PLENARY SPEAKERS

Russel Caflisch
University of California
Multiscale Mathematics for Plasmas
Plasmas make up 99% of the visible matter in the universe and are found in a wide range of natural and man-made systems, such as fluorescent lights, stars, the solar wind, and fusion reactors. Plasmas support a rich set of phenomena that exhibit variations on many different scales in time and in phase space (both position and velocity). Some of the physical processes involved in these phenomena include kinetic effects from Coulomb collisions, magnetic reconnection, Landau damping, and turbulent transport. In addition to these physical phenomena, numerical methods for plasmas confront a number of multiscale numerical phenomena such as grid heating in PIC methods and stiff particle interactions in kinetic codes. This talk will present a survey of some of these phenomena and of new analytic and numerical methods that have been developed to address them.

Margaret Cheney
Rensselaer Polytechnic Institute
Synthetic-Aperture Radar Imaging
Synthetic-aperture radar imaging is a technology that has been developed, very successfully, within the engineering community during the last 50 years. Radar systems not only make beautiful images of our earth, but also help identify and track military targets. One of the key components of this impressive technology is mathematics, and many of the open problems are mathematical ones. This lecture will explain, from first principles, the basics of radar and some of the mathematics involved in producing high-resolution radar images. The talk will conclude with a quick, superficial survey of some of the related open problems.

Leah Edelstein-Keshet
University of British Columbia
Mathematical Adventures in Cell Biology

Cell motility plays a vital role in the development and morphogenesis of multicellular organisms, in the function of our immune system, and in pathologies such as metastatic cancer. It also presents a fascinating topic where disciplines such as cell biology, biochemistry, mathematics, and scientific computation intersect. In this talk I will survey the work done in my group over the last few years on the actin-based motility of animal cells, and on the regulatory system that controls the spatio-temporal behaviour of a motile cell.

One of the first issues I address concerns the symmetry breaking that initiates cell polarization. In this first step, a cell must respond to a weak external signal (e.g. chemical gradient) by committing to a direction of motion. I discuss the biological signaling that is responsible, and describe some of the mathematics developed to understand the underlying mechanism. I also describe our successive steps at understanding the signaling pathways module by module, and how these steps eventually allowed us to develop a computational model for cell motility. I will also describe ongoing work with experimental biologists on specific aspects of this research related to carcinoma cells.

This work has been joint with Adriana Dawes, Stan Maree, Alexandra Jilkine, Yoichiro Mori, Ben Vanderlei, Veronica Grieneisen, Nessy Tania, and Georg Walther.

MINISYMPOSIUM SPEAKERS

Silas Alben
Georgia Institute of Technology
Swimming and Flapping in Vortex Wakes

We consider two problems related to the propulsion of flexible surfaces in vortex wakes. First, we study "inverted drafting" in flags, in which the drag force on one flag is increased by excitation from the wake of another. The types of drafting and dynamics (synchronization and erratic flapping) depend on the separation distance between the flags. Second, we present a simple model of a trout swimming in a cylinder wake, which saves energy by slaloming through a vortex street. We find analytic solutions and compare with previous experiments and numerics.

Xavier Antoine
Institut Elie Cartan Nancy (IECN), France
Analytical Preconditioning of Integral Equations in Acoustic Scattering

The aim of this talk is to present some new ways of building efficient and robust preconditioners for the iterative solution of acoustic integral equations in the high frequency regime. The problem is known to be difficult since it is highly non-definite positive and complex-valued. Essentially, the idea that we propose consists in building continuous pseudo-inverse operators of the underlying integral operator by means of operator theory techniques. Then, the matrix preconditioner is obtained by using a boundary element discretization. This point of view is called analytical preconditioning techniques.

We will give two directions. The first one uses the Calderon integral relations. Examples will be given for scattering by open surfaces and scattering by penetrable homogeneous scatterers. A second approach is based on the theory of pseudodifferential operators and microlocal analysis. Again, computational examples will show that this direction can be extremely useful for preconditioning the integral equation of acoustic scattering. We will also provide comparisons with algebraic preconditioners (SPAI, ILUT) to show that improved and more robust convergence rates can be expected. Finally, these preconditioners can be trivially integrated into a Fast Multilevel Multipole solver.

Guillaume Bal
Columbia University
Equations with Random Coefficients: Convergence to Deterministic or Stochastic Limits and Theory of Correctors

Equations with small scale structures abound in applied sciences. Such structures often cannot be modeled at the microscopic level and thus require that one understand their macroscopic influence. I will consider the situation of partial differential equations with random, highly oscillatory, potentials. One is then interested in the behavior of the solutions to that equation as the frequency of oscillations in the micro-structure tends to infinity. Depending on spatial dimension and the decorrelation properties of the random potential, I will show that the limit is the solution to either a deterministic, homogenized (effective medium) equation or a stochastic equation with multiplicative noise that should be understood in the sense of a Stratonovich product. More precisely, there is a critical spatial dimension above which we observe convergence to a deterministic solution and below which we observe convergence to a stochastic solution. In the former case, a theory of correctors to homogenization allows one to asymptotically capture the randomness in the solution to the equation with the small scale structure. Once properly rescaled, this corrector is shown to solve a stochastic equation with additive noise.

Alexander Barnett
Dartmouth University
A New Integral Representation for Quasi-periodic Fields and its Application to Periodic Scattering and Bloch Eigenvalue Problems

Many numerical problems in modern acoustic and electromagnetic applications involve the interaction of linear waves with periodic, piecewise-homogeneous media. Boundary integral equations are a natural approach, allowing high efficiency and high-order or spectral convergence. Periodizing can be achieved by replacing the free-space Greens function with its quasi-periodic cousin; however, this fails near parameter values corresponding to resonances of the empty unit cell. We fix this problem by returning to the free space Greens function, while adding auxiliary layer potentials on the lattice unit cell boundaries. We will show in 2D that the eigenvalue problem for Bloch waves in a photonic crystal, and the scattering from a grating, may both be solved robustly to 10 digits of accuracy with only a couple of hundred unknowns. The method leads to 2nd-kind equations, couples to existing BIE tools (including fast multipole acceleration) in a natural way, generalizes well to 3D, and avoids lattice sums entirely. Joint work with Leslie Greengard (NYU).

Osman Basaran
Purdue University
Electrohydrodynamic Tip Streaming and Emission of Charged Drops from Electrified Liquid Cones

When subjected to strong electric fields, raindrops in thunderclouds, pendant drops in electrospray mass spectrometry, and planar films form conical tips and emit thin jets from their tips. Theoretical analysis of the temporal development of such electrohydrodynamic (EHD) tip-streaming phenomena has heretofore been elusive given the large disparity in length scales between the macroscopic drops/films and the microscopic jets. Here, simulation and experiment are used to investigate EHD tip-streaming from a liquid film of finite conductivity. In the simulations, the full Taylor-Melcher leaky-dielectric model, which accounts for charge relaxation, is solved to probe the mechanisms of cone formation, jet emission, and breakup of the jet into small drops. Simulations show that tip-streaming does not occur if the liquid is perfectly conducting or perfectly insulating. A scaling law for sizes of micro-(nano-)scale drops produced from the breakup of the thin jets is also developed.

Richard Bertram
Florida State University
Mixed Mode Oscillations as a Mechanism for Pseudo-Plateau Bursting

We combine bifurcation analysis with the theory of canard-induced mixed mode oscillations to investigate the dynamics of a novel form of bursting. This bursting oscillation, which arises from a model of the electrical activity of a pituitary cell, is characterized by small impulses or spikes riding on top of an elevated voltage plateau. Oscillations with these characteristics have been called “pseudo-plateau bursting”. Unlike standard bursting, the subsystem of fast variables does not posses a stable branch of periodic spiking solutions, and in the case studied here the standard fast/slow analysis provides little information about the underlying dynamics. We demonstrate that the bursting is actually a canard-induced mixed mode oscillation, and use canard theory to characterize the dynamics of the oscillation. We also use bifurcation analysis of the full system of equations to extend the results of the singular analysis to the physiological regime. This demonstrates that the combination of these two analysis techniques can be a powerful tool for understanding the pseudo-plateau bursting oscillations that arise in electrically excitable pituitary cells and isolated pancreatic beta-cells.

Rebecca Betensky
Harvard University
Methods for Multiply Truncated Survival Data: Application to Age of Onset of ALS

The causes of sporadic amyotrophic lateral sclerosis (ALS) are unknown. Several risk factors have been implicated, including a positive family history and increasing age. Others, such as a history of trauma, have been difficult to validate, in part because epidemiological analyses have been hindered by methodological problems, including inadequate selection of control groups, small samples sizes and uncertainties in case ascertainment. A case-control study was performed at Massachusetts General Hospital to examine the role of hypothesized risk factors, such as early head trauma, and to identify additional risk factors. This study included 94 patients diagnosed with ALS, of whom 27 had suffered from head or neck trauma prior to their diagnosis. Sampling into the study required that subjects had experienced onset and diagnosis of ALS prior to study entry, and that they were alive and being followed at study entry. Crude analyses of age of onset for the subgroups with and without history of trauma, without correction for the sequence of events required for being sampled into the study, yield median ages of onset of 55.1 and 55.8, respectively, which are certainly underestimates. We propose two models for sequential truncation that cover the scenarios of interest. Within this framework, we propose nonparametric and semi-parametric estimators for the distribution of age of onset that are consistent. The semi-parametric estimators achieve improved efficiency through flexible parametric modeling of age at death (or end of follow-up) and/or age at study entry. We obtain estimates of the median age of onset of ALS of 63.2 (95% CI: 55.7,70,.4) among ALS patients with prior trauma and 66.3 (95% CI: 55.8,71.2) among ALS subjects with no prior trauma, suggesting a possible relationship between early trauma and ALS onset.

Gino Biondini

SUNY at Buffalo

Solitons Reflection in Boundary Value Problems and a Nonlinear Method of Images

In initial value problems (IVPs) for integrable nonlinear evolution equations (NLEEs), each soliton in an exact N-soliton solution is associated to a discrete eigenvalue of the scattering problem via the inverse scattering transform. The situation in initial-boundary value problems (IBVPs) is more complicated, however. For the nonlinear Schroedinger (NLS) equation on the half line, the IBVP only truly becomes linear for boundary conditions (BCs) of homogeneous Robin type. Importantly, the relation between solitons and discrete eigenvalues is preserved in the IBVP. Soliton solutions of NLS, however, do not satisfy these BCs in general. Moreover, numerical solutions of the IBVP show that solitons are reflected at the boundary—even though the soliton velocity is determined by the discrete eigenvalue, which is time-independent. The resolution of these apparent paradoxes is that discrete eigenvalues in the IBVP appear in symmetric pairs, and corresponding relations exist for the norming constants. For each soliton in the physical domain a symmetric counterpart exists, with equal amplitude and opposite velocity, whose presence ensures that the solution satisfies the BCs. The ostensible reflection of the soliton at the boundary of the physical domain corresponds to the interchanging of roles between "physical" and "mirror" solitons. These results provide a nonlinear analogue of the method of images in electrostatics. Here, however, the soliton reflection is accompanied by a reflection-induced shift, a remnant of the nonlinear nature of the problem. Similar phenomena arise for both the focusing and defocusing NLS (respectively with zero or constant BCs at infinity) and for the the Ablowitz-Ladik lattice.

Joseph C. Cappelleri

Pfizer Inc, New London, CT

Confidence Interval Estimation for Inter-Rater Reliability in a Two-Factor Random-Effects Design

We specify a two-factor random-effects model from an inter-rater reliability study, where effects of subjects and raters are random. The reliability measure is an intraclass correlation coefficient and our objective is to obtain an approximate confidence interval (CI) around it. We evaluated and illustrated four methods: (1) two-moment approximation, (2) higher-moment based using Pearson's systems of equations, (3) large-sample approximation using a linear combination of the mean squares, and (4) modified large-sample. Their empirical coverage probabilities of the one-sided 95% CIs and two-sided 90% CIs were compared by simulations. The two-moment approach can yield substantially lower-than-desired coverage probabilities on its lower confidence bound. The other three approaches performed better, with the modified large-sample method being the most satisfactory overall. (joint work with Kelly Zou, Carmen Arteaga, and Naitee Ting)

Hector Ceniceros
University of California Santa Barbara
Efficient Approaches for the Simulation of Flow-structure Interaction via the Immersed Boundary Method
The Immersed Boundary Method is a versatile tool for the investigation of flow-structure interaction. In a large number of applications, the immersed boundaries or structures are very stiff and strong tangential forces on these interfaces induce a well-known, severe time-step restriction for explicit discretizations. This excessive stability constraint can be removed with fully implicit or suitable semi-implicit schemes but at a seemingly prohibitive computational cost. In this talk, we address these problems and propose cost-effective computational strategies both in 2D and 3D.

Rick Chappell
University of Wisconsin
Bent Line Quantile Regression with Application to an Allometric Study of Land Mammals' Speed and Mass
Quantile regression, which models the conditional quantiles of the response variable given covariates, usually assumes a linear model. However, this kind of linearity is often unrealistic in real life. One situation where linear quantile regression is not appropriate is when the response variable is piecewise linear but still continuous in covariates. To analyze such data, we propose a bent line quantile regression model. We derive its parameter estimates, prove that they are asymptotically valid given the existence of a change-point, and discuss several methods for testing the existence of a change-point in bent line quantile regression together with a power comparison by simulation. An example of land mammal maximal running speeds is given to illustrate an application of bent line quantile regression in which this model is theoretically justified and its parameters are of direct biological interests. (Joint work with Chenxi Li)

Greg Chini
University of New Hampshire
Low-Dimensional Models from Upper Bound and Energy Stability Theory
A novel model reduction strategy for forced-dissipative infinite-dimensional nonlinear dynamical systems is described. Unlike popular but empirical methods (e.g. based on the Proper Orthogonal Decomposition), this new approach does not require extensive data sets from experiments or full PDE simulations. Instead, truly predictive reduced-order models are constructed via Galerkin projection of the governing PDEs onto a-priori basis functions. This basis set is obtained by solving a constrained eigenvalue problem drawn from energy stability and upper bound theory. Within the context of porous medium convection, we show that these eigenfunctions contain information about boundary layers and other complex dynamic features and, thus, are well suited for the low-order description of highly nonlinear phenomena. Crucially, our analysis reveals a gap in the eigenvalue spectrum that persists even for strongly supercritical forcing conditions, thereby enabling the identification of a rational truncation scheme. We demonstrate the efficacy of our approach via comparisons with Fourier—Galerkin approximations of various orders. Joint work with C. Doering, N. Dianati, and Z. Zhang.

