Dynamics Days 2006 – Bethesda Maryland

TALK Abstracts

Alben, Silas (CONTRIBUTED)
Brenner, Michael, Harvard University

Designing elastic sheets to self-assemble in a viscous environment

A recent work by Boncheva et al. (Proc. Nat. Acad. Sci. 2005, 102: 3924-3929) has raised some basic issues about designable self-assembly within the context of planar elastic sheets which fold into 3D structures under magnetic forces. While being agitated in water, millimeter-scale structures were shown to fold with varying success depending on the locations of magnets on the sheets. Our work considers how to design such structures, an understanding of which will be necessary when moving this process to the micron scale. Among the important parameters are the geometry of the flat sheet, the configurations of the magnets, and the ratios of magnetic to elastic forces. We consider this problem using a numerical model of an elastic sheet, and restrict to the simpler case of electrostatic forces in a quasi-static limit. We identify a simple algorithm for choosing configurations of electrostatic charges, and select ratios of charge strength to elastic energy using physical arguments. We then demonstrate our algorithm on dynamical foldings of a sphere and more general geometries in the overdamped viscous regime.

Bertozzi, Andrea (INVITED)
University of California, Los Angeles

Swarming by nature and by design

The cohesive movement of a biological population is a commonly observed natural phenomenon. With the advent of platforms of unmanned vehicles, this occurrence is attracting renewed interest from the engineering community. This talk will review recent research results on both modeling and analysis of biological swarms and also design ideas for efficient algorithms to control groups of autonomous agents. For biological models we consider two kinds of systems: driven particle systems based on force laws and continuum models based on kinematic rules. Both models involve long-rage social attraction and short-range dispersal and yield patterns involving clumping, mill vortices, and surface-tension-like effects. For artificial platforms we consider the problem of boundary tracking of an environmental material and consider both computer models and demonstrations on real platforms of robotic vehicles. We also consider the motion of vehicles using artificial potentials.

Blanchette, Francois (CONTRIBUTED)
Bigioni, T.P., University of Chicago

Multiple coalescence at liquid interfaces

We investigate numerically and experimentally the dynamics of a drop slowly coming into contact with a reservoir of the same fluid. In certain cases, the ensuing coalescence leaves behind a smaller daughter drop, which then bounces on the interface. We focus on cases where the drop repeatedly coalesces and pinches off, forming a sequence of progressively smaller drops. We determine the regime in which such a cascade can occur and describe for the first time the details of the mechanism behind multiple coalescence. Viscous damping of capillary waves is found to be crucial in determining whether pinch off will occur or not, despite the fact that only a small fraction of the available energy is dissipated by viscous effects. Time permitting, applications of our simulations to bubble pinch off from a nozzle and mixing in micro-capillaries will also be shown.

Bradley, Elizabeth (CONTRIBUTED)
Garnett, James, University of Colorado

Adaptive nonlinear resource distribution control

Control systems for software resources, such as network routers, are difficult to design because of the nonlinear nature of these systems and the bursty nature of the demands that are placed upon them. We present an adaptive, nonlinear model-reference control strategy that mitigates the effects of saturation in these systems and demonstrate the ability of this controller to help network routers gracefully survive denial-of-service attacks.

Campbell, David (INVITED)
Boston University

Intrinsic localized modes

Carr, Thomas (CONTRIBUTED)
Schwartz, Ira B., Nonlinear Dynamical Systems Section, Naval Research Laboratory, Dept of Mathematics, Southern Methodist University

Delayed-mutual coupling dynamics of lasers: scaling laws and resonances

We consider a model for two lasers that are mutually coupled optoelectronically by modulating the pump of one laser with the intensity deviations of the other. While coupling causes oscillatory output at the laser's relaxation frequency, significantly long delay introduces additional complexity as external cavity modes also become unstable. We derive the bifurcation and relevant scaling laws for both the internal and external modes and compare them to recent experimental results. There also exists a novel resonance phenomenon where for a specific value of the coupling there is a strong amplitude response. For delayed-mutual coupling there is a sharp parameter-space boundary that determines whether the resonance response is hysteretic.

