Banff International Research Station

for Mathematical Innovation and Discovery

WORKSHOP ON DYNAMICAL SYSTEMS & APPLICATIONS
JUNE 22 – 24, 2007

MEALS

*Breakfast (Buffet): 7:00 – 9:00 am, Donald Cameron Hall, Saturday & Sunday *(included in workshop)*
Coffee Breaks: As per daily schedule, 2nd floor lounge, Corbett Hall *(included in workshop)*
***Please remember to scan your meal card at the host/hostess station in the dining room for each breakfast.**

For meal options at The Banff Centre, there are buffets in Donald Cameron Hall (lunch:* 11:30 am – 1:30 pm; dinner: 5:30 – 7:30 pm), *Gooseberry's Deli, located in the Sally Borden Building, and The Kiln Cafe, located beside Donald Cameron Hall. There are also plenty of restaurants and cafes in the town of Banff, a 10-15 minute walk from Corbett Hall.

MEETING ROOMS

All lectures will be held in Max Bell 159. Hours: 6 am – 12 midnight. LCD projector, overhead projectors and blackboards are available for presentations. *Please note that the meeting space designated for BIRS is the lower level of Max Bell, Rooms 155-159. Please respect that all other space has been contracted to other Banff Centre guests, including any Food and Beverage in those areas.*

SCHEDULE

Friday

16:00 Check-in begins (Front Desk – Professional Development Centre - open 24 hours)
Lecture rooms available after 16:00.
19:30 Lectures (if desired) or informal gathering in 2nd floor lounge, Corbett Hall (if desired)
Beverages and small assortment of snacks available in lounge on a cash honour-system.

Saturday

7:00-8:45 Breakfast

8:45-10:15 Scaling behavior Chair: Radin
8:45 Schwartz
9:15 Thurston
9:45 Hastings

10:15-11:00 Coffee Break, 2nd floor lounge, Corbett Hall

11:00-12:00 Epidemiology and related topics Chair: Radin
11:00 Billings
11:30 Brooks

Lunch

1:30-3:00 Chemistry Chair: Hastings
1:30 Field
2:00 Sobel
2:30 Bar-Eli

3:00-3:45 Coffee Break, 2nd floor lounge, Corbett Hall

3:45-5:30 Dynamics, excitable systems: the heart and lasers, discussion
Chair: Hastings

- 3:45 Harkin
- 4:15 Kovanis
- 4:45 Landsman
- 5:15 Discussion

Dinner

Discussion

Sunday
7:00-8:45 Breakfast

8:45-10:15 Abstract dynamics Chair: Hastings

- 8:45 Bollt
- 9:15 Levere
- 9:45 Radin

10:15-10:45 Coffee Break, 2nd floor lounge, Corbett Hall

10:45-11:45 Topological dynamics I Chair: Radin

- 10:45 Sander
- 11:15 Wiandt

Checkout by 12 noon.

1 :15-3:15 Topological dynamics II Chair: Radin

- 1:15 Kunze
- 1:45 La Torre
- 2:15 Morgan
- 2:45 Discussion

** 2-day workshops are welcome to use the BIRS facilities (2nd Floor Lounge, Max Bell Meeting Rooms, Reading Room) until 15:00 on Sunday, although participants are still required to checkout of the guest rooms by 12 noon. There is no coffee break on Sunday afternoon, but self-serve coffee and tea are always available in the 2nd floor lounge, Corbett Hall. **

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ABSTRACTS

Speaker: K. Bar-Eli (Tel-Aviv University)

Title: Earth-Average Temperature: A Delay-Time Approach with Perturbations

Abstract:
The changes in the Earth's average temperature are investigated using a simple energy balance Model (EBM) of the Budyko-Sellers Ghil type expressed as a delay-differential equation describing the absorption and reflection of solar and surface radiations when the Suns constant is perturbed. The perturbation of the Suns insolation is done a) as a periodic time dependent changes and b) random, white noise, changes. A variety of oscillatory states due to the combined effects of the delay and the perturbations is obtained. Strong and sharp resonance effects on the temperature oscillations amplitude are observed. Implications of this study to newly found large periodic changes of earth temperatures "snowball" earth are discussed.