Dorota M. Dabrowska
University of California, Los Angeles
A Class of Semi-parametric Modulated Renewal Processes
Modulated renewal processes provide a large class of multi-state models which can be used for analysis of longitudinal failure time data. In biomedical applications, models of this kind are often used to describe

evolution of a disease and assume that patient may move among a finite number of states representing different phases in the disease progression. Several authors proposed extensions of the proportional hazard model for regression analysis of these processes. In this talk, we consider a general class of censored semi-Markov and modulated renewal processes and propose use of transformation models for their analysis. Special cases include modulated renewal processes with interarrival times specified using transformation models, and semi-Markov processes with one-step transition probabilities defined using copula-transformation models. We discuss estimation of finite and infinite dimensional parameters and develop an extension of the Gaussian multiplier method for setting confidence bands for transition probabilities and related parameters. A transplant outcome data set from the Center for International Blood and Marrow Transplant Research is used for illustrative purposes.

Bard Ermentrout
University of Pittsburgh
An Optimal Motor Velocity for Actin Filament Alignment
We consider a bundle of oriented actin filaments in a simplified geometry. Myosin motors move along the filaments at a fixed velocity which allows them to bring the filaments closer together. The filaments can spontaneously depolymerize and reform at arbitrary angles. The motors can fall off at a finite rate and attach at another rate. We show through both Monte Carlo simulations and analysis that there is an optimal motor velocity that maximizes the organization of the filaments into oriented bundles. We relate a particular limit of the model to the Kuramoto model with a novel kind of heterogeneity. We analyze the onset of oriented bundles from the completely disordered state. This work is done in collaboration with Lance Davidson and Callie Johnson.

Lisa Fauci
Tulane University
The Action of Waving Cylindrical Rings in a Stokes Fluid
Dinoflagellates swim due to the action of two eucaryotic flagella - a trailing, longitundinal flagellum that propagates planar waves, and a transverse flagellum that propagates helical waves. The transverse flagellum wraps around the cell in a plane perpendicular to the trailing flagellum, and is thought to provide both forward thrust along with rotational torque. Motivated by the intriguing function of this transverse flagellum, we study the fundamental fluid dynamics of a helically-undulating ring in a Stokes fluid. We use slender-body theory to compute the steady-state transverse and rotational swimming velocities of the ring in free- space, due to an imposed helical traveling wave. In addition, we study the dynamics of an undulating, elastic ring moving in both free-space and near a plane wall using the method of regularized Stokeslets.

Jason Fleischer
Princeton University
Rayleigh-Taylor Instability in Nonlinear Schrödinger Flow
The Rayleigh-Taylor instability (RTI) is a fundamental fluid instability which occurs when a heavy fluid is accelerated into a lighter one. While the RTI in classical fluids is a textbook problem, the instability in quantum fluids has received little attention. Here, we show that unlike the instability dynamics in normal fluids, the RTI in Schrödinger flow is strongly nonlinear and compressible from the start. The growth rate, obtained analytically, shows that inhibition due to wave diffraction has the same spectral form as viscosity and diffusion, despite the fact that the system is dispersive rather than dissipative. This gives formal support for the observation that turbulence in quantum fluids has the same scaling as that in normal fluids. Experimentally, we confirm the theory by demonstrating an all-optical RTI in a self-defocusing photorefractive crystal. The results hold for any Schrödinger flow, e.g. superfluids and quantum plasma, and introduce a new class of fluid-inspired instabilities in nonlinear optics. Joint work with Shu Jia.

Paul Gallo

Novartis Pharmaceuticals, East Hanover, NJ

Group Sequential Case Study: Early Termination of a Major Cardiovascular Outcomes Megatrial

The ACCOMPLISH study was a recent cardiovascular megatrial comparing antihypertensive regimens for their long-term effects on a mortality/morbidity endpoint. The study used a group sequential monitoring plan, and was ultimately terminated early by an independent Data Safety Monitoring Board (DSMB) due to superior efficacy in one of the treatment arms. How the results evolved as the trial proceeded, and the actions and decisions of the DSMB, raise and illustrate a number of challenging issues associated with interim monitoring - clinical and operational, as well as statistical issues with broader implications relating to the behavior of some group sequential schemes and adaptive design schemes, and proper interpretation of results. This presentation describes how the DSMB interpreted and dealt with the emerging efficacy signal, including modifying the schedule of interim looks and defining revised criteria, before coming to its decision.

Goëry Genty

Optics Laboratory, Tampere University of Technology, Finland

Optical Rogue Waves and Extreme-events in Optics

Significant recent experiments on the shot-to-shot instabilities in the extreme nonlinear optical spectral broadening process of supercontinuum generation have shown that these fluctuations contain a small number of statistically-rare "rogue" events associated with a greatly enhanced spectral bandwidth and the generation of localized temporal solitons with greatly increased intensity. Crucially, because these experiments were performed in a regime where modulation instability (MI) plays a key role in the dynamics, an analogy was drawn with hydrodynamic rogue waves, whose origin and dynamics has also been discussed in terms of MI or, as it often referred to in hydrodynamics, the Benjamin-Feir instability. The analogy between the appearance of localized structures in optics and the rogue waves on the ocean's surface is both intriguing and attractive, as it opens up possibilities to explore the extreme value dynamics in a convenient benchtop optical environment. In addition to the proposed links with solitons, other recent studies motivated from an optical context have experimentally demonstrated inks with nonlinear breather propagation. The purpose of this paper will be to discuss these results that have been obtained in optics, and to consider possible similarities and differences with oceanic rogue wave counterparts. Joint work with John M. Dudley, CNRS Institut FEMTO-ST, University of Franche-Comte, France.

Christophe Geuzaine

University of Liege, Belgium

A Model Reduction Algorithm for Solving Multiple Scattering Problems at High-frequencies

We present a multiple-scattering solver for non-convex geometries such as those obtained as the union of a finite number of convex surfaces. The algorithm is an extension, using finite elements, of the integral equation technique proposed in [1]. It is based on an iterative solution of the scattering problem, where each iteration leads to the resolution of a single scattering problem. At high frequencies the solution of each single-scattering problem can be greatly accelerated thanks to the phase reduction technique [2].

[1] C. Geuzaine, O. Bruno, and F. Reitich. On the O(1) solution of multiple-scattering problems. IEEE Transactions on Magnetics, 41(5):1488--1491, 2005.

[2] X. Antoine and C. Geuzaine. Phase reduction models for improving the accuracy of the finite element solution of time-harmonic scattering problems I: General approach and low-order models. Journal of Computational Physics, 228:3114--3136, 2009.

Charles J. Geyer
University of Minnesota
Aster Models for Life History Analysis

Aster models are a kind of generalized generalized linear models that allow certain forms of dependence between components of the response vector and also allow different components of the response vector to have conditional distributions from different families (e. g., some binomial, some Poisson, some normal). They were especially designed for analysis of life history data on plants and animals. They allow joint analysis of data on survival and reproduction measured for multiple time periods, correctly accounting for the dependence of variables on earlier variables.

Aster models are graphical models having graphs that are forests, each edge corresponding to a one-parameter exponential family conditional distribution of one component of the response given another. The joint distribution of the response vector is then a multiparameter exponential family. Hence canonical linear submodels are also exponential families and likelihood inference is straightforward. These models are implemented in an R package 'aster' available from CRAN. Papers and tech reports are available at http://www.stat.umn.edu/geyer/aster/. Please note that "generalized generalized linear models" in the first line is not a typo—the repetition of "generalized" is intended.

Roy Goodman
New Jersey Institute of Technology
Pitchfork and Hopf Bifurcations of Defect Modes

The nonlinear coupled mode equations describe the evolution of light in Bragg grating optical fibers. Defects (localized potentials) can be added to the fiber in order to trap light at a specialized location as a nonlinear defect mode. In numerical simulations these defect modes are seen to lose (linear) stability through several types of bifurcations. Inverse scattering is used to design defects in which the bifurcations can be easily observed and studied via the derivation of finite-dimensional reduced equations. Conditions are given for the existence Hamiltonian pitchfork and Hamiltonian Hopf bifurcations in these systems, as well descriptions of the dynamics near these bifurcations.

Philippe Guyenne
University of Delaware
Hamiltonian Modulation Equations for Surface Water Waves

We present a Hamiltonian approach to nonlinear modulation of surface water waves on arbitrary depth, both in two and three dimensions. It is based on the reduction of the water wave problem to a lower-dimensional system involving surface variables alone. This is accomplished by expressing the Dirichlet-Neumann operator of the fluid domain as a Taylor series in terms of the surface elevation. Simplified models such as Hamiltonian versions of the Dysthe equation are then derived using techniques of Hamiltonian perturbation theory for partial differential equations. This is joint work with Walter Craig and Catherine Sulem.

Hong Im
University of Michigan
Identifying Characteristics of Ignition in a Stratified Reactant Mixture Using Computational Singular Perturbation

The computational singular perturbation (CSP) technique is applied as an automated diagnostic tool to classify ignition regimes encountered in homogeneous charge compression ignition (HCCI) engines. Various model problems representing HCCI combustion are simulated using high-fidelity computation with detailed chemistry for hydrogen-air system. The simulation data are then analyzed by CSP. In a homogeneous system, the occurrence of two branches of explosive eigenvalues characterizes chain-branching and thermal ignition. Their merging point serves as a good indicator of the completion of the explosive stage of ignition. However, the merging point diagnostics is insufficient to differentiate spontaneous ignition from deflagration. As an alternate method, the active reaction zones are first identified by the locus of minimum number of fast exhausted time scales (based on user-specified error thresholds). Subsequently, the relative importance of transport and chemistry is determined in the region ahead of the reaction zone. A new index IT, defined as the sum of the absolute values of the importance indices of diffusion and convection of temperature to the slow dynamics of temperature, serves as a criterion to differentiate spontaneous ignition from deflagration regimes. These diagnostic tools applied to 1D laminar and 2D turbulent ignition problems allow automated detection of different ignition regimes at different times and location during the ignition events. The implication of the results in the context of modeling auto-ignition of nearly homogeneous turbulent mixtures is discussed. Joint work with Saurabh Gupta, Graduate Student, University of Michigan and Mauro Valorani, University of Rome, La Sapienza.

Michael P. Jones
University of Iowa
Estimation of Group-Specific Survival Functions from Case-Cohort Data
Prentice (1986) introduced the case-cohort design to reduce the cost and necessary manpower in conducting large cohort studies that arise from processing all information, especially those requiring lab analyses and coding of subject-maintained diaries, into measurable covariates. In this design all variables are measured on everyone in a randomly selected subcohort, but only on those experiencing the event of interest in the remaining non-subcohort. The goal in this presentation is the estimation of the group-specific survival functions when group membership is only partially known, as from case-cohort data. The nonparametric maximum likelihood estimator is derived along with some smoothed variations that require fewer assumptions. Consistency and asymptotic normality can be obtained. The small-sample behavior is investigated through simulation.

Tasso Kaper
Boston University
TBA

William L. Kath
Northwestern University
A State-Mutating Genetic Algorithm to Design Ion Channel Models
Realistic computational models of single neurons require component ion channels that reproduce experimental findings. Here a topology-mutating genetic algorithm that searches for the best state diagram and transition-rate parameters to model macroscopic ion-channel behavior is described. Important features of the algorithm include the topology-altering strategy, automatic satisfaction of equilibrium constraints (microscopic reversibility), and multiple-protocol fitting without the need for explicit weighting. Application of this genetic algorithm to design a sodium channel model exhibiting fast and prolonged inactivation observed in the dendrites of CA1 pyramidal neurons yields a six-state model with a novel topology that produces realistic activity-dependent action potential backpropagation when incorporated into current-clamp simulations.

Syed N. U. A. Kirmani
University of Northern Iowa
Length-biased Sampling and Related Estimation in Survival Analysis
In many practical situations, such as cross-sectional sampling, the observed random sample is biased in the sense that it does not represent the target population. The problem of estimating the target survivor function is considered in such contexts when the data for two independent competing risks having proportional hazards is observed. Independent random right censoring is also taken into account. The work to be presented has been carried out jointly with Jean-Yves Dauxois and Agathe Guilloux.

Lynn Kuo
University of Connecticut and Hoffman-La Roche Inc.
Dynamic Frailty and Change Point Models for Recurrent Events Data
We present a Bayesian analysis for recurrent events data using a nonhomogeneous mixed Poisson point process with a dynamic subject-specific frailty function and a dynamic baseline intensity function. The dynamic subject-specific frailty employs a dynamic piecewise constant function with a known pre-specified grid and the baseline intensity uses an unknown grid for the piecewise constant function. Implementation of Bayesian inference using a reversible jump Markov chain Monte Carlo algorithm is developed to handle the change of the dimension in the parameter space for models with a random number of change points. A data set provided by Grubbs et al. with recurrent times to mammary tumors for 59 rats is used to illustrate the application of the new models. We compare several models including constant or piecewise constant subject-specific frailty and a fixed number or a random number for the change points in the baseline using the pseudo-marginal likelihood criterion. We show that models with a random number of change points in the baseline improve upon that of a fixed number. (Joint work with Changhong Song)

Rachel Kuske
University of British Columbia
Routes to Mixed-mode Oscillations in Stochastic Systems
This talk will give an overview of routes to mixed-mode oscillations (MMOs) in stochastic systems, covering mechanisms such as coherence resonance and bifurcation delay, and discussing robustness of MMOs in piecewise linear models. Related to this variety of pathways for stochastic MMOs is the challenge of identifying appropriate models for real data. We discuss a suite of measures that can be used to extract key model properties from time series, thus facilitating model calibration.

Eric Lauga
University of California, San Diego
Optimization of Locomotion without Inertia
Fluid mechanics plays a crucial role in many cellular processes. One example is the external fluid mechanics of motile cells such as bacteria, spermatozoa, and essentially half of the microorganisms on earth. In this talk, we briefly introduce the physical background for small-scale fluids-based locomotion, and then pose two separate optimization problems addressing the optimal geometry and optimal gait of low-Reynolds number swimmers. First, we derive analytically and computationally the optimal waveform of an elastic flagellum. Second, we compute numerically the optimal locomotion by surface distortions of a sphere; we show in particular the appearance of waves, reminiscent of the metachronal waves displayed by cilia.

