates to the delay distribution of the nutrient recycling. The stability of the equilibrium solutions depends on the quantity of biomass in the system as well as on the length of delay.

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Chaos and Reliability in Fluctuation-Driven, Balanced Spiking Networks

The question of reliability arises for any dynamical system driven by an input signal: if the same signal is presented many times with different initial conditions, will the system entrain to the signal in a repeatable way? Reliability is of particular interest in large, randomly coupled networks of excitatory and inhibitory units. Such networks are ubiquitous in neuroscience, but are known to autonomously produce strongly chaotic dynamics an obvious threat to reliability. Here, we show that such chaos also occurs in the presence of weak and strong stimuli. However, even in the chaotic regime, intermittent periods of highly reliable spiking often coexist with unreliable activity. We propose a framework to better understand these complex dynamics, leveraging results from random dynamical systems (RDS) theory, by establishing the effect of the underlying chaotic attractor's geometry on output spike trains.

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PP0

Isochrons in the Fitzhugh-Nagumo Model

An isochron is the set of all points in the basin of an attracting periodic orbit that converge to the periodic orbit with the same asymptotic phase. We will demonstrate how, via the continuation of suitable orbit segments, isochrons can be computed accurately and reliably. As a concrete example we determine the isochrons of the Fitzhugh-Nagumo model as studied by Arthur Winfree in 1980.

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PP0

Aggressive Shadowing of a Low-Dimensional Model of Atmospheric Dynamics

Predictions of atmospheric dynamics suffer from the consequences of chaos: models quickly diverge from observations, as initial state uncertainty is amplified by nonlinearity. Using the Lorenz '96 coupled system, we extend a technique called inflation, whereby the ensemble of forecasts is regularly expanded artificially along contracting dimensions. Targeted inflation is shown to increase the length of time for which the best ensemble member remains close to the truth. Utilized appropriately, inflation may improve predictions for the future states of physical phenomena.

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PP0

Numerical Continuation of Invariant Solutions of Pdes with Symmetries

We consider the problem of numerically continuing solutions of partial differential equations (PDEs) with symmetries. In particular, we work with the 1D complex Ginzburg-Landau equation (CGLE) and will present a numerical study designed to continue a set of invariant solutions of the CGLE from one chaotic regime into another.

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PP0

Asymmetric Coherent Structures in One and Two Space Dimensions

We consider the effects of symmetry breaking perturbations on localized structures in one and two space dimensions. In particular, we develop a general framework for understanding the effects of such perturbations on pattern formation, construct a scenario under which isolas are predicted to bifurcate from a snaking solution branch, and demonstrate numerically that the solutions of such a system evolve as predicted.

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PP0

Assimilation of Lagrangian Ocean Data

Lagrangian instruments which are carried by the flow have become popular tools for providing measurements of ocean dynamics. Ocean dynamics are often modeled as nonlinear processes, and this nonlinearity creates a sensitivity to initial conditions and model parameters that can ruin forecasts even with relatively small errors in estimates of these parameters. This work focuses on assimilating Lagrangian tracer data into nonlinear models of ocean dynamics to improve estimates of initial conditions and model parameters.

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PP0

Asynchronous Inhibition and Small Neuronal Network Dynamics

In cortical neuronal network models, basket cells are assumed to mediate a fast phasic inhibitory signal through GABA-A synapses via synchronous release of neurotransmitter vescicles. Recent experiments have studied a class of basket cells that release asynchronous neurotransmitter release. In this study we investigate the dynamics of a small neuronal network with excitatory, fast-spiking inhibitory and a novel class of inhibitory neurons that can release neurotransmistter vescicles asynchronously.

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PP0

Voltage-Dependent Stochastic Gating Models Of Tric-B Channels

TRIC-A and TRIC-B are two, related, trimeric intracellular cation channels present in sarcoplasmic reticulum (SR) and are thought to provide counter-current for SR Ca^{2+}-release that is crucial for muscle contraction. We present stochastic models of the voltage-regulated gating of TRIC-B channels based on single channel data. We analyse the effects of different connectivity schemes on model behaviour in order to better evaluate and understand the role of this ion channel in intracellular calcium release and control.