Speaker: Lora Billings (Montclair State University)

Title: Multi-strain disease models with antibody-dependent enhancement

Abstract:
As we become more sophisticated in our resources to fight disease, pathogens become more resilient in their means to survive.
Antibody-dependent enhancement (ADE), a phenomenon in which viral replication is increased rather than decreased by immune sera, has been observed in vitro for a large number of viruses of public health importance, including flaviviruses, coronaviruses, and retroviruses. This increased viral growth rate is thought to increase the infectivity of the secondary infectious class. We study the complex dynamics induced by ADE in multi-strain disease models. In the models, ADE induces the onset of oscillations without external forcing. We derive approximations of the ADE parameter needed to induce oscillations and analyze the associated bifurcations that separate the types of oscillations. We investigate the stability of these dynamics by adding stochastic perturbations to the model. We also present a preliminary analysis of the effect of vaccination strategies. Though the models presented are specifically designed for dengue hemorrhagic fever, our results are applicable to any epidemiological system in which partial immunity increases pathogen replication rates.

Speaker: Erik Bollt (Clarkson University)

Title: Modeling and comparing non-conjugate systems-- Mostly Conjugate

Abstract:
A centerpiece of Dynamical Systems is comparison by an equivalence relationship called topological conjugacy. We present details of how a method to produce conjugacy functions based on a functional fixed point iteration scheme can be generalized to compare dynamical systems which are not conjugate. When applied to non-conjugate dynamical systems, we show that the fixed point iteration scheme still has a limit point, which is a function we now call a "commuter" — a non- homeomorphic change of coordinates translating between dissimilar systems. This translation is natural to the concepts of dynamical systems in that it matches the systems within the language of their orbit structures, meaning, in some sense, that orbits must be matched to orbits by some commuter function. We introduce methods to compare nonequivalent systems by quantifying how much the commuter functions fails to be a homeomorphism, an approach that gives more respect to the dynamics than the traditional comparisons based on normed linear spaces, such as L^2. Our discussion addresses a fundamental issue — how does one make principled statements of the degree to which a "toy model" might be representative of a more complicated system.

Speaker: Bernard P. Brooks (Rochester Institute of Technology)

Title: The dialogue dynamic of rumour transmission on various network topologies.

Abstract:
The dialogue dynamic of rumour transmission is based upon empirical rumor research. The propagation function addresses five factors of rumor transmission identified in the literature; uncertainty, anxiety, belief, novelty and ingroup/outgroup connection status. Monte Carlo simulations of the dialogue rumor propagation function flowing over various network topologies such as random and small world are presented.

Speaker: Richard J. Field (University of Montana)

Title: Oscillation and A Period-Doubling Transition to Chaos in a Simple Model of Tropospheric Chemistry.

Abstract: Joint work with *Peter Hess and Sasha Madronich, National Center for Atmospheric Research, Boulder, CO 80803.*

A simplified chemical model extracted from tropospheric photochemistry is investigated as the influx of NO (F_{NO}) into an isolated air mass initially containing only sunbathed oxygen (O_2), carbon monoxide (CO), and a trace of ozone (O_3) is varied. A subcritical Hopf bifurcation is encountered as F_{NO} is increased, beyond which the chemical steady-state is unstable and the system evolves to an oscillatory state. Oscillation results when the system alternately empties and refills with NO_x (NO + NO_2) as two radical-chain processes exchange dominance of the chemistry. An autocatalysis loop in the formation of O_3 is important to the observed instability. A period-doubling transition to chaos is observed at higher values of F_{NO}. The embedding dimension of the chaos is estimated to be four, and the original six-variable model can be reduced to a four-variable set of differential equations. The oscillatory periods are too long to be readily observed in real atmospheres. However, the appearance of this instability suggests that predictions based upon the temporal evolution of this model or more complex models of tropospheric chemistry based on it sometimes may be very sensitive to the exact initial conditions of [CO]/[NO_2] and [O_3]/[NO] prevailing.