Tim Lewis
University of California at Davis
The Effect of Voltage-gated Gap Junctions on Phase-locking in Neuronal Networks
Gap junction mediated electrical coupling is ubiquitous in neuronal systems. Electrical coupling is almost always modeled as a linear ohmic resistance between cells, where the coupling current is proportional to the transjunctional potential. However, the conductance of many gap junctions attenuates for increased voltage differences between cells. This voltage-gating process can evolve at different time scales. Because gap junction voltage-gating alters the strength of coupling between cells in a way that depends on the intrinsic states of the cells, it can affect the dynamics in neuronal networks. However, these effects are largely unstudied. We explore the effects of gap junction rectification on phase-locking in model neuronal networks. Using an extension of the theory of weak coupling, phase plane arguments, and numerical simulations, we examine both fast and slow rectification and their effects on the dynamics of networks of spiking neurons and networks of bursting neurons. Our study shows that the voltage-gating of gap junctions can affect neuronal network dynamics in a significant and complex manner.

Xiaofan Li
Illinois Institute of Technology
Interfacial Dynamics and Boundary Integral Methods

In this talk, boundary integral techniques are demonstrated for moving boundary problem of partial differential equations. In particular, a spectrally accurate boundary integral method for the velocities of moving interfaces in Stokes flow is explained in detail. In addition, a high-order boundary integral method For surface diffusions on elastically stressed axisymmetric rods is also presented. The possibility of singularity formation on the cylindrical surface is discussed.

Shaw-Hwa Lo
Columbia University
Discovering Influential Variables: A Method of Partitions

A trend in all scientific disciplines, based on advances in technology, is the increasing availability of high dimensional data in which are buried important information. A current urgent challenge to statisticians is to develop effective methods of finding the useful information from the vast amounts of messy and noisy data available, most of which are noninformative. This paper presents a general computer intensive approach, based on a method by Lo and Zheng for detecting which, of many potential explanatory variables, have an influence on a dependent variable Y. This approach is suited to detect influential variables, where causal effects depend on the confluence of values of several variables. It has the advantage of avoiding a difficult direct analysis, involving possibly thousands of variables, by dealing with many randomly selected small subsets from which smaller subsets are selected, guided by a measure of influence I. The main objective is to discover the influential variables, rather than to measure their effects. Once they are detected, the problem of dealing with a much smaller group of influential variables should be vulnerable to appropriate analysis. In a sense, we are confining our attention to locating a few needles in a haystack.

Wenbin Lu
North Carolina State University
Dimension Reduction and Variable Selection for Censored Regression

Methodology of sufficient dimension reduction (SDR) has offered an effective means to facilitate regression analysis of high dimensional data. When the response is censored, however, most existing SDR estimators can not be applied, or require some restrictive conditions. In this work we propose a new class of inverse censoring probability weighted SDR estimators for censored regression. Moreover, regularization is introduced to achieve simultaneous variable selection and dimension reduction. Asymptotic properties and empirical performance of the proposed methods are examined.

Stephen B. Margolis
Sandia National Laboratories
Propagation of Combustion Waves in Two-Phase-Flow Models of Porous Energetic Materials

Deflagrations in porous and/or granular energetic materials are characterized by regions of two-phase flow where significant velocity and temperature differences between gaseous and condensed phases can occur. These variations act to modify the structure and propagation velocity of the combustion wave relative to the single-phase problem, and lead to certain phenomena that are not generally present in the absence of such effects. In the present work, recent two-phase-flow models that describe propagating deflagrations under varying degrees of confinement, as represented by the pressure difference, or overpressure, between the burned and unburned regions, are reviewed. It is shown both through asymptotic and computational methods how the structure, propagation speed, final temperature, and stability of the combustion wave depend on the porosity and local pressure in the two-phase regions. In particular, exhibiting the burning-rate response as a function of overpressure is shown to predict the well-known transition from conductive to convective burning associated with the preheating of the unburned material by the reverse flow of the burned gases. Inclusion of temperature-nonequilibrium effects, the analysis of which requires the introduction of generalized matched asymptotic expansions, serves to further sharpen this transition and ultimately suggests a modified structure for the combustion wave in the convection-dominated regime.

Gareth H. McKinley
M.I.T., Hatsopoulos Microfluids Laboratory
'Beads on a String' Structures and Extensional Rheometry using Jet Breakup
Dilute polymer solutions are used in extensively in the formulations for water-borne paints, food, inks, cosmetics, etc to control the rheology and processing behavior of multi-component dispersions. These complex dispersions are processed and used over a broad range of shear and extensional rates. Typical commercial formulations have low viscosity and short relaxation times, and hence their non-Newtonian response is not apparent in a conventional rheometer. In a jet however, the action of surface tension leads rapidly (in the absence of viscoelastic effects) to capillary pinch-off and exposes the nonlinear response of the material. In this talk, we explore the influence of transient extensional rheology in the breakup of thin fluid threads at time scales of 1 ms and below. In a typical capillary-thinning rheometry experiment with low viscosity fluids, the presence of inertial, elastic and viscous effects on small length and time scales leads to complex dynamics in a necking fluid thread and the formation of a beads-on-a-string morphology. By contrast, in a fluid jet experiment, it is possible to influence the dynamics of the bead formation process by controlling the amplitude and frequency of the imposed disturbances. High deformation rates can be obtained in jetting flows, and the growth and evolution of instability during jetting and break-up of these viscoelastic fluids shows the influence of both elasticity and extensibility. We show that by carefully controlling the excitation frequency at which a fluid jet is excited, it is possible to drive the break-up in a particularly simple and symmetric mode, which can be used to extract extensional viscosity information using familiar capillary thinning analysis. Joint work with Vivek Sharma and Arezoo Ardekani.

Andreas Muench
University of Oxford
Dewetting of Polymer Films
In recent years, both experimental and theoretical results indicate the importance of slip at the liquid/solid interface and its influence on the dynamics and morphology of nanoscale liquid polymer films. Including the slippage in a continuum model gives rise to a whole family of thin film models for different regimes of slippage that span the range from no- and weak slip to strong slip where the slip length is very large. We consider in particular the models for large slip regarding various aspects of the film morphology and dynamics, such as the instability that occurs at the rim of holes that open in dewetting films, or on the dewetting rate. We compare our results with experiments by Karin Jacobs and her group.

Andre Nachbin
IMPA, Brazil
Discrete and Continuous Random Water Wave Dynamics
In FACM 2005 I presented different ways in which one can derive reduced models for studying surface water waves over random bottom topographies. My goal was to present different ways through which one can perform the asymptotic analysis at level of the 2D nonlinear potential theory equations. In this talk I will address asymptotic issues related to the wave solutions rather than the differential operators. I will overview some important mathematical issues and related physical phenomena, connected with water waves in random media. I will present some recent results and discuss issues that (I believe) lack a better mathematical understanding.

Hoai-Minh Nguyen
Courant Institute
Cloaking for the Helmholtz Equation
In this talk, I will present estimates for the Helmholtz equation involving a small inclusion in 2D or 3D for arbitrary frequency and their application for cloaking.

Barbara Niethammer
University of Oxford
Effective Evolution and Screening in Dilute Diblock-copolymer Systems
We study a free boundary problem describing the micro phase separation of diblock copolymer melts in the regime that one component has small volume fraction such that the phases separate into an ensemble of small spheres. An asymptotic analysis within a gradient flow setting can be used to derive mean-field equations for the evolution of particle centers and radii. It turns out that on a time scale of the order of the average volume of the spheres, the evolution is dominated by coarsening and subsequent stabilization of the radii of the spheres, whereas migration becomes relevant on a later time scale. We also show how the underlying gradient flow structure can be used to rigorously derive the corresponding mean-field equations. (Based on joint work with M. Helmers, X Ren, and Y. Oshita.)

Astrid A. Prinz
Emory University
Variability and Robustness in Neuronal Networks
Neuronal oscillators, especially the central pattern generator circuits that control rhythmic behaviors such as breathing, need to function reliably throughout life despite ongoing turnover of their molecular components and other perturbations. How is this stability achieved? I will discuss recent results that show how parameter non-uniqueness, membrane conductance co-regulation, and activity-dependent homeostatic regulation through negative feedback loops act together to ensure reliable neuronal network function. My presentation will highlight how fruitful interactions between electrophysiology experiments and numerical modeling can advance our understanding of complex system dynamics at the intersection of physics and biology.

Victor Roytburd
Rensselaer Polytechnic Institute
Propagation of Extremely Short Pulses in Doubly-resonant Optical Media
Over the last few years there have been exciting achievements in designing artificial optical materials (metamaterials) with very unusual properties. For example, in some frequency regimes, they may be "left-handed" (with the left-oriented triplet of the electric, magnetic, and wave vector) and have a negative refractive index. The experimental realization of the left-handed property is based on the resonant response of the artificial material to both electric and magnetic fields. I will discuss our recent results (theoretical and computational) on propagation of extremely short electromagnetic pulses for a simple model of homogeneous doubly-resonant media.

Overview of Division of Mathematical Sciences, NSF
I will discuss what I learned about NSF, while working at the Foundation.

- NSF goals and structure
- Mathematical and Physical Sciences Directorate / Division of Mathematical Sciences
- Structure and programs
- What is happening inside?
- Proposal preparation tips

Tobias Schaefer
College of Staten Island
A Lie Transform Method for Random Dynamical Systems
Weakly stochastic Hamiltonian systems arise naturally in the context of fiber optics and soliton dynamics. The noise interacts with the deterministic trajectories in a highly complicated way and it is, in general, difficult to develop a systematic perturbation expansion due to operator assymmetry in the associated Fokker-Planck equation. The purpose of this talk is to introduce an entirely new idea based on Lie transforms to treat such systems.

Arthur Sherman
NIDDK
Predictions and Tests of the Dual Oscillator Model
Insulin secretion in vivo is pulsatile with a period of ~ 5 min and correlates with in vitro oscillations of electrical activity, calcium, and metabolism. We have proposed a model in which a slow metabolic, possibly glycolytic, oscillation drives the electrical activity through oscillations of K(ATP) channel conductance. We have now tested the model experimentally in two ways. Current-voltage ramps show that K(ATP) conductance oscillates and, moreover, is asymmetrical, with higher conductance during the silent periods than during the active periods. This is consistent with models in which electrical activity is driven by metabolism, but not with models in which metabolic oscillations are secondary to calcium oscillations. Computer simulations of coupled cells were used to validate the interpretation of total slope conductance in the hyperpolarized voltage range as K(ATP) conductance despite propagated action potentials from unclamped cells. We have also confirmed the model prediction that NAD(P)H oscillates when calcium oscillations are inhibited by the K(ATP) channel opener diazoxide.

Andrey Shilnikov
Georgia State University, Neuroscience Institute and Department of Mathematics
Polyrhythms of Synchronous Bursting in Models of Multifunctional Central Pattern Generators
We study polyrhythms of synchronous bursting patterns in models of inhibitory networks, such as a multifunctional Central Pattern Generator (CPG) controlling several locomotive behaviors of an animal. We show that the onset of a specific rhythm in such a CPG made of realistic Hodgkin–Huxley-type interneurons can be determined by an order parameter being the duty cycle of bursting. Various configurations of CPG models are analyzed and the universal mechanisms for synergetics of the bursting patterns are examined. We discuss the multistability of inhibitory networks that results in polyrhythmicity of its synchronous bursting patterns. The emergence of synchronous rhythms in the networks in question is closely tied to the temporal characteristics of the bursting neurons. It is shown that when an individual interneuron is close to a transition into tonic spiking, the dynamics of the network become highly sensitive to small changes in synaptic coupling strengths. We reveal the way the network can alter the burst durations of its neurons to designate the pacemakers among them. This endows the network with flexible synchronization properties leading to the multistability of coexistent bursting rhythms. Joint work with Jeremy Wojcik, Robert Clewley, and Igor Belykh.

Frances K. Skinner
Toronto Western Research Institute, University Health Network and University of Toronto
Interneuron Networks – Details that Matter?
The hippocampus is an intensely studied brain structure that is involved in learning and memory. It expresses several population activities that are controlled by a diverse collection of inhibitory cells, or interneurons. These interneurons are known to have different intrinsic characteristics in terms of the density and distribution of voltage-gated channels on their dendrites. Furthermore, different interneuron types fire at particular phases of various population activities, suggesting distinct and specific contributions to behavioural patterning. These interneurons form inhibitory networks that are coupled by chemical

and/or electrical connections and can expect to contribute to population network output by modulating the level of spike to spike synchrony. In particular, electrical connections as mediated by gap junctions are located at dendritic sites far from the cell bodies of the interneurons. In this talk, I will describe our ongoing work to understand how the intrinsic properties of interneurons affect the level of synchrony in electrically coupled networks using phase response curves and weakly coupled oscillator theory.

Sara A. Solla
Northwestern University
Decoding Neural Signals for the Control of Movement

The activity of neurons in primary motor cortex provides the signals that control the execution of movements. One still unresolved crucial question is that of identifying the code used by this neural ensemble. We address this question through the analysis of data obtained for an awake behaving monkey. An implanted multielectrode array records the activity of about one hundred neurons in primary motor cortex during the execution of a sequence of straight reaches to nearby targets. A natural representation for the ensemble activity is provided by a high-dimensional space in which each axis represents the activity of a single neuron as an independent degree of freedom.

However, the observed correlations among neurons whose activity is modulated by the task suggest that the population activity is confined to a low-dimensional space within the high-dimensional space of independent firing activities. We have used linear and nonlinear methods for dimensionality reduction to find the low-dimensional structure that captures the underlying relationship between population neural activity and behavioral task. The use of multidimensional scaling in conjunction with an empirical measure of geodesic distances yields a low-dimensional manifold whose intrinsic coordinates capture the geometry of the task in the external physical space. Although the dimensionality of this manifold is as expected for neurons whose activity is independently and linearly modulated by reach direction, its local curvature is a consequence of neural interactions as captured by a generalized linear model.

Howard A. Stone
Princeton University
The Formation of Bacterial Streamers in Laminar Curved Channel Flows

Bacterial biofilms have an enormous impact on medicine, industry and ecology. These microbial communities are generally considered to adhere to surfaces or interfaces. Nevertheless, suspended filamentous biofilms, or streamers, are frequently observed in natural ecosystems where they play crucial roles by enhancing transport of nutrients and retention of suspended particles. Recent studies in streamside flumes and laboratory flow cells have hypothesized a link with a turbulent flow environment. However, the coupling between the hydrodynamics and complex biofilm structures remains poorly understood. Here, we report the formation of biofilm streamers suspended in the middle plane of curved microchannels under conditions of laminar flow. We use numerical simulations of the flow in curved channels to highlight the presence of a secondary vortical motion in the proximity of the corners, which suggests an underlying hydrodynamic mechanism responsible for the formation of the streamers. In addition, we develop a matched asymptotic expansion solution for flow around two boundaries intersecting at an angle and spanning the small gap between two horizontal plates. Finally, we couple the models of the flow field with slender body theory applied to an elastic filament, which represents the flexible biofilm streamer. Thus, we bring together experiments, simulations, asymptotics, and models for the fluid-structure interaction to rationalize the spatial and temporal development of bacterial streamers.