Carlson, Jean (INVITED)
University of California, Santa Barbara

Friction from Atomic to Tectonic Scales

Friction, fatigue, and failure in materials remain difficult to predict in most settings. These basic phenomena are responsible for catastrophic collapses of societal infrastructure (e.g. bridges, building, and dams), and are intrinsically linked to geophysical hazards (e.g., earthquakes, landslides, and volcanoes). The talk presents an overview of ongoing work and new opportunities for theory, simulation, experimentation, and observation of friction, fatigue, and failure phenomena from atomic to tectonic scales. We begin at the smallest scales, where progress in scientific computing is making it possible to numerically explore macroscopic friction and wear arising from increasingly rich dynamical effects as they propagate up from smaller scales, and to track increasingly complex aspects of the internal dynamics along with their macroscopic consequences. At intermediate scales, investigations focus on rate and state constitutive laws describing rough dry surfaces, granular systems, amorphous solids, and lubricated interfaces. At the largest scales, we focus on the earthquake problem. Recent results in theory, computer simulation, and laboratory experiments along with the increasing resolution of seismic data are leading to new opportunities to use constraints imposed by the underlying physics to reduce uncertainties associated with seismic modeling and observations. A multiscale approach tackles these questions in unison, exploring how insights and observations from theory, simulations, and the laboratory impact field observations, and motivating questions for theory from needs, constraints, and observations which arise in the earth.

Egolf, David (CONTRIBUTED)

Fishman, Matthew P., and Egolf, David A., Dept. of Physics, Georgetown Univ., Dept of Physics, Georgetown Univ.

Revealing the building blocks of spatiotemporal chaos: Deviations from extensivity

Researchers have made relatively little progress in developing a predictive theory of far-from-equilibrium, spatially-extended chaotic systems. Even descriptions of the fundamental degrees of freedom and the nature of their interactions --- central elements of statistical mechanics --- are lacking. Using high-precision studies of the fractal dimension as a function of system length for the complex Ginzburg-Landau equation, we have uncovered deviations from extensivity on a length scale consistent with the chaotic length scale, indicating that this spatiotemporal chaotic system is composed of weakly-interacting building blocks, each containing about two degrees of freedom. Our results also suggest an explanation of some of the 'windows of periodicity' found in spatiotemporal systems of moderate size.

Finney, Charles (CONTRIBUTED)

Daw, Stuart, Oak Ridge National Laboratory

Hydrodynamics of conical spouted beds

Spouted beds are a unique form of fluidized beds with special engineering relevance and interesting dynamical behavior. They typically have been employed to fluidize particles that pose difficulty for traditional fluidized beds. A conical spouted bed has an inverted conical base partially filled with solid particles, much like a funnel with vertex downward, in which the particles flow downward until they are entrained upwards in a central fluid jet. This spout core proceeds above the particle bed free surface into a fountain, which at times resembles a water fountain, where the particles follow ballistic trajectories before falling onto the bed free surface to complete the cycle. We will details efforts to characterize this system and to develop and validate sophisticated computational models in the context of nuclear fuel particle coating.

Galanis, Jennifer (CONTRIBUTED)

Harries, Daniel, Sackett, Dan, NICHD, Losert, Wolfgang, UMD, Nossal, Ralph, NICHD, NIH

Spontaneous patterning of confined granular rods

Vertically vibrated rod-shaped granular materials confined to quasi-2D containers self organize into distinct patterns. We find consistent with theory and simulation a density dependent isotropic-nematic transition. Along the walls, rods interact sterically to form a wetting layer. For high rod densities, complex patterns emerge as a result of competition between bulk and boundary alignment. A continuum elastic energy accounting for nematic distortion and local wall anchoring reproduces the structures seen experimentally.

Gauthier, Daniel (INVITED)
Duke University

Using dissipative spatial structures to achieve ultra-low-light-level optical switching

Photonic circuits require elements that can control optical signals with other optical signals. Ultra-low-light-level operation of all-optical switches opens the possibility of photonic devices that operate in the single-quantum regime, a prerequisite for quantum-photonic devices. I will describe a new type of all-optical switch that exploits the extreme sensitivity to small perturbations displayed by instability-generated dissipative optical patterns [1]. Such patterns, when controlled by applied perturbations, enable control of microwatt-power-level output beams by an input beam that is over 6,000 times weaker. In comparison, essentially all experimental realizations of light-by-light switching have been limited to controlling weak beams with beams of either comparable or higher power thus limiting their implementation in cascaded switching networks or computation machines. Furthermore, our measured switching energy density of much less than one photon per square wavelength suggests that our device can operate at the single-photon level with modest system improvement. [1] A.M.C. Dawes, L. Illing, S. M. Clark, and D. J. Gauthier, "All-optical switching in rubidium vapor".