Speaker: Anthony Harkin (Rochester Institute of Technology)

Title: Nonlinear Dynamics of Cavitation.

Abstract:

Cavitation can be roughly described as the violent, nonlinear collapse of a gas or vapor bubble immersed in a liquid. The energy released by a rapidly collapsing bubble can be significant. This is most dramatically seen in the phenomenon of sonoluminescence, where a short burst of light is emitted from inside a pulsating bubble during the collapse phase of each oscillation cycle. Cavitation may result in significant erosion to the surfaces of nearby solid objects, such as maritime propeller blades, and cavitation erosion has been exploited for industrial, medical and laboratory applications. This focus of this talk will be to describe a mathematical model of a pulsating bubble, and to show how techniques from dynamical systems theory can be used to derive a threshold for the onset of acoustic cavitation.

Speaker: Harold Hastings (Hofstra University)

Title: Stability of Large Systems.

Abstract:
We address a long-standing dilemma concerning stability of large systems. MacArthur (1955) and Hutchinson (1959) argued that more "complex" natural systems tended to be more stable than less complex systems based upon energy flow. May (1972) argued the opposite, using random matrix models; see Cohen and Newman (1984, 1985), Bai and Yin (1986). We show that in some sense both are right: under reasonable scaling assumptions on interaction strength, Lyapunov stability increases but structural stability decreases as complexity is increased (c.f. Harrison, 1979; Hastings, 1984). We apply this result to a variety of network systems.

Speaker: Vassilios Kovanis (Air Force research Laboratory Wright-Patterson Air Force Base)

Title: Dynamics of Diode Laser Devices.

Abstract:

In this talk we will review recent developments in photonic monolithic integration from the point of view of dynamical systems. One of the fundamental goals of photonic monolithic integration is to replace in various communication systems discrete devices with completely integrated ones that can perform complex logical operations with ultra fast speeds. A few simple but intriguing examples will be reviewed, including diamond shaped lasers as well two section passively mode locked quantum dot lasers. Experimental measurements and proposed nonlinear rate equations will be discussed.

Speaker: Herb Kunze (University of Guelph)

Title: A collage coding approach to model identification and parameter estimation for systems of deterministic ODEs.

Abstract: This is joint work with E. Vrscay of Applied Math at University of Waterloo. Differential equations are often used to construct an idealized model of a phenomenon under study. Experimental observations can be used to refine both the form of the model and the values of any parameters therein, at which point the model can be used to generate predictions. We have been interested in recent years in these processes of model identification and parameter identification. Examination of the literature reveals a collection of frequently unjustified ad-hoc methods. In this talk, we present a rigorous framework for tackling such questions for systems of deterministic ODEs. The general approach is referred to in the literature as collage coding because of its philosophical and mathematical connection to the theory and tools of fractal imaging. It bears mentioning that our novel approach brings with it a sense of cohesiveness because of its robust nature and its broader applicability to such inverse problems for partial differential equations and integral equations.

Speaker: Alexandra Landsman (Naval Research Laboratory)

Title: Synchronization of mutually coupled systems in the presence of long delays

Abstract:
Complete chaotic synchronization of end lasers has been observed in a line of mutually coupled, time-delayed system of three lasers. As mentioned in the October 6 issue of Science (vol. 314, p. 37), this experiment has significance to synchronization of other nonlinear systems with long delays, where it has been proposed by Singer and colleagues that a similar mechanism may be at work behind the observed synchronization of the opposite hemispheres of the brain. Time delays significantly complicate the analysis, and the mechanism behind the synchronization has so far not been elucidated. The present work uses ideas from generalized synchronization to explain chaotic synchronization in the presence of long delays. As an example, the three laser system is analyzed, using stability analysis close to the synchronization manifold. The results explain and predict the dependence of synchronization on various parameters, such as time-delays, strength of coupling, and dissipation. One interesting and counter-intuitive result of the analysis is that increasing the delay actually improves synchronization. The analytically based predictions agree with numerical results.