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PP0

Dynamics, Networks and Energy Efficiency

Models of innovation uptake can be based on various factors: a) rational decision-making with regards to the intrinsic value of a product; b) social spreading of technology or ideas induced by peer-to-peer communication of information; c) interaction with the "market' via a global feedback. For certain innovative technologies or behaviours the decision to adopt may be based on a combination of these factors. This is particularly the case for energy-related innovations, where some are more visible and socially desirable (such as solar panels) compared to others which are hidden (such as home insulation). We introduce a threshold diffusion model for the dynamics of the adoption of such innovations that is based on a combination of all three factors, along with dynamical-systems inspired methods for analysing and understanding the numerically observed diffusion behaviour.

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PP0

Optimal Control in Lagrangian Data Assimilation

Inferring the state of an ocean flow is an integral part of environmental monitoring, conservation efforts, and mitigation strategies for weather events. Autonomous vehicles with a limited capacity for locomotion are increasingly being used for data assimilation of quantities of interest in the ocean, including the time-dependent velocity field. We assess the efficacy of optimal control techniques to guide Lagrangian data assimilation in 1- and 2-dimensional flows, focusing on assimilation of the velocity field itself.

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PP0

An Adaptive Algorithm for Estimation of Synaptic Strengths in a Network of Neurons

The behavior of interconnected neurons depends largely on the synaptic coupling and can be analyzed using nonlinear dynamical models. Finding the strength of connections requires developing a new system identification method to overcome problems of nonsmooth error function and unobservable states. We describe an adaptive algorithm to determine the connections in a self-oscillatory network of Izhikevich neurons. Individual membrane potentials are observed and the states of the model are estimated by the Unscented Kalman Filter.

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Lobe Dynamics and Homoclinic Tangles in Atmospheric Flows

The primary concern for geophysical flows are the finite

time nature and the arbitrary time dependence in contrast to classical dynamical systems. Recent work on 2D quasi-horizontal approximations of atmospheric motion have demonstrated that there are aperiodic, finite-time analogs of homoclinic tangles and lobe dynamics, e.g., around hurricane boundaries, such as using FTLE based identification of coherent structures. We apply methods based on Lagrangian descriptors (due to Mancho and co-workers) to locate distinguished hyperbolic trajectories (DHTs) and generate corresponding finite-time stable and unstable manifolds to study lobe dynamics, as applied to atmospheric flow as well as fluid experiments. We compare the Lagrangian descriptor approach with the FTLE-based approach.

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PP0

Stability and Bifurcation Analysis of Rigid Spacecraft Spin Stabilization Using Delayed Feedback Control

The stability and bifurcation of closed loop delayed feedback control for spin stabilization of a rigid spacecraft is investigated, in which intermediate axis spin is stabilized. Linear stability is analyzed via the exponential-polynomial characteristic equation, while the normal form of the Hopf bifurcation is analytically obtained via the method of multiple scales and verified using continuation software. The obtained stability regions and bifurcations are verified with numerical simulations.

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PP0

Bifurcations of Large Networks of Two Dimensional Integrate and Fire Neurons

Recently, a class of two-dimensional integrate and fire models has been used to faithfully model spiking neurons. This poster introduces a technique to reduce a full network of this class of neurons to a mean field model, consisting of a system of switching ordinary differential equations. The mean field equations are able to qualitatively and quantitatively describe the bifurcations that the full networks display. Extensions to heterogeneous networks of oscillators and other applications are discussed.

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PP0

Pattern Formation in Small-world Networks

The Turing instability is a classic mechanism for the formation of spatial structures in non-equilibrium systems and has recently been investigated by Nakao and Mikhailov in the context of complex networks. Inspired by their work we investigate the Swift-Hohenberg equation when posed on a small-world network. We find a branch of solutions that snakes upward when a quintic term is included, just as in the PDE setting.