Goldburg, Walter (INVITED)
University of Pittsburgh

Turbulence and statistical mechanics at a free surface

Particles that float on the surface of a turbulent, incompressible fluid, sample only the two, horizontal components of the velocity there. Thus their motion is that of a compressible system. These particles can absorb and return energy and vorticity to the fluid below them. In that sense the floaters do not form an independent system obeying conservation laws, even when moving on an inviscid fluid. Experiments are described in which the turbulent dynamics of the floaters is measured, as are statistical properties such as their rate of entropy decrease and the velocity divergence autocorrelation function. Where possible, the measurements will be compared with simulations and with statistical mechanical ideas.

Gollub, Jerry (CONTRIBUTED)
Arratia, Paulo, Haverford/Penn

Using stretching fields to predict the progress of chemical reactions in the presence of stirring by chaotic advection

Diffusively limited chemical reactions between initially separated reactants occur at the interfaces between them during mixing. We study such reactions in two-dimensional electromagnetically driven fluid flows exhibiting chaotic advection for a variety of flow patterns and Reynolds numbers. By measuring the stretching field of the flow, which is essentially the field of finite time Lyapunov exponents, we show that the extent of the acid-base chemical reaction can be predicted. A single parameter, the product of the mean Lyapunov exponent and the number N of mixing cycles, can be used to predict the time-dependent total product for flows having different dynamical features.

Gurel, Fatma (CONTRIBUTED)
Ermentrout, G. Bard, University of Pittsburgh

Effects of electrical and chemical coupling in a network of coupled oscillators

Recently, A. Gelperin, J. Flores, J.W Wang, and B. Ermentrout developed a model for the olfactory lobe in Limax. We consider a phase model for our analysis where we have represented the activity of each oscillator by its phase. The oscillators are taken to be identical and for our numerical computations they are considered as a ring of oscillators. In the absence of a frequency gradient, we show that synchrony is a stable solution up to a certain value of relative coupling strength after which the solutions bifurcate. By computing the normal form for the bifurcation we determine the stability of new solutions. Using the model in the Limax paper, we determine the characteristics of the coupling functions by numerically computing the adjoint. We justify the propositions made in the Limax paper by numerical simulations.

Herrmann, Hans (INVITED)
University of Stuttgart

Pattern Formation of Dunes

I will present a set of differential equations describing the time evolution of a granular surface under the action of wind and gravity. These three equations coupling the fields of topography, sand flux and wind velocity allow to reproduce the formation and motion of dunes of different type. The solutions of the equation are in very good quantitative agreement with data obtained from field measurements of real dunes in North Africa and Brazil. They also allow to study the collision of dunes giving rise to solitary behaviour or to breeding depending on the parameters. Of particular interest is also the study under martian conditions and the resulting morphologies of dunes on Mars. Adding another equation describing the growth of plants permits to study the competition between sand motion and vegetation. In this way one can understand the transformation of crecent to parabolic dunes, a phenomenon often observed along coast.

Karma, Alain (INVITED)
Northeastern University

Patterns of voltage and calcium signaling in cardiac cells and tissue

Khain, Evgeniy (CONTRIBUTED)
Leonard M. Sander Department of Physics and Michigan Center for Theoretical Physics, The University of Michigan, Ann Arbor, Michigan 48109

Physics of secondary tumor formation: effects of cell-cell adhesion

Effects of cell-cell adhesion Formation of dense secondary tumor from a low density suspension of randomly located mobile cells is investigated using a discrete 2-D stochastic lattice model. Tumor growth is associated with the formation and growth of cell clusters. First, small-size clusters that contain several cells are formed from the homogenous state as a result of non-zero cell-cell adhesion. Then these clusters start growing; for subcritical adhesion parameter, the growth is entirely determined by proliferation (the first scenario) and for supercritical adhesion parameter, there is also a phase separation between high density clusters of cells and low density 'gas' of cells (the second scenario). In the case of a sufficiently small proliferation rate, the dynamics in the second scenario can be dictated by the coarsening process, where larger clusters (tumors) grow at the expense of smaller ones.