Becca Thomases
University of California
A Stokesian Viscoelastic Flow: Transition to Mixing and Oscillations

To understand observations of low Reynolds number mixing and flow transitions in viscoelastic fluids, we study numerically the dynamics of the Oldroyd-B viscoelastic fluid model. The fluid is driven by a simple time-independent forcing that creates a cellular flow with extensional stagnation points. We find that at O(1) Weissenberg number these flows lose their slaving to the forcing geometry of the background force, become oscillatory with multiple frequencies, and show continual formation and destruction of small-scale vortices. This drives flow mixing. These new flow states are dominated by a single large vortex, which may be stationary or move persistently from cell to cell. Increasing the number of degrees of freedom by increasing the number of driving cells broadens the temporal frequency spectrum and yields richer dynamics with no persistent vortices and improved fluid mixing.

Shravan Veerapaneni
Courant Institute of Mathematical Sciences, New York University
Large Scale Simulations of Vesicles Suspended in 3D Viscous Flows
Vesicles are locally-inextensible closed membranes that possess tension and bending energies. Vesicle flows model numerous biophysical phenomena that involve deforming particles interacting with a Stokesian fluid. The evolution equations characterizing vesicle dynamics are stiff, nonlinear and non-local. Consequently, they pose significant challenges for numerical solution. We will present new schemes for simulating the three-dimensional hydrodynamic interactions of large number of vesicles. They incorporate a stable time-stepping scheme, high-order spatio-temporal discretizations, spectral preconditioners, and a new reparameterization scheme capable of resolving extreme mesh distortions in dynamic simulations. We will present simulations of vesicles suspended in linear and quadratic external flows and in presence of gravitational field.

Michael Weinstein
Columbia University
Solitons, Defect Modes and Effective Mass
I will discuss the bifurcation of spatially localized defect modes into spectral gaps for the linear and nonlinear Schroedinger /Gross-Pitaevskii (NLS /GP) equations with a periodic potential. Our analysis uses a Lyapunov-Schmidt reduction based on a spectral localization “near to” and “far from” a spectral band edge. Effective mass (associated with the homogenized medium) plays an important role in the dynamic stability of soliton-like states of NLS /GP. This talk is based on joint work with B. Ilan and with M. Hoefer.

Benjamin S. White
ExxonMobil Corporate Strategic Research, Annandale, NJ
On the Chance of Freak Waves at Sea
When deep-water surface gravity waves traverse an area with a curved or otherwise variable current, the current can act analogously to an optical lens, to focus wave action into a caustic region. In this region, waves of surprisingly large size, alternately called freak, rogue, or giant waves are produced. We show how this mechanism produces freak waves at random locations when ocean swell traverses an area of random current. When the current has a constant (possibly zero) mean with small random fluctuations, we show that the probability distribution for the formation of a freak wave is universal, that is, it does not depend on the statistics of the current, but only on a single distance scale parameter, provided that this parameter is finite and non-zero. Our numerical simulations show excellent agreement with the theory, even for current standard deviations as large as 1.0 m/s. Since many of these results are derived for arbitrary dispersion relations with certain general properties, they include, in addition to ocean waves, many other physical phenomena, such as previously published work on caustics in geometrical optics and acoustics.

Song Yang
NIH
Improving the Log Rank and Related Tests of Treatment Effect by Incorporating Adaptive Weights with Survival Data

For testing treatment effect with time to event data, the log rank test is the most popular choice and is optimal for proportional hazards alternatives. When a range of possibly non-proportional alternatives are possible, combinations of several tests are often used. Currently available methods inevitably sacrifice power at proportional alternatives and may also be computationally demanding. We introduce some versatile tests that use adaptively weighted log rank statistics. Extensive numerical studies show that these new tests almost uniformly improve the tests that they modify, and are optimal or nearly so for proportional alternatives. In particular, one of the new tests maintains optimality at the proportional alternatives and also has very good power at a wide range of non-proportional alternatives, thus is the test we recommend when flexibility in the treatment effect is desired. The adaptive weights are based on the model of Yang and Prentice (2005). Joint work with Ross Prentice.

Ehud Yariv
Technion - Israel Institute of Technology
Electro-kinetic Self Propulsion Animated by Inhomogeneous Ion Pumping

Electrokinetics processes involve the coupling between electrostatics, ionic transport, and hydrodynamics. The universal element in electrokinetic phenomena is the Debye layer, a thin region in space, adjacent to charged solid-electrolyte interface, wherein charge separation is significant. This layer allows for transformation between gradients in chemical potentials and fluid motion. Electrokinetic phenomena are ubiquitous in colloidal science, and have been used for decades in various applications in molecular biology. Common to such applications is the need for an external “driver,” say an imposed electric field.

It has been speculated that various biological motors propel through liquids using an electrokinetic mechanism via self-generated electric fields driven by inhomogeneous ion exchange. This phenomenon was conceptually proven in recent experiments using synthetic nano-rods. In this talk I will present an electrokinetic model which describes the self-propulsion mechanism.

The governing equation are characterized by a distinct scale separation, associated with the smallness of the Debye thickness compared with particle size. Systematic use of matched asymptotic expansions extracts an approximate macroscale description from the exactly-posed microscale equations. The macroscale boundary conditions in this description reflect asymptotic matching with the Debye-scale fields. Using slender-body theory, the macroscale model is used to analyze the self-propulsion of inhomogeneous nano-rods. The predicted direction of motion agrees with the experimental data.

Qiang Zhang
City University of Hong Kong
Anomalous Phenomena in a Simple Granular System

We present several surprising phenomena that occur in an extremely simple granular system of a single inelastic, spherical particle falling under gravity and colliding with walls of a symmetric funnel. One might naively expect that, on average, particles would fall through funnels with steeper sides more quickly, exert a smaller total impulse on the funnel walls, and lose less energy. However, we show that there are special ranges of angles of the funnel walls for which exactly the opposite occurs. Typically, the particle will experience a sequence of collisions that is highly sensitive to the location at which it enters the funnel and nearby particle trajectories become widely dispersed. However, in the special angular ranges this is not the case and the particle can experience sequences of collisions that have a highly coherent structure. We provide a theoretical analysis that can predict and explain this surprising behavior. We also show that such anomalous phenomena occur in both frictionless and frictional particle systems and the frictional force dramatically enhances the anomalous phenomena. This is due to the stability of the highly coherent structure in these granular systems.

CONTRIBUTED TALKS

Jeffrey Aristoff
Princeton University
Elastocapillary Imbibition
When a wetting liquid invades a porous medium or a capillary tube, the penetration speed is known to decrease as the square root of time. We examine the elastocapillary imbibition of a wetting liquid between flexible sheets, and demonstrate that the pressure-induced inward deflection leads to a non-monotonic behavior of the invading meniscus until eventually the flow is blocked. A model based on lubrication theory is formulated as a nonlinear free-boundary problem, which is solved numerically using finite-difference methods. At early times the deformation of the sheets is insignificant, and the penetration speed is unaffected. At later times, as the penetration distance approaches the elastocapillary length, the deformation becomes appreciable and the flow accelerates. Shortly thereafter, the gap at the air-liquid interface goes to zero, and the flow necessarily stops. Biological applications of this transient wetting of flexible boundaries will be discussed. Joint work with Howard Stone.

Cecilia Domoz Behn
University of Michigan
Modeling the Interaction between Circadian and Sleep-wake Regulatory Systems
Recent experimental advances have begun to identify both feedforward and feedback components involved in interactions between the circadian and sleep-wake regulatory systems. However, many details of these mechanisms remain unclear. Mathematical modeling provides a theoretical framework in which to explore these interactions and establish constraints that can inform experimental work.

We have constructed a novel network modeling framework that describes both neuronal activity and concentrations of the neurotransmitters released by these nuclei. Network interactions are mediated through neurotransmitter action. Using this formalism, we modeled interactions among primary brainstem and hypothalamic nuclei involved in rat sleep-wake regulation and the circadian pacemaker in the suprachiasmatic nucleus (SCN). The SCN population model displays circadian fluctuations in mean activity level with higher mean activity levels during the 12-hour light period and lower mean activity levels during the 12-hour dark period. Network connectivity was based on experimentally-identified direct and indirect synaptic projections. With this integrated homeostatic and circadian network model, we analyzed the dynamic influences of the circadian pacemaker on sleep-wake patterning and the mechanisms by which feedback from sleep-wake populations to the SCN affects network function. Joint work with Victoria Booth. Acknowledgements: AFOSR FA9550-08-1-0111

Elizabeth L. Bouzarth
Duke University
Modeling Immersed Biological Fibers and Fluids with Regularized Stokeslets
The method of regularized Stokeslets provides a way to calculate fluid velocities in the Stokes fluid flow regime due to a collection of regularized point-forces. In this discussion, the method of regularized Stokeslets will be used to model several examples of slender structures immersed in low Reynolds number fluid flow. The study of these immersed rigid and flexible fibers is inspired by biological factors, such as pulmonary cilia, primary nodal cilia, the endothelial glycocalyx, and actin transport, as well as corresponding laboratory fluid dynamics experiments. In particular, the method of regularized Stokeslets will be used to further explore the documented stretch-coil transition and macroscale behavior for inextensible flexible fibers immersed in a cellular flow pattern.

Matthew Causley
New Jersey Institute of Technology
The Frequency-dependent Havriliak-Negami Dielectric Permittivity Model
The frequency-dependent Havriliak-Negami dielectric permittivity model, $\epsilon(\omega) = \epsilon_\infty+\frac{\epsilon_s-\epsilon_\infty}{(1+(i\omega\tau)^\alpha)^\beta}$, where $0<\alpha,\ \beta<1$, generates the entire class of dielectric models used in numerical simulations of time-domain propagation and scattering of electromagnetic waves. We present a numerical method to incorporate this model in a solver for Maxwell's equations which now contain fractional differential operators. We give a complete stability and error analysis of the method and a validation against the exact solution available in some simple cases.

Bhavin Dalal
New Jersey Institute of Technology
Electric Field Induced Self-assembly of Particles on Fluid Interface
Self-assembly of particles, or clustering of particles into desired patterns, has the potential to revolutionize many fields of science and technology, including biology, colloidal science, and materials engineering. One of the most-widely used techniques for two-dimensional assembly is based on capillary forces that act on particles trapped on a liquid surface. The capillarity-induced self-assembly, however, has several limitations: it can be applied only to relatively-large particles of radius larger than ~10 micron; the monolayers thus formed are not defect-free and lack long-range order; and the lattice spacing of the monolayer cannot be adjusted. We show that these shortcomings can be overcome by applying an external electric field normal to the interface. The technique also allows us to dynamically control the lattice spacing. We also show that the technique works for rod-like and cubical particles floating on a liquid surface. A rod floating on the fluid interface experiences both a lateral force and a torque normal to the interface due to capillarity. In the presence of an electric field, rods are also subjected to an electric force and torque and they assemble along the line joining their centers. Joint work with Sathish Gurupatham, Mansoor Janjua, Sai Nudurupati, Ian Fischer, Pushpendra Singh, and Nadine Aubry.

Arnaud Goullet
New Jersey Institute of Technology
Evolution of Large Amplitude Internal Solitary Waves with Varying Bottom Topography using a Regularized Model
We consider the evolution of large amplitude internal solitary waves in the density stratified ocean. The ocean is then modeled by a two-layer system with different fluid densities. A regularized model for strongly nonlinear internal waves developed to eliminate the shear instability at the interface of the two layers is extended to include the effect of slowly-varying bottom topography. The new time evolution equations are solved numerically using a pseudo-spectral method along with a fourth order Runge-Kutta time integration scheme. Numerical solutions will be presented for the interaction of large solitary waves with bottom topography and validated with available experimental data. Joint work with Wooyoung Choi.

Sathish Gurupatham
NJ Institute of Technology
Spontaneous Dispersion of Particles on Liquid Surfaces
When small particles (e.g., flour, pollen, etc.) come in contact with a liquid surface, they immediately disperse. The dispersion can occur so quickly that it appears explosive, especially for small particles on the surface of mobile liquids like water. This explosive dispersion is the consequence of capillary force pulling particles into the interface causing them to accelerate to a relatively large velocity. The maximum velocity increases with decreasing particle size; for nanometer-sized particles (e.g., viruses and proteins), the velocity on an air-water interface can be as large as _47 m/s. We also show that particles oscillate at a relatively high

frequency about their floating equilibrium before coming to stop under viscous drag. The observed dispersion is a result of strong repulsive hydrodynamic forces that arise because of these oscillations.

Michael Higley
New Jersey Institute of Technology
Dispersion of Particles through Collision in a Bubbly Liquid
Spheres sinking in a bubbly liquid can show random lateral motions typical of diffusion. The Galton board, or quincunx, is a classic model in which collisions of a sphere with fixed pegs lead to diffusive lateral motion. We show how the quincunx model can be adapted to a fluid setting to describe the lateral dispersion of sinking spheres. Apart from the lateral motion, collisions in the classic Galton board create an effective terminal velocity for the spheres. We likewise predict this effect using the fluid Galton model.

Christel Hohenegger
Courant Institute of Mathematical Sciences
Stability of Active Suspensions and the Role of Diffusion
One of the challenges in modeling the transport properties of complex fluids (e.g. many biofluids, polymer solutions, particle suspensions) is describing the interaction between the suspended micro-structure with the fluid itself. Here I will focus on understanding the dynamics of active suspensions, like swimming bacteria or artificial micro-swimmers. Using a recently derived kinetic model, I have investigated the linearized structure of such an active system near a state of uniformity and isotropy. I show that system instability can arise only from the dynamics of the first azimuthal mode in swimmer orientation, that the growth of fluctuations for a suspension of anterior actuated swimmers is associated with a proliferation of oscillations in swimmer orientation, that diffusion acts as a smoothing parameter, and that at small-scales the system is controlled independently of the nature of the suspension. Finally a prediction about the onset of the instability as a function of the volume concentration of anterior actuated swimmers and a comparison with numerical simulations is made.