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PP0

Rigorous Numerical Verification of Uniqueness and Smoothness in a Surface Growth Model

We study three different methods, based on numerical data and a-posteriori analysis, to verify rigorously the uniqueness and smoothness of global solutions. The methods are applied to a scalar surface growth model and compared numerically. Despite of being scalar, this model is similar to 3D-Navier Stokes and serves as a toy problem.

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PP0

Sleep-Wake Transition Dynamics

Regulation of sleep-wake transitions presents a unique mathematical challenge in understanding sleep. Competitive interactions between two mutually inhibitory neuronal networks are involved in these transitions and it is known that wake bout durations follow a power-law distribution in several species. Here we explore the role of network architecture in generating sleep-wake transitions and develop a statistical tool to analyze simulated distributions of activity bouts.

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PP0
Bifurcations and Rhythms in a Mutually Inhibitory Three-Neuron Network

Inhibitory neuronal networks arise throughout the central nervous system and play an important role in rhythm generation. It is thus crucial to understand the mechanisms underlying the dynamics of these networks and how feedback signals from physiological components modulate their outputs. We consider a mutually inhibitory three-neuron network and analyze how intrinsic dynamic features, synaptic connections, and various inputs interact to affect complex bifurcation structures of the network and thereby modulate network outputs.

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PP0
Saturated Perturbation in Pyragas Methods Through Nonlinear Feedback Control

Using time-continuous control for controlling chaos was stated by Pyragas. He introduced the proportional and delayed feedback control methods. He modified them by a saturated perturbation based on a piecewise linear control law to avoid large perturbations and multistability. We propose an alternative nonlinear bounded element into the feedback law. Local convergence is shown while the desired saturation of the perturbation is assured. Different aspects of our proposal are analyzed and confronted with Pyragas methods.

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PP0
Prey Switching with a Linear Preference Trade-off

We study piecewise-smooth models of predator-prey interaction to describe predator's adaptive change of diet. We show that a 1 predator-2 prey system with a tilted switching manifold between the discontinuous vector fields goes through a Hopf-like bifurcation, followed by an adding-sliding bifurcation, and period doubling. Our model simulations capture the periodicity in the ratio between predator's preferred and alternative prey types exhibited by data on freshwater plankton.

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PP0
Global Dynamics of the Subcritical Hopf Normal Form Subject to Pyragas Time-Delayed Feedback Control

Pyragas time-delayed feedback control is designed to stabilize an unstable periodic orbit, such as the one in the widely used normal form of a subcritical Hopf bifurcation. Previous work focused primarily on the mechanism of stabilization. Here we present a global picture of the dynamics induced by the time-delayed feedback. In particular, we consider how infinitely many delay-induced Hopf bifurcation curves move as the 2π-periodic feedback phase is varied.

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PP0
A New Phase Space Method for Radar/acoustic Target Discrimination

We have developed a method for target discrimination employing chaos based waveforms and a nearest neighbor strand separation metric. Chaotic rf FDTD simulation or acoustic experimental waveform data reflected from several similar targets were embedded and nearest neighbor strands were identified. We distinguish between targets by choosing between optimized known strand configurations that minimize the average strand separation of unknown scattered waveforms. The method is robust in the presence of substantial noise and clutter.

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PP0
Localised States and Pattern Formation in a Neural Field Model of the Primary Visual Cortex

The primary visual cortex has been shown to maintain localised patterns of activity when oriented stimuli are presented in the visual field. For specific choices of the connectivity function defining intra-cortical connections it is possible to derive a PDE reduction that allows for standard dynamical systems tools to be applied. We compute and path follow both radially-symmetric bump solutions and non-radially-symmetric patterns with D6 symmetry;

these solutions are linked to experimental observations.

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PP0

Mining Experimental Data from the Chaotic Waterwheel

A large collection of experimental data of the motion of a Malkus-Lorenz waterwheel is analyzed. Progress will be reported on a number of fronts: application of Gottwalds 0-1 test for chaos to the data; determining fixed point location from phase space trajectories; extracting the motion of the waters center of mass location from the time series data; and determining the variation of total water mass in the wheel (generally assumed constant) via dynamic force measurements.