Landsberg, Adam (CONTRIBUTED)
Friedman, Eric, Operations Research and Industrial Engineering, Cornell University, Joint Science Dept., Claremont McKenna, Pitzer, and Scripps Colleges

A renormalization approach to combinatorial games: The geometry of chomp

Combinatorial games, which include chess, checkers, go, nim, chomp, dots-and-boxes, etc., have captivated mathematicians, computer scientists, and players alike. In this talk, I will describe a novel approach to combinatorial games that unveils surprising connections between such games and key ideas from physics and nonlinear dynamics: scaling, renormalization, crystal growth, and chaos. I will focus largely on the game of chomp, which is one of the simplest in a class of unsolved combinatorial games. The key discovery is that there exist geometrical patterns underlying such games that encode all the essential information about the game. These patterns 'grow' very much like crystals grow (i.e., exhibiting a type of geometric invariance), and can be analyzed using renormalization methods from physics. The analysis of these crystal-like patterns reveals the geometric structure of the winning and losing positions in the combinatorial game.

McCoy, Jonathan (CONTRIBUTED)
Brunner, Will, Max Planck Institute of Dynamics and Self-Organization, Pesch, Werner, University of Bayreuth, Bodenschatz, Eberhard, Cornell University, Max Planck Institute of Dynamics and Self-Organization, Cornell University

Localized resonances in spatially forced pattern formation

Periodic forcing provides a basic tool for probing the response of a spatially extended system to changes in its external environment. We report experimental results on spatially periodic forcing of thermally driven convection in a large aspect ratio fluid layer. This system displays a number of two-dimensional resonant pattern formation phenomena in which the system spontaneously breaks a symmetry in order to accommodate the forcing. A novel form of spatiotemporal chaos, consisting of localized resonance structures, which mediate the transition from forced straight rolls to the generic state of spiral defect chaos, will be the focus of this presentation. This work is supported by the National Science Foundation under grant no. DMR-0305151 and by the Max Planck Society.

Meron, Ehud (INVITED)
Ben Gurion University

Species diversity in dryland vegetation: A pattern formation approach

A striking feature shared by many ecosystems is the high species diversity they support. Even more intriguing are observations of high species diversity in drylands, where the population densities and the total community biomass are low relative to other biomes. Two recent developments shed new light on these observations, (i) the discovery of key species that facilitate the growth of other species as environmental stresses increase, and (ii) the discovery of symmetry breaking vegetation patterns in arid and semi-arid regions. The impacts of these developments on species coexistence and exclusion will be studied using a new mathematical model for interacting plant communities in water limited systems. The model will first be confronted with field observations of facilitation and vegetation patterning, and then be used to study mechanisms of species-diversity change in response to biotic and abiotic stresses.

Mistelli, Tom (INVITED)
National Cancer Institute, NIH

Dynamics of the cell nucleus and of genes

Moon, Sung Joon (CONTRIBUTED)
Levin, Simon, Kevrekidis, Yannis, Princeton University

Coarse-grained dynamics of alignment in animal group models

Coordinated motion in animal groups, such as bird flocks and fish schools and their models gives rise to remarkable coherent structures. Using equation-free computational tools we explore the coarse-grained dynamics of a model for the orientational movement decision in animal groups, consisting of a small number of informed 'leaders' and a large number of uninformed, nonidentical 'followers'. The direction in which each group member is headed is characterized by a phase angle of a limit-cycle oscillator, whose dynamics are nonlinearly coupled with those of all the other group members. We identify a small number of proper coarse-grained variables (using uncertainty quantification methods) that describe the collective dynamics, and perform coarse projective integration and equation-free bifurcation analysis of the coarse-grained model behavior in these variables.

Nishikawa, Takashi (CONTRIBUTED)
Motter, Adilson E., Los Alamos National Laboratory, Lai, Ying-Cheng, Arizona State University, Hoppensteadt, Frank C., New York University, Southern Methodist University

Synchronizability of complex networks

In a network of dynamical elements, one of the most fundamental issues concerns the relationship between the network structure and the collective dynamics of the system. Attracting particularly much attention recently is the relationship between the network structure and the synchronizability of an oscillator network. In this presentation, I will describe a general framework due to Pecora and Carroll, which is widely used to characterize the synchronizability of a network, independently of the individual oscillator dynamics and of the signals exchanged among the oscillators. Then, I will apply the method to scale-free networks to demonstrate a curious, counter-intuitive effect of the heterogeneity of the degree distribution of the network: It can compromise the synchronizability of the network, even though it generally brings the oscillators closer together, in terms of the average distance between oscillators along the links. I will also apply the method to address the problem of optimizing the synchronizability of a network by assigning weights and directions to links, and show that oriented spanning trees of the network lead to optimal schemes of weight/directionality assignment.