Sajiya Jalil
Georgia State of University
Synchronization in a Bursting Half-center Oscillator with Slow-to-fast Reciprocal Inhibition
Our modeling studies reveal that a pair of busters reciprocally coupled by fast non-delayed inhibition can synchronize, contrary to the conventional belief. Various measures are computed to quantify the synchrony between the specific models of leech heart interneurons. We also discuss the bistability of co-existing in-phase and anti-phase synchronous bursting patterns in the half-center oscillator (HCO). In addition, we examine temporal characteristics of inhibitory synaptic connections, varying from fast to slow, to establish synchronization within the HCO. Our study of inhibitory synchronization and co-existing dynamical rhythms may help one better understand switching mechanisms between different neuronal rhythms of a CPG upon various dynamical conditions and inputs. Joint work with Andrey Shilnikov and Igor Belykh.

Ahmed Kaffel
Virginia Tech
On the Stability of Plane Parallel Viscoelastic Shear Flows in the Limit of Infinite Weissenberg and Reynolds Numbers
The elastic effects on the hydrodynamic instability of parallel shear flows are investigated through a linear stability analysis. We focus on the Upper Convected Maxwell model in the limit of infinite Weissenberg and Reynolds numbers. Specifically, we study the effects of elasticity on the instability of a few classes of simple parallel flows particularly for the plane Poiseuille and Couette flows and for the hyperbolic-tangent shear layer and the Bickley jet flows. The equation of stability is derived and solved numerically using the spectral Chebyshev collocation method. This algorithm is computationally efficient and accurate in

reproducing the eigenvalues. We consider flows bounded by walls as well as flows bounded by free surfaces. In the inviscid, nonelastic case all the flows we study are unstable. In the case of wall bounded flow, there are instabilities in the shear layer and Bickley jet flows. In all cases, the effect of elasticity is to reduce and ultimately suppress the inviscid instability. Joint work with Michael Renardy.

Jinglai Li
Northwestern University
Extracting Solitons from Perturbed and Noisy Signals
When studying optical solitons in the presence of perturbations, it is often required to extract the underlying soliton from a perturbed signal. We propose an iterative method for doing this, and show it converges for sufficiently small perturbations. In addition, we show the specific perturbations that most easily cause divergence of the iteration. We also present examples showing improved agreement (in comparison with more commonly used methods) between results from soliton perturbation theory and numerical simulations.

Srdjan Ostojic
Columbia University, Center for Theoretical Neuroscience
Firing Rate Dynamics of Integrate-and-fire Neurons
In the recent years linear-nonlinear (LN) models have become a popular way of describing neural activity elicited by a time-varying input. In these models, the output firing rate is obtained by processing the input through a cascade consisting of two consecutive stages: (i) a linear temporal filter is applied to the input; (ii) the outcome is transformed non-linearly to obtain a firing rate. Such a decomposition in two sequential processing stages is mathematically appealing, however from a biophysical perspective it seems difficult to identify two distinct mechanism that would correspond to the two stages. An alternative is therefore to model neural data using integrate-and-fire (IF) models which incorporate some essential biophysical mechanisms. In this communication, we examine the relationship between IF and LN models by representing a pool of integrate-and-fire neurons as a LN cascade. To this end, we exploit known analytic results for IF models, that we complement with numerical simulations. More specifically, we consider a pool of uncoupled IF neurons receiving a time-varying input that is identical across all neurons, and which we call the signal. In addition, every neuron receives an independent white-noise input which corresponds to background activity of the surrounding network. We represent the relationship between the signal and the time-varying output firing rate by an LN cascade. We first compute analytically the linear temporal filter by linearizing the firing dynamics around the baseline activity set by background noise. We then determine the static non-linear transformation in the limit of slowly varying inputs. We find that the analytically determined linear filter and static non-linearity are very close to the optimal linear filter and static non-linearity obtained numerically with the use of reverse correlation analysis. Moreover, a comparison with numerical simulations shows that the LN cascades provides an excellent approximation of the output of a pool of integrate-and-fire neurons if background noise is strong. The accuracy of the LNP approximation is improved if the linear filter is not constant over time, but if instead it is adaptive in the sense that it depends on the instantaneous firing rate of the population. Finally, we show that in the case of exponential integrate-and-fire neurons, the LNP cascade reduces to a simple rate model. Joint work with Nicolas Brunel.

Dov Rhodes
Technion, Israel
The Elongated Shape of a Dielectric Drop Deformed by a Strong Electric Field
A dielectric drop is suspended within a dielectric liquid and is exposed to a uniform electric field. Because of polarization forces, the drop deforms from its initial spherical shape, becoming prolate along the field direction.

For a strong electric field, the elongation is significant, and the drop becomes long and slender. When the ratio of the permittivities of the drop and surrounding liquid is not too large, the ends remain rounded.

The slender limit was originally solved by Sherwood (J. Phys. A, vol. 24, 1991, p. 4047) using a singularity representation of the electric field. Here, we revisit it using matched asymptotic expansions. The electric field within the drop is continued into a comparable solution in the 'inner' region, at the drop cross-sectional scale, which is

itself matched into the singularity representation in the 'outer' region, at the drop longitudinal scale.

The expansion parameter of the problem is the large aspect ratio of the elongated drop. In contrast to familiar slender-body analysis, this parameter is not provided by the problem formulation, and must be found throughout the course of the solution. The aspect-ratio scaling, roughly as the \$6/7\$-power of the electric field, is identical to that found by Sherwood (1991).

The predicted drop shape is compared to the boundary-integral solutions of Sherwood (J. Fluid Mech., vol. 188, 1988, p. 133). While the agreement is better than that found by Sherwood (1991), the weak logarithmic decay of the error terms still hinders the calculation of an accurate approximation. We obtain the leading-order shape correction which improves the asymptotic approximation. Joint work with Ehud Yariv.

Michel Tsukahara

New Jersey Institute of Technology

Probability of Granular Jamming in a 2D Hopper: Simple Models and DEM Simulations

First, we consider a simple model of 2D granular flow in a hopper. In this model, particles are initially placed randomly in a circular sector and move in a straight line with constant velocity toward the center of the sector. All particles have the same speed. Jamming is defined to happen when particles are found in a certain configuration, to be defined, near the center of the sector at the same time. The derivation of an analytical formula of the jamming probability for this model is presented. This derivation leads us to consider the following combinatorial problem: what is the number of subsets without a certain number of consecutive elements in a given ordered set? Secondly, we consider 2D DEM simulations of granular flow in a hopper. We focus on the jamming probability, the average time before jamming and the average number of beads falling through the hole when jamming occurs. The dependency of these quantities on the number of particles in the system, the hole size, the friction coefficient, particle length and hopper angle is presented.

Kaitlyn Voccola

Rensselaer Polytechnic Institute

Polarimetric Synthetic-aperture Inversion in the Presence of Noise and Clutter

In synthetic-aperture radar (SAR) imaging, a scene of interest is illuminated by electromagnetic waves. The goal is to reconstruct an image of the scene from the measurement of the scattered waves using airborne antenna(s). We focus on a polarimetric radar system in which two dipole antennas mounted on an aircraft are used to transmit two orthogonally polarized electromagnetic waves. The same two antennas are used to receive the waves scattered back from the objects present in the scene of interest. This type of radar collects four sets of data, one for each possible transmit and receive antenna pair. Our goal is to develop an imaging scheme aimed at reconstructing curve-like targets, for example the edge of any number of man-made targets. It is well known that the scattering of a line or curve is highly directional, or anisotropic. In order to incorporate our knowledge of the scattering behavior we model our targets as a collection of dipole elements at various ground locations and with various orientations. In addition we include in our scene clutter, or unwanted scatterers, which are also modeled as a set of dipoles. We distinguish between target and clutter by assuming the clutter scatters isotropically, or equally in all directions. The target, on the contrary, is assumed to scatter in only one direction, the direction perpendicular to the radar line of sight. Finally we also assume that our data may be corrupted by measurement, or thermal, noise.

After our forward model is established we develop an analytic method for inversion. Based on our fully polarimetric model we aim to reconstruct a target scattering matrix at each pixel instead of the typical target reflectivity, a scalar value, found in the standard SAR setting. Specifically we develop a filtered-backprojection type reconstruction method where the filter is chosen in order to minimize the mean-square error of the image. We choose this statistical critierion because we assume our target, clutter, and noise are all second-order stochastic processes. We find that the optimal filter, based on this criterion, results in a coupled backprojection filter. That is, we find it is advantageous to use all four sets of data in the reconstruction of each component of the target scattering matrix. This result indicates that the typical individual processing of each data set is not the optimal reconstruction scheme for fully polarimetric data.

Lei Wang
University of Michigan
A Lagrangian Vortex Method for the Barotropic Vorticity Equation on a Rotating Sphere
We present a Lagrangian vortex method for the barotropic vorticity equation on a rotating sphere. The method tracks the flow map and absolute vorticity using Lagrangian particles and panels. The velocity is computed from the Biot-Savart integral on the sphere. An adaptive refinement strategy is implemented to resolve small-scale features and a treecode is used for efficient computation. Results are presented for Rossby-Haurwitz waves and vortex interactions.

Margaret A. Watts
Florida State University
Characterization of the Roles Played by Slow Variables in Phantom Bursting
Bursting oscillations are common in neurons and endocrine cells. One type of bursting model with two slow variables has been called 'phantom bursting' since the burst period can be intermediate between the time constants of two slow variables. A phantom bursting model can produce bursting with a wide range of periods: fast (short period), medium, and slow (long period). We describe a measure (which we call the 'dominance factor') of the relative contributions of the two slow variables to the bursting produced by a simple phantom bursting model. Using this tool, we demonstrate how the control of different phases of the bursting can be shifted from one slow variable to another by changing a model parameter. We then show that the dominance factor curves obtained as a parameter is varied can be useful in making predictions about the resetting properties of the model cells. Joint work with Joel Tabak and Richard Bertram.

POSTERS

John Adeyeye
Winston-Salem State University
Polynomial Dynamical Systems and Molecular Network Modeling

Discrete dynamical systems are ubiquitous not only in engineering but also the life sciences. Especially during the last decade finite dynamical systems, that is, discrete dynamical systems with a finite phase space have been used increasingly in systems biology to model a variety of biochemical networks, such as gene regulatory networks and signal transduction networks. In many cases, the available data quantity and quality is not sufficient to build detailed quantitative models such as systems of ordinary differential equations, which require many parameters that are frequently unknown. In addition, discrete models tend to be more intuitive and more easily accessible to life scientists. Three types of discrete modeling frameworks have been used primarily for this purpose: Boolean networks, so-called logical models, and certain classes of Petri nets. While these types of dynamical systems are well suited to encoding a variety of molecular mechanisms with a minimum of abstraction, they have the disadvantage that they lack a nice mathematical structure that can aid in their analysis. Over the last several years, polynomial dynamical systems over finite fields have been studied as a modeling framework for molecular networks. These represent a very general class of multi-level time-discrete dynamical systems that generalize Boolean networks. Large arrays of theoretical and computational tools from computational algebra are available for their study. The other model types can be cast in this framework. We develop a class of polynomial dynamical systems that is mathematically rich and unifies previous approaches and are finding increasing use in systems biology. We establish results that relate their structure to their dynamics.

Shuchi Agrawal
New Jersey Institute of Technology
Multi Mode Cavity Effects Using Microwave Heating of Ceramic Slabs

Two-dimensional reaction diffusion equations, which contain a functional and an inhomogeneous source term, are good models for describing microwave heating of thin ceramic slabs in a multi mode, highly resonant cavity. A thin ceramic slab situated in a TE_{103} cavity is modeled in the small Biot number limit to study the dynamics of the heating process. Numerical methods are applied to accurately approximate the steady state solutions of these equations and to determine their stability for Neumann boundary conditions.

Rudrani Banerjee
New Jersey Institute of Technology
A Usage Rate Sensitive Warranty Servicing Strategy with Imperfect Repairs

A warranty policy for a product should balance the interests of both producer and consumer. Consumer protection is typically provided by a guarantee of replacement or some form of repair of the product failing within a promised warranty period, while an approach to provide a corresponding protection for the manufacturer is to limit the maximum usage allowed under warranty. Such warranty policies are two-dimensional, and the warranty expires at the end of the promised warranty period or upon reaching the maximum usage allowed, whichever occurs sooner. From a manufacturer's point of view, reducing warranty costs is an issue of great interest. In this work, we look at two different servicing strategies for a two-dimensional warranty scheme involving minimal and imperfect repairs. Our work demonstrates the modeling and analysis of costs under these servicing strategies and compares their performance to other strategies that have been investigated in the literature. Joint work with Professor Manish Bhattacharjee (NJIT).

Vladimir Bondarenko
Georgia State University
Ca^{2+} Alternans and Re-entry in Wild Type and TNF-α Overexpressing Transgenic Mouse Tissues: Insights from Mathematical Modeling
Investigations have shown that tumor necrosis factor-α (TNF-α) may play a significant role in promoting cardiac arrhythmias. In this study, we modified our model of mouse ventricular myocytes to investigate the consequences of electrical remodeling due to TNF-α overexpression. The modified model simulated differences in action potential (AP) shape and duration that were predominantly due to altered expression of two major K^+ repolarization currents: a rapidly-inactivating transient outward K^+ current, $I_{Kto,f}$, and an ultra-rapidly activating K^+ current, I_{Kur}. The model reproduced experimental measurements of differences in Ca^{2+} handling in myocytes from wild type (WT) and transgenic (TG) mice: reduced $[Ca^{2+}]_i$ transients and slower Ca^{2+} sequestration rate into the sarcoplasmic reticulum (SR) in TG mice. As in experiments, the model also predicted that Ca^{2+} alternans developed at longer basic cycle lengths in TG compared to WT mice. The greater susceptibility to Ca^{2+} alternans was attributed to a slower Ca^{2+} sequestration rate by the SR. Programmed stimulation with a premature impulse showed that longer S1-S2 intervals were effective at eliciting re-entry in TG compared to WT mice, confirming experimental findings of a greater susceptibility of TG mice to re-entrant arrhythmias. Joint work with P.S. Petkova-Kirova, B. London, G. Salama, R.L. Rasmusson.