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PP0

Dynamics of An Seqihrs Epidemic Model with Media Awareness, Quarantine, Isolation and Cross-Protective-Immunity

An autonomous deterministic non-linear epidemic model SEQIHRS is proposed for the transmission dynamics of a highly contagious disease with quarantine, isolation and cross-protective-immunity. The DFE is GAS for $\mathcal{R}_0 < 1$ and for $\mathcal{R}_0 > 1$ the unique endemic equilibrium is LAS. The impact of non-pharmaceutical prophylaxis through media awareness is assessed and estimated through a new approach. It is observed that if the level of transmission by isolated individuals in hospitals is high enough, then the use of quarantine and isolation could offer a detrimental population-level impact.

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PP0

Delayed Feedback Attitude Stabilization of Rigid Body Motion on So(3) Via Liapunov-Krasovskii Functionals

This paper addresses the stabilization problem of rigid body motion on SO(3) in presence of an unknown constant time delay in the measurements. By employing a Lyapunov-Krasovskii functional, a delay dependent stability condition is obtained in terms of a linear matrix inequality, which results in linear control gain matrices. In addition, an estimate of the region of attraction of the system is obtained. A set of simulations are performed and compared with previous works.

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An Agent-Based Model for Stripe Formation in Zebra Fish

Zebra fish develop stripe patterns composed of pigmented cells during their early development. Experimental work by Kondo and his collaborators has shed much light on how stripes form and how they are regenerated when pigmented cells are removed. Theoretical work has focused on reaction-diffusion models. Here, we use an agent-based model for cell birth and movement to gain further insight into the processes and scales involved in stripe formation and regeneration.

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PP0

Use of Optogenetics for Control of Cortical Seizures

The use of charge balanced feedback control for the suppression of seizure like activity has been successfully demonstrated in one and two dimensional cortical models. The controller works through control of bifurcations. Extending this, we study the bifurcations produced by charge balanced optogenetic control in a two dimensional cortical model by the optical stimulation of neurons, and its effect on the non-linear dynamics of seizures.

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PP0

Modeling of Chaotic Time Series Using Chamfer Distance

We tried to make a mathematical model of low dimensional chaos by using Chamfer distance which is used in computer vision.

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PP0

Dynamics of Vegetation Patterns under Slowly Varying Conditions

We consider an extension of the Klausmeier model for vegetation patterns, that incorporates nonlinear diffusion. With continuation software an overview of coexistent stable steady states can be constructed: the Busse balloon. It is found that patterns exhibited by the model repeatedly suffer from abrupt decreases in wavenumber ultimately leading to desert, as a parameter decreases. It will be shown that these abrupt changes correspond directly to interactions with the boundary of the Busse balloon.

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PP0

Amplitude Equations for a Period-Doubling Bifurcation in a Neural-Field Model

We examine a two population neural-field model with temporal periodic forcing and a piecewise linear firing rate. We perform computer simulations and observe a period doubling bifurcation with non-zero wave-number. We then use the piecewise linear nature of the firing rate to construct analytically the underlying spatially homogeneous periodic orbit. Performing linear stability analysis allows us to predict the position of the bifurcation. Finally we formulate the amplitude equations for this model.

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PP0

Multiple Rhythms from One Network: Phase Plane Analysis of Rhythmic Activity in Turtle Motor Circuits

We analyze a proposed central pattern generators ability to produce differing motor patterns from a single pool of neurons under different tonic drives. A key issue is a particular motoneurons response to different phasic synaptic inputs. We study the impact of these phasic inputs on motoneuron phase space and on properties of associated trajectories and show how these yield sufficient conditions for reproduction of observed rhythms. A contraction argument leads to existence of a stable solution.

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Investigating Network Structure in Locomotor Models

Central pattern generators (CPGs) are neuronal networks that produce rhythmic activity in the absence of both rhythmic input and afferent feedback. These networks underlie various rhythmic animal movements, such as locomotion. We propose and analyze CPG networks that are able to replicate particular locomotor patterns. This extends previous modeling efforts by providing a more detailed description of the contribution of intrinsic neuronal dynamics and network structure to the mechanisms underlying rhythm generation in locomotion.