Pine, David (CONTRIBUTED)
Gollub, J.P., UCSB and Haverford College, Brady, J.F., Caltech, Leshansky, A. M., Technion, New York University

Chaos and threshold for irreversibility in sheared suspensions

Slowly sheared suspensions of solid particles are governed by time-reversible equations of motion. Here we report a precise experimental test showing that time-reversibility fails for slowly sheared suspensions. We study a dense suspension of PMMA particles (index and density matched to the fluid) at low Reynolds number in a Couette cell using oscillatory strain. We find that there is a concentration-dependent threshold strain amplitude beyond which particles do not return to their starting configurations after one or more cycles. Instead, their displacements follow the statistics of an anisotropic random walk. We determine the dependence of the effective diffusivities on strain amplitude and the concentration dependence of the threshold. The experimental results are compared to numerical simulations, which demonstrate that the threshold strain amplitude is associated with a pronounced growth in the Lyapunov exponent for chaotic particle interactions. The comparison illuminates the connections between chaos, reversibility, and predictability.

Plentz, Dietmar (CONTRIBUTED)
Unit of Neural Network Physiology, LSN, NIMH, NIH

Functional Topology and Architecture of Cortical Networks in the Critical State

In the neocortex, each neuron receives thousands of synaptic inputs and distributes its activity to an equally large number of neurons. While convergence of many simultaneous inputs is required to elicit postsynaptic action potentials (Ref), the topology and architecture that describes propagation of synchronous activity in cortical networks is unknown. Here we report on the functional organization of superficial cortex layers that describes the propagation of synchronous activity in the form of a branching process, i.e. neuronal avalanches. Using a robust algorithm derived from Bayesian estimates of network connectivity, the functional small-world topology is characterized by a cluster-coefficient >0.7, a small network diameter, and sparse connectivity. The architecture consists of hierarchically interleaved small-world sub-networks formed at different link activation levels. Reciprocally coupled neuronal groups that provide and receive common inputs from other groups constitute the dominant network motifs. The hierarchical self similarity and feed forward motifs efficiently integrate cooperativity and selectivity among synchronized neuronal groups for cell assemblies of different retrieval frequencies.

Porter, Mason (CONTRIBUTED)
Mucha, Peter J., University of North Carolina, Chapel Hill, Newman, M. E. J., University of Michigan, Friend, A.J., Georgia Institute of Technology, Warmbrand, Casey, University of Arizona, California Institute of Technology

A network analysis of committees in the United States House of Representatives

Network theory provides a powerful tool for the representation and analysis of complex systems of interacting agents. Here we investigate the networks of committee and subcommittee assignments in the United States House of Representatives from the 101st--108th Congresses, with committees connected according to “interlocks" or common membership. We examine the House's community structure using several algorithms and reveal strong links between different committees as well as the intrinsic hierarchical structure within the House as a whole. We combine our network theory approach with analysis of roll call votes using singular value decomposition and successfully uncover political and organizational correlations between committees in the House without the need to incorporate other political information. This is joint work with Peter Mucha, Mark Newman, A.J. Friend, and Casey Warmbrand.

Ray, Will (CONTRIBUTED)
Karst, Nathaniel, Rebello, Clinton, Roy, Rajarshi, Univ. of Maryland

Identification of recurrent dynamics in a semiconductor laser with time-delayed optical feedback

When a semiconductor laser is presented with moderate amounts of delayed optical feedback, the light dynamics will often demonstrate strong chaotic fluctuations. We experimentally investigate changes in the system dynamics through time-delay embedding as the injection current is tuned to make the transition between two dominant chaotic regimes. Recurrent evolutions of the system trajectory in the power dropout regime are studied using a time-delay embedding of the optimal path for the fluctuations. For injection currents near the boundary of these regimes, the observed light fluctuations demonstrate an intermittency between two or more attractors. The high-dimensional dynamics make it difficult to distinguish between these attractors using the intensity time traces alone. Dynamic transitions are identified with space-time representations of the dynamics and a Hilbert phase analysis with recurrence plots.

Rericha, Erin (CONTRIBUTED)
Parent, Carole, Losert, Wolfgang, University of Maryland

How does Dicty find its way?