Daniel Cargill
New Jersey Institute of Technology
Bandwidth Dependence of Soliton Phase Distributions in Simulations of Stochastic Dispersion Managed Nonlinear Schrodinger Equations

The nonlinear Schrodinger equation (NLSE) is ubiquitous as a model of physical systems. In particular, it governs the envelope dynamics of electric fields (solitons) in optical fiber communications and mode-locked lasers. In optical communications, modulation formats such as phase-shift-keying (PSK) and differential PSK are becoming the industry standard, and dispersion management is emerging as the primary tool for dealing with cross channel chatter in wavelength-division-multiplexing systems. In contrast, mode-locked lasers used to generate ultra precise frequency combs rely on control of the carrier-envelope phase difference. Since the phase is an integral part of these systems, their reliability is intimately connected to the likelihood of large phase deviations do to influences such as amplification, manufacturing imperfections, violations of slowly-varying-envelope approximations, or intra- or inter-channel interactions with data. The most direct approach of applying a numerical Monte Carlo scheme to noise driven NLSE proves computationally unrealistic due to the extremely low probability of a large phase deviation occurring, therefore requiring an intractable number of numerical runs to resolve the tails of the probability density curve. In light of this, one is forced to use a model reduction method such as soliton perturbation theory (SPT) to computationally recover the probability of rare events occurring. The equations produced by SPT are often sufficient to describe the perturbed evolution of the soliton's amplitude, frequency, and position; however, we show here that the predicted evolution of the soliton's phase is often dominated by the interaction with dispersive radiation. Since SPT inherently neglects radiation interaction, this method fails to capture the correct evolution of a soliton's phase.

In this work, we demonstrate that soliton perturbation theory, though widely used, predicts an incorrect phase distribution for solitons of the stochastically driven NLSE in physically relevant parameter regimes. We propose a simple variational model that accounts for the effect of radiation on phase evolution and correctly predicts its distribution. Finally, we extend this model to stochastically driven NLSE with dispersion management. Joint work with Richard Moore and Colin McKinstrie.

Qiang Chen
University of Delaware
Convolution Quadrature Applied to Time Domain Scattering Problem

Historically, time domain boundary integral equations applied to electromagnetic or acoustic scattering problems often give rise to unstable marching-on-time (MOT) methods. However, by using the convolution quadrature (CQ) method, it can be shown that MOT is stable if an appropriate underlying multistep or implicit Runge-Kutta method is chosen. In this talk, we will show how to apply the CQ method to the time domain electric field integral equation (EFIE), and present some theoretical results on the stability and convergence of the resulting MOT scheme. In particular, we show that dispersion and dissipation phenomena arise when using the CQ method to solve time domain EFIE. We also give some numerical results which support the theory.

Jean Fitzmaurice

USDA Agricultural Research Service, Hydrology and Remote Sensing Lab

Online Vegetation Parameter Estimation using Passive Microwave Remote Sensing Observations

In adaptive system identification the Kalman filter can be used to identify the coefficient of the observation operator of a linear system. Here the ensemble Kalman filter is tested for adaptive online estimation of the vegetation opacity parameter of a radiative transfer model. The radiative transfer model is the observation operator for this problem and maps the surface soil moisture state to a remote sensing radiobrightness temperature. A state augmentation approach is used where the vegetation parameter is added to the soil moisture state vector. The filter consists of a two-layer soil hydrology model and the radiative tranfer model and is tested for a 184 day period with daily updates using simulated remote sensing observations. Satisfactory estimation results are obtained for both static and idealized time-varying vegetation parameter cases. Persistent excitation, adding small variance mean zero Gaussian noise, is required in the time-varying case to converge close to the true estimate, consistent with theory. Besides surface soil moisture, vegetation information could be extracted from passive microwave observations using an adaptive system identification filtering approach.

Roy Goodman

New Jersey Institute of Technology

Recent Experiments in the NJIT Applied Math Capstone Laboratory--2.5 problems in chaotic scattering

Undergraduate students in applied math at NJIT take a “capstone” course in applied mathematics before they graduate. This course looks at problems from all sides, combining mathematical analysis and modeling with laboratory experiments and numerical simulation. This year, the course has focused on chaotic scattering in physical systems. In the first case, we designed a physical implementation of the “two-bounce resonance” phenomenon, explained in recent papers by Goodman and Haberman. The system consists of a curved landscape on which a ball is rolled, and was carved out of high-density urethane foam by our colleagues in the architecture department using a three-axis mill. In the other two, closely related, experiments we studied chaotic scattering of light by curved reflective surfaces, using Christmas ornaments, tomato-sauce cans, rear-view mirrors, cameras, lasers, a fog machine, and Matlab. Joint work with Daniel Cargill and the 2010 Capstone Class.

Peter Gordon

New Jersey Institute of Technology

Thermal Explosion in Porous Media as a Blow up Problem

We consider a model of thermal explosion in porous media which is a natural generalization of the well known problem of self-ignition introduced by I.M. Gelfand and G.I. Barenblatt in 1959. We rigorously prove that, similar to Gelfand-Barenblatt problem, the thermal explosion (finite time blow-up of all solutions for the problem with nonnegative initial data) occurs exclusively due to the absence of weak solution of the corresponding stationary problem that is absence of stationary temperature distribution.

Laura Guglielmini
Princeton University
Three-dimensional Features in Low-Reynolds-number Confined Corner Flows

In recent microfluidic experiments with solutions of bacteria we observed the formation of biofilms in the form of thread-like structures, called "streamers", which float in the middle plane of the channel and are connected to the side-walls at the inner corners. Motivated by this observation, we discuss here the pressure-driven low-Reynolds-number flow around a corner bounded by the walls of a rectangular cross-section channel. We numerically solve the flow field in a channel of constant cross-section, which exhibits 90 degrees sharp corners, turns with constant curvature, or portions with slowly changing curvature along the flow direction, for small values of the Reynolds numbers and including the limit of vanishingly small Reynolds numbers. In addition, we develop a matched asymptotic expansion solution for a flow around two boundaries intersecting at an angle and spanning the small gap h between two horizontal plates. We illustrate the basic features of the flow in these channel geometries by describing the three-dimensional velocity field and the distribution of streamwise vorticity and helicity, and we compare the numerical solutions with predictions based on the asymptotic approach. We demonstrate that near a corner or a change in the curvature of the side wall the flow is three-dimensional and pairs of counter-rotating vortical structures are present, as first identified by Balsa(1998). Finally, we discuss how this secondary flow depends on the significant geometric parameters, the aspect ratio of the channel cross-section, the radius of curvature of the turn and, more generally, the variation of the curvature of the channel side boundary. We believe that these three-dimensional secondary flow structures are relevant to transport problems with complex fluids where accumulation of material at the boundary is possible. Joint work with R. Rusconi, S. Lecuyer, and H.A. Stone.

Joon Ha
Indiana University Purdue University Indianapolis
Bursting in a Two-compartmental Neuron Model

We study the possibility of bursting in a two-compartment model arising from the dopaminergic neuron. We found that the model can generate bursting given the difference in the time constants for variables in the two compartments. We determine conditions on heterogeneity of coupling required for bursting. We discuss how the onset of bursting can be achieved and how the number of spikes in the burst can vary. This type of bursting can also be present in neuronal networks coupled by gap junctions, which determines a broad range of applications for our results. Joint work with Alexey Kuznetsov.

Andong He
Penn State University
Inertial Corrections to the Darcy's Law for Hele-Shaw Flows

The classical treatment of modeling flows in a Hele-Shaw cell is on the Darcy's law. The inertia of the flow is neglected in most physical scenarios; but it may play an important role in determining the interfacial stability if, for example, the Reynolds number is large. We derived a generalization of the Darcy's law which includes the inertial effects of the flow. By using the conformal mapping approach we obtained a generalized Polubarinova-Galin equation. We also perturbed the conformal mapping from the base state, to quantitatively describe how the inertia may alter the linear stability of the interface.

Ernest Ho
University of Toronto, Toronto Western Research Institute
Individual Neuron Characteristics and the Control of Slow Population Activities

Objective: Slow oscillations (SOs) are population activities of frequencies from 0.5 to 5 Hz occurring in many brain areas. Examples of SOs include the cortical EEG K-complex during NREM sleep and the large irregular activities in the hippocampus. Despite their prevalence, mechanisms underlying SOs are currently poorly understood. Here, we develop mathematical network models constrained by data extracted from an

in vitro preparation expressing SOs. Our goal is to achieve a mechanistic understanding of SOs in general through the analyses of these mathematical network models.
Methods: We use a combination of data extraction, simulation and mathematical analyses to understand how SOs are generated. We first extract relevant synaptic quantities from experiments using thick hippocampal slices from mice in which spontaneous inhibitory-based SOs occur. We use these quantities in our inhibitory network simulations. We vary the input-output characteristics (i.e. f-i curve) of the constituent inhibitory neurons, the inhibitory coupling conductance (gsyn), and excitatory variance as parameters of simulation. Finally, in order to explain the trends and make predictions from our simulation results, we approximate the network with mean field equations and perform mathematical analysis via these equations.
Results: Simulated networks with differing f-i characteristics of constituent neurons have diverging SO behaviour. We see strong SO responses for networks with a more linear f-I curve for their constituent neurons. A network with its neurons having a high curvature f-I curve has weaker SO responses, but that which can be observed for a larger set of gsyn values. Mathematical analyses conclude that solutions for SO tend to "clump" together in a narrow region of gsyn values for a more linear f-I curve of constituent neurons. SO solutions tend to "spread out" for networks with a high curvature f-I curve for their neurons.
Conclusion: Intrinsic properties of individual neurons are critical in determining the overall characteristics of SOs. For robust SO responses, a tradeoff has to be made between a strong response and a weaker response that can be observed for a wider range of gsyn values. This tradeoff is facilitated by the curvature of f-I curves. Our results may generalize to SOs occurring in other brain areas. Joint work with Liang Zhang and Frances K. Skinner.

David J. Horntrop
New Jersey Institute of Technology
Microstructure Evolution in Density Relaxation by Tapping
The density relaxation phenomenon is modeling using both Monte Carlo and discrete element simulations to investigate the effects of regular taps applied to a vessel having a planar floor filled with monodisperse spheres. Results suggest the existence of a critical tap intensity which produces a maximum bulk solids fraction. We find that the mechanism responsible for the relaxation phenomenon is an evolving ordered packing structure propagating upwards from the plane floor. Joint work with Anthony D. Rosato(1), Oleksandr Dybenko(1), Vishagan Ratnaswamy(1), and Lou Kondic(2).
(1) Granular Science Laboratory, Department of Mechanical and Industrial Engineering, NJIT
(2) Department of Mathematical Sciences and Center for Applied Mathematics and Statistics, NJIT

Md. Shahadat Hossain
New Jersey Institute of Technology
Modeling of Blood Flow in the Human Brain
The non-Newtonian properties of blood, i.e., shear thinning and viscoelasticity, can have a significant influence on Cerebral Blood Flow (CBF) distribution in the human brain. The aim of this work is to quantify the role played by the non-Newtonian nature of the blood. Under normal conditions, CBF is autoregulated to maintain baseline levels of flow and oxygen to the brain. However, in patients suffering from heart failure (HF), Stroke, or Arteriovenous malformation (AVM), the pressure in afferent vessels varies from the normal range within which the regulatory mechanisms can ensure a constant value for the cerebral flow rate, leading to impaired cerebration in patients. It has been reported that the change in the flow rate is more significant in certain regions of the brain than others, and that this might be relevant to the pathophysiological symptoms exhibited in these types of patients. We have developed mathematical models of CBF under normal and different pathophysiological conditions that use direct numerical simulations (DNS) for the individual capillaries along with experimental data in one dimensional model to determine the flow rate, as well as methods for regulating CBF under normal and diseased conditions. The

model also allows us to determine which regions of the brain would be affected severely under these conditions. Joint work with Bhavin Dalal, Ian Fischer, Pushpendra Singh, and Nadine Aubry.

Shidong Jiang
New Jersey Institute of Technology
An Efficient Algorithm for the Evaluation of Certain Convolution Integrals with Singular Kernels
An efficient algorithm is presented for the evaluation of certain convolution integrals with singular kernels. The algorithm is based on accurate and efficient sum-of-exponential approximation for the singular convolution kernel. The convolution integral can then be computed recursively, thus reducing both the computational and storage cost. The algorithm is illustrated via its application on the dielectric model.

Anmar Khadra
NIH
Correlating T Cell Avidity to Autoantibody Affinity in Predicting Type 1 Diabetes Disease Onset: A Modeling Approach
During the progression of Type 1 Diabetes (T1D), high risk individuals exhibit multiple islet autoantibodies and high avidity T cells which progressively destroy insulin secreting beta-cells. In particular, novel autoantibodies, such as those against IA-2 epitopes (aa1-256), had predictive rate of 100% in a 10-year follow up (rapid progressors), unlike conventional autoantibodies that required 15 years follow up for a 74% predictive rate (slow progressors). The discrepancy between these two groups is believed to be associated with CD8+ and CD4+ T cell avidity. Quantification and modeling autoreactive T cell avidities from high risk individuals may serve as means of staging patients for clinical trials of preventive or interventional therapies. For this purpose, we build series of mathematical models incorporating multiple clones of pathogenic CD4+ and CD8+ T cells, together with B lymphocytes, to investigate the interaction of T cell avidity with autoantibodies in predicting disease onset. These models are instrumental in testing several experimental observations associated with T cell avidity, including the observed phenomenon of avidity maturation. The model shows that the level and longevity of autoantibodies depends not only on the avidity of T cells, but also on the killing efficacy of these cells.

Dongwook Kim
New Jersey Institute of Technology
The Effects of Periodic and Non-periodic Inputs on the Dynamics of a Medial Entorhinal Cortex Layer II Stellate Cell Model
Information flows from the neocortex to the hippocampus through the superficial layers (II and III) of the entorhinal cortex (EC). Stellate cells (SCs) are the most abundant cell type in layer II of the medial EC and provide the main afferent system to the hippocampus. SCs display subthreshold rhythmic oscillations at theta frquencies (4 - 12 Hz). These patterns are generated mainly as the result of the interaction between
a persistent sodium (Ip) and a hyper-polarization activated (h- or Ih) currents. We focus on the effect of oscillatory inputs at various frequencies on the sub- and super-threshold activity of SCs. These include (1) the effect of high-frequency Poisson-distributed trains of combined excitatory and inhibitory conductance-based synaptic inputs on the SC's subtheshold oscillatory activity, and (2) the effect of sinusoidal inputs at various frequencies on the SC's firing frequency (super-threshold activity). The control parameters are the maximal synaptic conductance and the sinusoidal input amplitude respectively. We present the results of our simulations and show that for values of the control parameter large enough but still in a biophysically plausible range these results depart from the linear prediction. More specifically, in (1) our simulations show that the peak in power spectrum for the SC's output voltage first decreases, for low values of the maximal synaptic conductance, but increases significantly for higher values. The peak frequency remains almost unchanged. In (2), we found more than one peak in the output firing-frequency vs . input sinusoidal frequency graphs. These findings suggest a special role for the SC's intrinsic currents Ih and Ip. Joint work with Horacio G. Rotstein.