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PP0

Growth of Diffusion Limited Aggregation (DLA)-Grass like branched pattern via Turing pattern formation in a Belousov-Zhabotinskii (B-Z) type reaction system

Nanostructured growth DLA-Grass like branched pattern in a B-Z type reaction system by using ethyl acetoacetate-adipic acid as a duel organic substrate has been reported. The system in liquid phase has been found to show Turing type pattern. The solid phase nucleation has been found to occur in the colloidal phase (composed of nano size particles) and has been found to grow in symmetric crystal pattern with the progress of the reaction finally exhibit DLA morphology.

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PP0

Return Times and Rates of Fluid Mixing

Research in smooth ergodic theory is delivering results on rates of mixing in abstract dynamical systems. We report on the relevance of such results to fluid mixing problems.

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PP0

Stochastic Endemic Sir Model and Its Properties

We consider the stochastic endemic SIR model. This is a

generalization of the classic endemic SIR model in which the coefficients depend on a semi-Markov process describing a random media. Under stationary conditions of the semi-Markov media we study an averaging and diffusion principles for the perturbed stochastic endemic SIR model. In the case of avereging principle we get classic endemic SIR model with averaged coefficients, and in the case of diffusion approximation we obtain the diffusion endemic SIR model. We also study stability properties of the stochastic endemic SIR model.

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PP0

Performance Evaluation of Indoor Power Line Communication Using Chaos CDMA

Power line communication is a technology that is used for data transmission on electric power lines. Because impedance mismatching and branched lines cause signal reflections, power line channels possess multi-pass fading characteristics. In this study, the performance of a synchronous code division multiple access (CDMA) using the chaotic spreading sequences with constant power is estimated in indoor power line channels.

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PP0

Coupled Aircraft Nose Landing Gear and Fuselage Dynamics

Under certain conditions during take-off and landing, pilots may experience sometimes quite strong vibrations in the cockpit. We present a mathematical model for a coupled aircraft nose landing gear and fuselage system. A bifurcation analysis reveals that self-sustained shimmy oscillations of the landing gear can trigger considerable fuselage dynamics. The system behaviour depends strongly on the modal characteristics of the fuselage.

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PP0

A Discontinuous Galerkin Method for Modeling Transcription

A Discontinuous Galerkin Finite Element Method is used for the simulation of a nonlinear conservation law PDE which models traffic flow with several traffic lights. This is used to model the motion of polymerases on ribosomal RNA. Physically relevant pauses are incorporated into the model. These pauses result in delays during the transcription process, possibly affecting protein production. Using the DG solution, the average delay experienced by a polymerase is estimated.

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PP0

Linear Frequency Response Theory for Autonomous, Chaotic Oscillators

We propose to define a linear frequency response function for autonomous, structurally stable chaotic oscillators, which measures the change of the average frequency under a stationary perturbation. We furthermore link this frequency response function to the field of zero Lyapunov vectors and discuss the applications and limitations of this approach.

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PP0

Empirically Determined Adjoint Operators for the Coarse Control of Distributed Microscopic Processes

We present a method for the design of coarse-grained linear controllers for spatially distributed processes in a multi-scale, "equation-free' computational environment. This method is applied to two prototypical problems: a black-box linearized Ginzburg-Landau simulator and a FitzHugh-Nagumo simulator based on Lattice-Boltzmann methods. In both cases, short bursts of the full simulation are used to locate the steady state and approximate the adjoint of the Jacobian well enough for an effective coarse

controller to be designed.

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PP0

Kneading Invariants for the Elucidation of Chaos

A computational technique based on the symbolic description utilizing kneading invariants is proposed for the exploration of parametric chaos in systems with the Lorenz attractor. The technique elucidates the stunning complexity and universality of the patterns discovered in the biparametric scans of given models and detects their organizing centers codimension-two T-points and separating saddles.

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