As a cell chemotaxis, or moves towards chemical signals, it transduces external chemical signals into mechanical motion. A cell's ability to chemotax is crucial for many biological processes, from wound healing to the spread of cancer. We present our experimental investigations on Dictyostelium Discodeum a model organism for chemotaxis. We expose the cells to three types of external signals: a shallow background gradient of the signaling molecule cyclic-AMP, a localized signal composed of cyclic-AMP attached to beads, and a mechanical stimulus caused by pushing beads against the exterior of the cell. For each stimulus we ask: what is the fidelity of the gradient sensing pathway and how does it influence the mechanical response?

Restrepo, Juan (CONTRIBUTED)
Ott, Edward, Hunt, Brian, IREAP, University of Maryland

The onset of synchronization in large networks of coupled oscillators

We study the emergence of collective synchronization in networks of heterogeneous oscillators. We generalize first the classical all-to-all Kuramoto model of coupled phase oscillators to the case of a general topology of the network of interactions. We find that for a large class of networks there is still a transition from incoherence to coherent behavior at a critical coupling strength that depends on the largest eigenvalue of the adjacency matrix of the network. We also find approximations to a suitably defined order parameter past the transition. We test our theories with numerical simulations and find good agreement. We also consider more realistic oscillators coupled in a network. By extending previous results for the all-to-all case to the case of a network, we show that the largest eigenvalue of the adjacency matrix determines the onset of coherence in this more general case as well.

Schiff, Steven (CONTRIBUTED)
Huang, Xiaoying, Wu, Jian-Young, Georgetown University, George Mason University

Spatiotemporal organization of cortical dynamics

Neural systems think through patterns of activity. But understanding pattern formation in nonlinear systems driven far from equilibrium remains a largely open problem today. I will show experiments demonstrating the recent discovery of spontaneously organizing episodes of activity from slices of rat visual cortex within which arise plane and spiral waves, organizing out of irregular and chaotic wave activity. The spirals have true drifting phase singularities, behavior replicated in mean field continuum models of cortex. A proper orthogonal decomposition illustrates the evolution of the coherent structures that compose such activities. The energy tends to concentrate into a small number of dominant coherent modes as these episodes organize, and then disseminates onto a larger number of modes prior to termination. I will further show evidence that spatiotemporal patterns from human epileptic seizures evolve dynamically through discriminable stages, and that the coherent modes of such seizures may follow a similar organizing pattern as seen in the rat experiment.

Schwartz, Jen (INVITED)
University of Pennsylvania

The Fysics of Filopodia (or The Physics of Philopodia)

Cell motility is driven by the dynamic reorganization of the cellular cytoskeleton which is composed of actin. Monomeric actin assembles into filaments that grow shrink branch and bundle. Branching generates new filaments that form a mesh-like structure that protrudes outward allowing the cell to move somewhere. But how does it know where to move? It has been proposed that filopodia serve as scouts for the cell. Filopodia are bundles of actin filaments that extend out ahead of the rest of the cell to probe its upcoming environment. Recent in vitro experiments [Vignjevic *et al.* J. Cell Bio. **160** 951 (2003)] determine the minimal ingredients required for such a process. We model these experiments analytically and via Monte Carlo simulations to estimate the typical bundle size and length. We also estimate the size of the mesh-like structure from which the filopodia emerge and explain the observed nonmonotonicity of this size as a function of capping protein concentration which inhibits filament growth. Finally we also address the morphology of the mesh-like structure or protrusion otherwise known as the lamellipodium.

Shew, Woodrow (CONTRIBUTED)

Shew, Woodrow L., Poncet, Sebastien, Pinton, Jean-Francois, Ecole Normale Superieur de Lyon

Path instability and wake of a rising bubble

The dynamics of millimeter sized air bubbles rising through still water are investigated using precise ultrasound measurements combined with high speed video. From measurements we deduce the forces acting on the bubble and tie the dynamics of the bubble's wake to observed oscillatory instabilities of the bubble's path: zigzag and spiral motions.

Smith, Jeff (INVITED)