Toufik Laadj
Virginia Tech
Initial Value Problems for Creeping Flow of Maxwell Fluids
We consider the flow of nonlinear Maxwell fluids in the unsteady quasistatic case where the effect of inertia is neglected. We study the well-posedness of the resulting PDE initial-boundary value problem. It can be shown that this well-posedness depends on the unique solvability of an elliptic boundary value problem. We present results for the case of sufficiently small initial data and for a simple shear flow problem with arbitrary initial data. We solve our problem using an iteration between linear subproblems. The limit of the iteration provides the solution of our original problem. The talk will illustrate the basic steps of the proof. Joint work with Michael Renardy.

Jing Li
New Jersey Institute of Technology
Modeling with Bivariate Geometric Distributions
We study systems with several components which are subject to different types of failures. Examples of such system include twin engines of an airplane or the paired organs in a human body. We find that such a system using conditional arguments can be characterized as multivariate geometric distributions. We prove the characterizations of the geometric model can be achieved using conditional probabilities, conditional failure rates or probability generating function. These new models are fitted to the data using the method of moment estimators, Maximum likelihood estimators and Bayes estimators. The last two estimators are obtained by solving score equations. We also compare two methods of moment estimators in each of the several bivariate geometric models to evaluate their performance using the variance-covariance matrix. This comparison is done through a Monte-Carlo simulation for increasing sample sizes. The chi-square goodness-of-fit tests are used to evaluate model performance.

Te-Sheng Lin
New Jersey Institute of Technology
Thin Films Flowing Down Inverted Substrates: Two Dimensional Flow
We consider free surface instabilities of films flowing on inverted substrates within the framework of lubrication approximation. We allow for the presence of fronts and related contact lines, and explore the role which they play in instability development. It is found that a contact line, modeled by a commonly used precursor film model, leads to free surface instabilities without any additional natural or excited perturbations. A single parameter D=(3Ca)^{1/3}\cot\alpha, where Ca is the capillary number and \alpha is the inclination angle, is identified as a governing parameter in the problem. This parameter may be interpreted to reflect the combined effect of inclination angle, film thickness, Reynolds number and the fluid flux. Variation of D leads to change of the wave-like properties of the instabilities, allowing us to observe traveling wave behavior, mixed waves, and the waves resembling solitary ones. Joint work with Lou Kondic.

Enkeleida Lushi
Courant Institute of Mathematical Sciences, New York University
Chemotaxis Effects in Suspensions of Active Bacteria
Suspensions of motile bacteria are known to undergo complex dynamics in response to critical chemicals dissolved in the fluid they are in. They move preferentially toward the higher concentration of such a chemoattractant in a process called chemotaxis. To study this phenomenon, we have developed a new model based on kinetic theory that is coupled to both the fluid and the chemoattractant dynamics. We study the linear stability of a nearly isotropic suspension and show an instability due to chemotaxis occurs at finite wavelengths, for pusher and puller bacteria alike. Full numerical simulations of the system in two

dimensions are performed to study the nonlinear dynamics. We observe aggregation in suspensions of puller bacteria and mixing in suspensions of pusher bacteria. Joint work with Michael J. Shelley.

Matt Malej
New Jersey Institute of Technology
Numerical and Asymptotic Modeling of Evolving Nonlinear Ocean Surface Wave Fields
The main focus of this work is asymptotic and numerical modeling of nonlinear ocean surface wave fields. In particular, this work is concentrated around a development of an accurate and efficient numerical model for a short-term prediction of evolving nonlinear ocean waves, including extreme waves such as "Rogue" waves, that are known to occur more frequently than anyone ever imagined. Derivations of asymptotically reduced models, based on the small wave steepness assumption, as well as relatively weak transverse dependence, will be presented and their corresponding numerical simulations via Fourier pseudo-spectral methods will be discussed. The simulations are initialized with a well-known JONSWAP wave spectrum and different angular distributions (giving both short and long crested waves) are employed. Both single deterministic, as well as Monte-Carlo simulations and the corresponding analysis will be presented. Based on preliminary numerical results, certain conclusions are drawn on the validity of the so-called Modified Nonlinear Schrodinger equation (mNLS) of Dysthe (1979) in relation to realistic ocean surface waves and its ability to predict the occurrence of large amplitude extreme waves known as Rogue/Freak waves.

Yi Mao
National Institute for Mathematical and Biological Synthesis, University of Tennessee
Dynamic Modeling of Proteins: Physical Basis for Molecular Evolution
Dynamic modeling of a coarse-grained elastic protein model provides an effective way of exploring the relationship between protein structure and function. In particular functionally important residues are identified by a variety of computational methods based on the fluctuation and correlation analysis. The results from the modeling provide great insights into how molecular physics constrains evolutionary pathways of proteins. Emergence of drug resistance behaviors in HIV-1 protease is discussed as an example.

Jennifer Miller
University of Delaware
Mathematical Modeling and Analysis of a Continuum Model for Three-zone Swarming Behavior
Swarms in nature have been modeled with individuals but a continuum model may be better suited to scaling up to larger swarms and to some types of theoretical analysis. In place of individuals, we consider the swarm's velocity field and density. Models including zones of repulsion, orientation, and attraction are popular in ecological modeling of animal groups. We model the reactions to the varying density in these three zones using integro-differential equations and then use linear stability analysis to explore first and second order models of constant density swarms.

Brock Mosovsky
University of Colorado, Boulder
Transitory Dynamics and Transport in Hamiltonian Systems
Invariant manifolds have long been recognized as important structures that help to govern global behavior in dynamical systems. Hyperbolic manifolds in particular, by their very definition, relate information about the exponential contraction and expansion of nearby trajectories within the flow, and so play crucial roles in the dynamics of such systems, lending insight into the mechanisms by which mixing, transport, chaos, and other complex global phenomena are produced. When these hyperbolic invariant manifolds intersect, lobes are formed containing packets of trajectories that remain coherent in the Lagrangian sense provided their bounding manifolds remain intact, and tracking these lobes provides a means for quantifying flux between coherent structures in the flow. While identifying the hyperbolic invariant manifolds of autonomous dynamical systems is generally well-understood, the problem is

complicated by the introduction of aperiodic time-dependence. In the latter case, methods employing finite-time Lyapunov exponents (FTLE) or identifying so-called distinguished hyperbolic trajectories have recently gained popularity as ways of uncovering the global manifold structure of such flows.

We introduce the concept of a ``transitory'' dynamical system, whose time-dependence is confined to a compact interval, and present a new method for quantifying transport between Lagrangian coherent structures in the phase space of transitory Hamiltonian systems. Our computation of the invariant manifolds in the phase space relies on the autonomous nature of the vector fields on either side of the time-dependent transition interval and we reduce the information required to quantify lobe transport to knowing only the relevant heteroclinic orbits in the flow. As examples of the application of this theory, we consider a fluid flow in a rotating double-gyre configuration and a simple model of a resonant accelerator. Finally, we compare our results for the computation of invariant manifolds and identification of Lagrangian coherent structures to those obtained using FTLE, discussing the benefits and limitations of each method.

Christina Mouser
Medgar Evers College
Hematopoietic Stem Cell Proliferation Modeling under the Influence of Hematopoietic Inducing Agent and Chemotherapy Treatment
The process by which Hematopoietic Stem Cells (HSC) residing in the bone marrow differentiate into blood cells is known as hematopoiesis. Hematopoietic Inducing Agents (HIAs), such as the cytokine erythropoietin (EPO) and granulocyte-colony stimulating factor (G-CSF) play a vital role in hematopoiesis and are capable of inducing the proliferation of stem cells. In previous work, we incorporated the effect of HIA in a mathematical model consisting of a set of differential delay equations. The aim of the current work is two-fold. First, the effect of HIA will be altered to become time-dependent, in order to make it more representative of what is physiologically observed. Second, the effect of chemotherapy treatment will be added into the model. Patients receiving chemotherapy to eliminate cancer cells, experience a significant loss of HSC. They are consequently treated with injections of HIA to restore leukocyte counts to normal levels. Our goal is to determine the dynamic equilibrium of chemotherapy drugs and HIA during hematopoiesis. Joint work with Eliana Antoniou, James Tadros, and Evros Vassiliou.

Choongseok Park
Indiana University Purdue University Indianapolis, Center for Mathematical Biosciences
Bursting Dynamics of a Network Consisting of Two Inhibitory Cells and Two Excitatory Cells
Networks of reciprocally connected excitatory and inhibitory neurons display various firing activity patterns to which their functional status are often attributed. For example, synchronized and clustered rhythms within Basal Ganglia (BG) are known to be responsible for pathological symptoms such as tremor in Parkinson's Disease. Analyzing this activity pattern in terms of intrinsic cell properties and synaptic coupling properties has mathematical and physiological, even clinical importance.

In this poster presentation, we study anti-phase bursting dynamics of a network of excitatory and inhibitory bursting cells. While this anatomical organization may be very generic, we consider an example of consisting of two pairs of neurons from mammalian basal ganglia consisting of two STN cells and two GPe cells. We will show qualitatively the existence and stability of anti-phase bursting cluster solution and its dependence on parameters. We will also obtain bifurcation diagram which describes the behavior of anti-phase cluster solution as some parameter changes. To achieve these goals, we reduce the network using fast-slow analysis and then construct two dimensional maps.

Aminur Rahman
New Jersey Institute of Technology
A Scheme for Analyzing the Dynamics of Logical Circuits
An algorithm was developed to map Boolean algebraic functions of discrete circuits to elementary algebraic functions. In [3] it is shown that a simple discrete planar dynamical model of the R-S flip-flop circuit can

mimic the behavior observed for physical realizations of the circuit. However, this model was developed in an ad-hoc manner. A systematic algorithmic approach is preferred in order for the model to more accurately represent observed behavior and facilitate further investigation. Also, with a rigorous algorithm other circuits may be modeled with similar ease. Joint work with Denis Blackmore.

Juri Rappaport
Russian Academy of Sciences
Statistical Simulation of the Total Penetrating Keratoplasty
Biostatistical analysis of the cornea human transplantations is performed at different time periods after the surgery. The results of the total penetrating keratoplasty on human eyes are analyzed. The endothelium and morphology characteristics are considered in time and dynamics. The statistical prognosis for the patient's vision with and without correction, corneal thickness, myopia and astigmatism after the surgery is given. The electronic cornea microscopy dates are processed. Computational analysis of the endothelium cells is used for the donor's choice. The quality of the surgery is estimated on the basis of the transplant's transparency and time behavior of endothelium characteristics: density, quality and quantity of the endothelium cells. The keratoconus case study is elaborated in detail.

Katha Anki Reddy
Clark University
Dynamics of Sheared Inelastic Dumbbells
We study the dynamical properties of the homogeneous shear flow of inelastic dumbbells in two dimensions as a first step towards examining the effect of shape on the properties of flowing granular materials. The dumbbells are modelled as smooth fused disks characterised by the ratio of the distance between centers (L) and the disk diameter (D), with an aspect ratio (L/D) varying between 0 and 1 in our simulations. Area fractions studied are in the range 0.1 to 0.7, while coefficients of normal restitution, en from 0.99 to 0.7 are considered. The simulations are based on the event driven methodology for circular disks, but the procedure for predicting collisions is much more complicated due to the non-circular shape of the particles and due to particle rotation. The average orientation is measured using an order parameter S, which varies between 0 (for a perfectly disordered fluid) and 1 (for a fluid with the axes of all dumbbells in the same direction). We investigate power-law fits of S as a function of (L/D) and (1 - en^2). There is a gradual increase in ordering as the area fraction is increased, as the aspect ratio is increased or as the coefficient of restitution is decreased, and the order parameter has a maximum value of about 0.5 for the highest area fraction and lowest coefficient of restitution considered here. The mean energy of the velocity fluctuations in the flow direction is higher than that in the gradient direction and the rotational energy, though the difference decreases as the area fraction increases, due to the efficient collisional transfer of energy between the three directions. The distributions of the translational and rotational velocity are Gaussian to a very good approximation. The pressure is found to be remarkably independent of the coefficient of restitution. The pressure and dissipation rate show relatively little variation when scaled by the collision frequency for all the area fractions studied here, indicating that the collision frequency determines the momentum transport and energy dissipation even at the lowest area fractions studied here. The mean angular velocity of the particles is equal to half the vorticity at low area fractions, but the magnitude systematically decreases to less than half the vorticity as the area fraction is increased, even though the stress tensor is symmetric.

David Saintillan
University of Illinois at Urbana Champaign
Dynamics and Pattern Formation in Large-scale Suspensions of Polarizable Particles in Electric Fields
The ability to manipulate small particles at the micro- and nanoscale plays a central role in a wide range of technological applications, from self-assembly to cell sorting to biochemical analysis. To this end, electric fields offer a low-cost and efficient method of controlling particle motions. Yet, understanding and

modeling the dynamics that result when many particles are present remains a challenge in many situations. In this work, we use theory and large-scale numerical simulations to analyze the dynamics in suspensions of polarizable particles undergoing dielectrophoresis (DEP) and induced-charge electrophoresis (ICEP). In suspensions undergoing DEP only, particle aggregates are predicted to appear in the form of long chains in the direction of the electric field, in agreement with previous studies. The rapid formation of these chains is then followed by a slow dynamic coarsening process, by which chains coalesce resulting in a mesoscopic pattern formation. When both DEP and ICEP occur, chaining altogether disappears and is replaced by transient particle pairings, which result in hydrodynamic particle diffusion and in a nonuniform microstructure with transient clusters surrounded by clarified regions, as demonstrated by particle occupancy statistics. We conclude by discussing applications of this study to the assembly of colloidal structures by electrophoretic deposition. Joint work with Jae Sung Park.

Angshuman Sarkar
Visva-Bharati University, Department of Statistics, West Bengal, India
Probability of Correct Searching in Supersaturated Design
A supersaturated design is capable of identifying the active factors from a large set of potential factors. While constructing such a design one should be aware that the design should identify the active factors with high probability. The present work introduces the concept of probability of correct searching in multi-level supersaturated design. The probability of correct searching for both the symmetric and asymmetric factorial experiments has been thoroughly studied in this work. A criterion for comparing two competitive designs is proposed for symmetric factorial experiment based on probability of identifying active effects. The work also presents an algorithm for constructing multi-level supersaturated design for the asymmetric factorial experiment which will maximize the probability of correct search. Joint work with Dennis Lin and Kashinath Chatterjee. Key words and phrases: Asymmetric factorials, genetic algorithm, multi-level supersaturated design, symmetric factorials.