National Institute of Neurological Disorders and Stroke, NIH

Multi-state dynamics and instability of a neural network oscillator

The neural network generating the rhythm of breathing in the mammalian nervous system represents an interesting model system for studying dynamical properties of a neural oscillator. Oscillations in the respiratory network can be readily studied under a variety of experimental conditions ranging from the intact nervous system in vivo to highly reduced states of the network isolated in vitro, employing a range of methods including electrophysiological recording of single neuron and neural population activity, as well as real-time imaging of cell and network activity. We have found experimentally that the network from neonatal rodents isolated in vitro spontaneously generates an inspiratory-related motor rhythm, with stable amplitude and period from cycle to cycle. Progressively elevating neuronal excitability causes periodic modulation of this rhythm, evoking (in order) mixed-mode oscillations, quasiperiodicity, and ultimately disorganized aperiodic activity. Thus the respiratory oscillator follows a well-defined sequence of behavioral states characterized by dynamical systems theory, which includes discrete stages of periodic and quasiperiodic amplitude /frequency modulation that can progress to aperiodic chaos-like behavior. Real-time imaging shows cycle-to-cycle fluctuations in the spatial pattern of network activity that are associated with quasiperiodic behavior. We have also found periodic, mixed-mode periodic, and quasiperiodic breathing patterns in neonatal rodents as well as human infants in vivo. Cellular-level recordings in vitro indicate that an important component of the oscillator consists of a heterogeneous, coupled population of cells where a subset of the neurons behave as autonomous cellular oscillators when the excitatory synaptic coupling is experimentally eliminated. Biophysically realistic models of this heterogeneous network exhibit multi-state activity patterns similar to those observed experimentally. The model simulations suggest that transitions from stable periodic oscillations to mixed mode and quasiperiodic states result from asynchrony of neuronal activity within the network. Our studies provide an example of how spatiotemporal asynchrony may contribute to periodic state transitions, instability, and multi-state activity patterns of a neural oscillator.

Strogatz, Steve (INVITED)

Cornell University

Crowd synchrony on the Millennium Bridge

Soon after the crowd streamed onto London's Millennium Bridge on opening day, the bridge began to sway from side to side. Meanwhile, many pedestrians spontaneously fell into step with the bridge's vibrations, inadvertently amplifying them. In this talk, I'll present a simple model of this unexpected (and now notorious) phenomenon, borrowing ideas from mathematical biology and applying them to this fascinating problem in civil engineering. Video footage of the bridge vibrations and synchronized crowd behavior will be shown. This is joint work with D. Abrams, A. McRobie, B. Eckhardt, and E. Ott.

Tang, Chao (INVITED)
UCSF

The yeast cell cycle network as a dynamic system

Despite the complex environment in and outside of the cell, various cellular functions are carried out reliably by the underlying biomolecular networks. How is the stability of a cell state achieved? How can a biological pathway take the cell from one state to another reliably? Here we address these questions from a dynamic systems point of view. We study the network regulating the cell cycle of the budding yeast, investigating its global dynamical property and stability. We found that this network is extremely stable and robust for its function. The stationary states of the cell, or states at checkpoints in general, correspond to global attractors. The biological pathway of the cell-cycle sequence is a globally attracting trajectory. This network also has a high structural stability--its function is robust to most parameter changes. A simplified Boolean model is constructed which captures the main features of the network's dynamics and property.

Theriot, Julie (INVITED)
Stanford University

Protein polymer and fluid dynamics in cell motility

Tighe, Brian (CONTRIBUTED)
Socolar, J.E.S, Duke University, Physics, Schaeffer, D.G., Mitchener, W.G., Huber, M.L., Duke University, Mathematics

Force distributions in a triangular lattice of rigid bars

We study the uniformly weighted ensemble of force balanced configurations on a triangular network of nontensile contact forces. For periodic boundary conditions corresponding to isotropic compressive stress, we find that the probability distribution for single-contact forces decays faster than exponentially. This super-exponential decay persists in lattices diluted to the rigidity percolation threshold. On the other hand, for anisotropic imposed stresses, a broader tail emerges in the force distribution, becoming a pure exponential in the limit of infinite lattice size and infinitely strong anisotropy.

Tsang, Yue-Kin (CONTRIBUTED)
Birch, Daniel, Young, W.R., Scripps Institution of Oceanography, University of California at San Diego, Courant Institute of Mathematical Sciences, NYU

Planktonic population in a spatially variable environment

Plankton in the upper ocean plays an essential role in the global carbon cycle by converting carbon dioxide and other dissolved nutrients into particulate matter. Thus, the plankton population is an important parameter in models of global climate and climate change. We study, analytically and numerically, the dependence of planktonic biomass on the environmental variability using a two-dimensional advection-diffusion model with spatially varying logistic growth. As a result of the interplay between the growth profile and the flow field, the plankton population can reach a statistical steady state or become extinct. We derive expressions for an upper bound on the biomass and the critical velocity below which the population is sustained.

Urbach, Jeffrey (CONTRIBUTED)

Vega Reyes, F., Booth, J. Cameron, Egolf, David, Georgetown University

Shear flow in a vertically vibrated granular layer

Couette flow provides an important testing ground for hydrodynamic descriptions of granular fluids. Typically the shearing of the medium is the only fluidizing force, so that the energy of the grains cannot be changed independently from the shear rate. We present a series of experiments and molecular dynamics simulations of a horizontally sheared granular monolayer, which is also heated by vertical vibration. We find that the experimental velocity profile is approximately exponential over a wide range of conditions. This behavior is reproduced in the simulation if friction with the vibrating plate is included. With frictionless plates, the velocity profile is approximately linear but we find a surprising instability to a state with large slip at one boundary breaking the symmetry of the flow.

Wambaugh, John (CONTRIBUTED)

Uehara, Jun, Matas, Jean-Philippe, Behringer, Robert, Department of Physics and Center for Non-Linear and Complex Systems, Duke University, Durham, NC 27708

Square amplitude granular waves

Vertically oscillated granular media are known to be a pattern-forming system with rich dynamics. In analogy to the classic experiments of Faraday, variations in the driving amplitude and frequency allow the selection of various spatio-temporal patterns. We investigate the patterns formed in a vertically oscillated powder as functions of driving and an additional parameter -- ambient pressure. At certain combinations of parameters we observe the phenomena of square amplitude waves. For these patterns we find there to be only two phases of amplitude, with discontinuous jumps across phase boundaries. We show that the formation of these patterns is coincident with the maximum diffusive penetration of gas through the layer during a half cycle. If diffusion occurs on faster scales, patterns typical of the zero-pressure case occur. If diffusion is slower, only a portion of the granular layer is involved.

Weiss, Howie (CONTRIBUTED)

Ugarcovici, I., Rice, Sosa, M., Penn State University

The dynamics of density dependent Leslie population models

Biologists have confirmed that for several species, the survival probabilities and fertility rates are density dependent. In particular, using 20 years of 'high quality' population data, Penn State fisheries experts have documented the density dependence of survival probabilities for brown trout in a local stream. Since the trout are territorial and fishing is prohibited in this pristine stream, it seems natural to model the trout population using a density dependent Leslie population model, and we hope begin this modeling project soon. Mathematically, with several students we have been studying the dynamics of large classes of such nonlinear population models and have found a plethora of extremely complicated dynamical behaviors, many of which have not been previously observed in age structured population models, and which may give rise to new paradigms in population biology.

Wiesenfeld, Kurt (CONTRIBUTED)
Peles, Slaven, School of Physics, Georgia Institute of Technology, Atlanta, GA, Rogers, Jeffrey L., HRL Laboratories LLC. Malibu, CA, Georgia Institute of Technology

Reducing symmetry to produce stable synchronization

Spontaneous synchronization of passively coupled fiber lasers has been successfully demonstrated in a number of recent experiments. Our iterated map model for fiber laser arrays explains these phenomena. Unexpectedly, array configurations with a high degree of physical symmetry produce coherent solutions with poor stability properties. We find that by reducing the symmetry of the array in a particular way, we can obtain robustly stable coherent solutions. Such an array design can be implemented either by combining fibers with different physical properties or by underpumping some of the lasers in the array. The same qualitative behavior has been observed experimentally.

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Dynamical advantages of scale-free networks

A dynamical analysis of common network topologies is given and it is reported that a scale-free structure has two vital and distinctive features. Firstly, complex but nevertheless reproducible states exist and secondly, single-site induced state switching reminiscent of gene-expression control. This indicates that scale-free networks have key dynamical advantages over other network topologies that could have contributed to their evolutionary success and thus may provide another reason for their prevalence in nature.

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Hump-to-spout transition in selective withdrawal

Selective withdrawal is a flow-driven topology transition of a steady-state interface. In the experiment, an interface between two immiscible liquids is deformed by an external flow, typically imposed by withdrawing liquid through a tube inserted into the upper layer. For low flow rates, the interface deforms into a hump. Above a threshold flow rate, liquid from both layers are withdrawn. The interface is ``broken" and forms into a steady spout. Near the transition, the hump tip becomes highly curved and, correspondingly, the spout radius becomes very thin. Using experiment and numerics, we show that the hump shape vanishes via a saddle-node bifurcation, not as via an approach towards a steady-state singular shape, and that the lengthscale selection at the transition is robust. The minimum hump radius is always roughly a seventh of the maximum hump height, regardless of the detailed flow geometry or reservoir conditions.