Evgeny Savel'ev
Virginia Tech
Control of Homogeneous Shear Flow of Multimode Maxwell Fluids
We study stresses arising in a viscoelastic medium undergoing parallel homogeneous shearing motion. The medium is assumed to obey the constitutive law of a multimode upper convected Maxwell fluid. We consider the shearing rate as a control input and investigate the controllability of the stresses. The objective is to achieve a certain stress state at final time via variations of the shear rate. The controllability of the shear stresses is easily established, but controllability of normal stresses is a quite difficult problem. We show that the problem is related to a calculus of variations problem. We show that the set of attainable stress configurations is constrained within a convex set characterized by the solution of certain minimization problems. In the case of two relaxation modes, we can show that all stress values within this convex set can actually be achieved.

Mitra Shojania-Feizabadi
Seton Hall University, South Orange, NJ
A Coupled Differential Equation Model for Multi-drug Lipid Lowering Therapy for Hypercholesterolaemia
Recent experimental papers in the medical literature have reported successes for a combination therapy for hypercholesterolaemia, integrating statin therapy to reduce production of cholesterol in the liver, and the use of Ezetimibe to inhibit cholesterol absorption by the blood. We have developed a model for this process that not only reproduces the experimental results, but also provides an explanation for the synergistic effects of the two therapies. The model, based on a pair of coupled differential equations, separately models cholesterol production and cholesterol concentration in the blood, and can easily be modified to suggest the effect of secular---particularly periodic---variation in diet, and by varying its parameters, to characterize the

range of values for which the interaction of the therapies is synergistic, and those for which the approaches may interfere. Joint work with Thomas Marlowe.

Asya Shpiro
Medgar Evers College
Reaction Time in Bistable Perception: Modeling and Experiments

Perceptual bistability occurs when an observer is presented with an ambiguous stimulus which supports two distinct interpretations. Only one interpretation ("percept") is being perceived at any given moment, and perception switches between the two. Varying the details of the stimulus, it is possible to affect the amount of time spent perceiving each interpretation. We call a percept "strong" if it is perceived for more than half of the observation time; the other percept is therefore a "weak" one.

The rivalry between the percepts does not start immediately after the stimulus is presented to an observer. It takes time for the brain to resolve the ambiguity that it encounters and to choose one of the percepts. This time can be interpreted as a reaction time on a bistable stimulus. We use neuronal competition models to show that if the strong percept becomes visible first, the reaction time is shorter than the reaction time if the weak percept becomes visible first. The results of the simulations are consistent with the results of the psychophysics experiments that we conduct to measure reaction times in three bistable perception phenomena: binocular rivalry, bistable motion of plaids, and bistable depth ordering.

David Simpson
University of British Columbia
Mixed Mode Oscillations in a Stochastic, Piecewise-Linear System

A wide range of physiological systems exhibit excitability, such as neural systems, cardiovascular tissues and ion channels, as do many physical systems. A prototypical model for excitability is the FitzHugh-Nagumo model. In the absence of noise this system typically exhibits a canard - over a small parameter range both small amplitude and large amplitude oscillations are possible. When noise is present mixed-mode oscillations commonly occur.

We study a piecewise-linear version of the FitzHugh-Nagumo model with small, additive, white, Gaussian noise (piecewise-linear systems are used commonly in modeling systems with sudden transitions). Within each smooth region of phase space the system is Ornstein-Uhlenbeck and may be solved explicitly. Upon accounting for changes at the boundaries of these regions we are able to describe the nature of mixed-mode oscillations and quantitatively analyze the noise response. In particular we find that the noise response differs in some respects to the traditional FitzHugh-Nagumo model containing a cubic function.

Gideon Simpson
University of Toronto
Spectral Analysis for Matrix Hamiltonian Operators
We study the spectral properties of matrix Hamiltonians generated by linearizing about soliton solutions of the nonlinear Schrödinger equation. Using a hybrid analytic-numerical proof, we show that there are no embedded eigenvalues for the three dimensional cubic nonlinearity and other nonlinearities. Though we focus on the 3d cubic problem, the goal of this work is to present a new, robust, algorithm for verifying the spectral properties needed for stability analysis. We also present several cases for which our approach is inconclusive and speculate on ways to extend the method. This is joint work with J.L. Marzuola (Columbia University).

Hansong Tang
The City University of NY
Coastal Flow Simulation using CFD/GFD and Domain Decomposition Methods

Coastal ocean flow phenomena span a vast range of spatial and temporal scales, and accurate simulation of them requires multi-scale/multi-physics approaches. For this purpose, a hybrid computational fluid dynamics (CFD) and geophysical fluid dynamics (GFD) approach is proposed to simulate coastal ocean flows. The former is able to accurately resolve small-scale flow phenomena, and the latter can predict large-scale background currents .The resulting hybrid system will be able to capture flow phenomena with spatial scales from centimeters to hundreds of kilometers.

In order to demonstrate the feasibility and potential of the proposed hybrid system, a three-dimensional, unsteady, incompressible CFD model is coupled with the FVCOM model, a coastal ocean model. The strategies to couple the two models, which are based on two set of PDEs, will be discussed. The coupling is two-way and realized using domain decomposition method or zonal method with aid of Chimera overset grids. The hybrid approach is applied to thermal effluents discharged from ports with diameters in order of centimeters into a river of kilometers in length, and the simulations results are compared with those obtained with pure CFD approach from aspects of accuracy, computing CPU time, etc. In addition, the modeling results of a coastal flow using the hybrid approach are presented, together with discussions on issues for further development of the proposed hybrid system. Joint work with Xiuguang Wu.

Qiming Wang
New Jersey Institute of Technology
Nonlinear Evolution of Surfactant Covered Viscous Drops
The effect of insoluble or soluble surfactant on the deformation of a viscous drop surrounded by another viscous fluid in an imposed flow is studied numerically. The effect of bulk surfactant solubility is considered in the limit of large bulk Peclet number by solving a boundary layer equation. Steady deformation response curves are presented for various parameter values. Similar to the case of insoluble surfactant, above a critical capillary number, a drop can form a sharp tip and tip-streaming can occur when the ratio of interior to exterior fluid viscosity is very small.

Xiaojun Wang
Virginia Tech
Well-posedness of the UCM Fluid in the Limit of Infinite Weissenberg Number
Viscoelastic flows at high Weissenberg number present many challenges for mathematical analysis; even more so than Newtonian fluids at high Reynolds number do. There are flow instabilities, singular features along walls and separating streamlines, and numerical difficulties. The study of limiting equations, in which the Weissenberg number is formally set to infinity, is a logical first step in gaining a partial understanding of the high Weissenberg number limit, analogous to the study of the Euler equations for the high Reynolds number limit. The goal of this article is a well-posedness result for the equations arising in the infinite Weissenberg number limit of the upper convected Maxwell fluid. An iteration scheme is used to show the well-posedness of the initial-boundary value problem for incompressible hypoelastic materials which arise as a high Weissenberg number limit of viscoelastic fluids. We first assume the stress is a rank-one matrix and develop energy estimates to show the problem is locally well-posed. This problem is related to incompressible ideal magnetohydrodynamics (MHD). We show that the more general case can be handled by a generalization of the method we developed. Joint work with Michael Renardy.

Margaret Watts
Florida State University
Characterization of the Roles Played by Slow Variables in Phantom Bursting
Bursting oscillations are common in neurons and endocrine cells. One type of bursting model with two slow variables has been called 'phantom bursting' since the burst period can be intermediate between the time constants of two slow variables. A phantom bursting model can produce bursting with a wide range of periods: fast (short period), medium, and slow (long period). We describe a measure (which we call the 'dominance factor') of the relative contributions of the two slow variables to the bursting produced by a simple phantom bursting model. Using this tool, we demonstrate how the control of different phases of the

bursting can be shifted from one slow variable to another by changing a model parameter. We then show that the dominance factor curves obtained as a parameter is varied can be useful in making predictions about the resetting properties of the model cells. Joint work with Joel Tabak and Richard Bertram.

Jeremy Wojcik
Georgia State University
Poincaré Return Mapping for Models of Elliptic Neurons
We propose a novel computer assisted method for the effective construction and accurate examination of families of Poincaré return mappings for voltage maxima in models of elliptic bursting neurons. Such busters are adequately described by dynamical systems with two characteristic time scales: slow and fast. A feature of a slow-fast dynamical model is that its solutions stay close to the so-called slow motion manifolds, comprised of equilibria and limit cycles of its fast subsystem. In the context of neurodynamics they are respectively called quiescent and tonic spiking equilibria. We reveal the topology of the manifolds in the phase space of an elliptic neuron model to define the Poincaré mappings for oscillatory dynamics of the fast membrane potential. The algorithms discussed allow us to create a full family of Poincaré mappings to get insight into driving forces on the dynamics of a model in question over an entire parameter range. Of special interests are these mappings for nonlocal bifurcations at transitions between states of the model. This includes mechanisms of transitions between tonic spiking and bursting, between quiescence and tonic spiking, bifurcations of bursting, the emergence of various mixed mode oscillations, and their interactions with bursting and quiescence etc. The examination of nonlocal bifurcation at these transitions is accomplished through reduction of the multidimensional model to a one-dimensional voltage next amplitude mapping: T: Vn ?Vn+1. Such mappings allow us to identify and study bifurcations and complex dynamics of the model at such transitions. We note that the reduction to next amplitude mappings for maximal values of oscillatory voltage alone is highly advantageous as the behavior of any neuron model are manifest through the evolution of accumulative voltage dynamics which can only be accessed in experimental studies in most cases. We examine the mathematical Fitzhugh-Nagumo-Rinzel model, a bursting modification of the classical Hodgkin-Huxley model, as well as the Terman-Rubin model for the external segment of globus pallidus. We begin by creation of the respective slow motion manifolds through parameter continuation techniques. Next we are then able to extrapolate a set of maxima's, for each limit cycle of the manifold, to be used as initial conditions for the solution set for a given parameter. We then find the next maxima for the set of initial conditions creating a next amplitude map. Varying the parameter yields a family of next amplitude maps that allow for the identification of periodic and chaotic attractors, as well system repellers and homoclinic solutions that globally organize the dynamics of the model. We are then able to predict and/or identify the mechanisms for state transitions in the models, before the actual transition. Joint work with Andrey Shilnikov.

Jacek Wrobel
New Jersey Institute of Technology
High-order Bisection Method for Computing Invariant Manifolds of 2-D Maps
We describe an efficient and accurate numerical method for computing smooth approximations to invariant manifolds of planar maps, based on geometric modeling ideas from Computer Aided Geometric Design (CAGD). The unstable manifold of a hyperbolic fixed point is modeled by Bezier interpolant (a Catmull-Rom spline) and properties of such curves are used to define a rule for adaptively adding points to ensure that the approximation resolves the manifold to within a specified tolerance. Numerical tests on a variety of example mappings demonstrate that the new method produces a manifold of a given accuracy with far fewer calls to the map, compared with previous methods. A brief introduction to the relevant ideas from CAGD is provided. Joint work with Roy Goodman.

Hui Wu
New Jersey Institute of Technology

Oscillatory Patterns in Relaxation Oscillators of FitzHugh-Nagumo Type with Inhibitory Global Feedback

The Belousov-Zhabotinsky (BZ) reaction is a prototypical example of nonlinear chemical oscillators. The Oregonator is the most widely accepted model for the BZ reaction and describes the dynamics of the activator and inhibitor chemical compounds. For the appropriate parameters values, models of FitzHugh-Nagumo (FHN) type posses the main features of the Oregonator, cubic-like nonlinear activator nullclines and separation of time scales, and capture the relaxation oscillators observed in the BZ reaction. We use these models to investigate the out-of-phase oscillatory patterns observed in the BZ reaction with global inhibitory feedback. We present the result of our simulations showing that these patterns can be obtained by using standard (smooth) FHN models, and also piecewise-linear (PWL) models of FHN type where each branch of the cubic nullcline has been substituted by a line segment. The latter models are more amenable for mathematical analysis. We investigate the mechanism of generation of out-of-phase patterns using spike-time response curves (STRCs) and spike-time difference maps (STDMs). The STRC techniques we use describe how the timing of the next peak of an oscillation is affected by a single input coming from the inhibitor. The STDM combines the STRCs of both participating oscillators to provide information about their synchronization properties. For PWL models of FHN type, STRCs can be computed analytically. We compare the results obtained by using these methods with results from direct simulations for both smooth and PWL models of FHN type for an appropriate range of parameters. Joint work with Horacio Rotstein.

Kuan Xu
New Jersey Institute of Technology

Efficient Numerical Computation of Fluid Interfaces with Soluble Surfactant

We address a difficulty in the computation of fluid interfaces with soluble surfactant. At the large values of bulk Peclet number typical of fluid-surfactant systems, a transition layer forms adjacent to the interface in which the surfactant concentration varies rapidly, while its gradient at the interface must be evaluated accurately to determine bulk-interface exchange of surfactant, surface tension, and the drop's dynamics. We present a fast and accurate hybrid numerical method that incorporates a separate singular perturbation reduction of the transition layer into a full numerical solution of the interfacial free boundary problem. Results are presented for a drop of arbitrary viscosity in the Stokes flow limit, where the underlying flow solver for insoluble surfactant uses a direct (primitive variable) boundary integral method. We also propose a novel Green's function approach to the transition layer equation governing the bulk concentration of soluble surfactant and this new method is demonstrated by numerical results.

Peixin Zhang
New Jersey Institute of Technology

Confidence Bands for Survival Functions under Semiparametric Random Censorship Models

For estimating survival functions, semiparametric random censorship models have been proposed as an alternative to the classical nonparametric approach that leads to the Kaplan—Meier estimator. The use of the latter estimator has been so pervasive that all approaches of constructing confidence bands have employed it. With the choice of correct parametric specifications, however, the approach employing a semiparametric survival function estimator has the potential of producing tighter confidence bands. This approach has not been investigated. Under this framework, we propose a simultaneous confidence band that employs a novel bootstrap strategy called model-based resampling. This approach has the correct asymptotic validity and indeed produces a tighter confidence band than those based on the Kaplan—Meier estimator. We present a preliminary simulation study to showcase our proposed procedure.