Speaker: Davide La Torre (University of Milan, Italy)

Title: A collage coding approach to model identification and parameter estimation for systems of random ODEs.

Abstract: Joint work with E. Vrscay of Applied Math at University of Waterloo and H. Kunze of Math & Stats at University of Guelph.

Most natural phenomena or the experiments that explore them are subject to small variations in the environment within which they take place. As a result, data gathered from many runs of the same experiment may well show differences that are most suitably accounted for by a model that incorporates some randomness. Differential equations with random coefficients are one such class of useful models. In this talk, we consider such equations as random fixed point equations. We develop a collage coding approach for estimating the mean values and variances of the random coefficients from (a collection of) experimental data sets.

Speaker: David Morgan (Harvard University)

Title: Constructing constrained invariant sets in multi-scale continuum systems

Abstract:
We present a method we name the Constrained Invariant Manifold (CIM) method, a visualization tool to construct stable and unstable invariant sets of a map or flow, where the invariant sets are constrained to lie on a slow invariant manifold. The construction of stable and unstable sets constrained to an unstable slow manifold is exemplified in a singularly perturbed model arising from a structural-mechanical system consisting of a pendulum coupled to a viscoelastic rod. Additionally, we present an extension of the Step and Stagger method of Sweet, Nusse and Yorke to calculate a δ-pseudo orbit on a chaotic saddle constrained to the slow manifold in order to be able to compute the Lyapunov exponents of the saddle.

Speaker: Michael A. Radin (Rochester Institute of Technology)

Title: Boundedness, Periodic and Monotonic Character of the Positive Solutions of a Non-Autonomous Rational Difference Equation.

Abstract: This is joint work together with Mark R. Bellavia from the University of Rhode Island.

It is our goal to examine the Boundedness, Periodic and Monotonic Character of the solutions of a Non-Autonomous Rational Difference Equation. First we will investigate the behavior of the solutions with one periodic sequence and then extend the investigation of the solution with two periodic sequences. In particular, we will analyze what happens to the solutions when the periods are of even order, odd order, and the relationship if the terms of both sequences and how that will affect the behavior of the solutions.

Speaker: Evelyn Sander (George Mason University)

Title: A classification of explosions.

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

Speaker: Ira Schwartz (Naval Research Laboratory)

Title: The Dynamics of Noise Induced Escape-New Scaling Laws

Abstract:
Noise is ubiquitous in nature, and is becoming more important as devices are engineered down to nano scales. Examples arise in nano-mechanical oscillators and Josephson junctions, to name a few. Noise induced escape from potentials is one important dynamical aspect which is found in many areas of physics where switching behavior between states is observed. In this talk, noise-induced escape from a metastable state of a dynamical system is studied close to a saddle-node bifurcation point, but in the region where the system remains underdamped. We find the energy of escape scales as a power of the distance to the bifurcation point. Moreover, we make a prediction of two types of scaling and the corresponding critical exponents. Both theory and numerical simulations will show how the scaling depends on the interaction between noise and the underlying deterministic dynamics.

Speaker: Sabrina G. Sobel (Hofstra University)

Title: Apparently spontaneous activations in the Belousov-Zhabotinsky reaction

Abstract: Joint work with Richard J. Field and Harold M. Hastings Hofstra University and the University of Montana.

The unstirred, ferroin catalyzed Belousov-Zhabotinsky (BZ) reaction is a prototype chemical system exhibiting traveling waves of oxidation in an oscillatory or excitable medium. A typical thin-layer BZ medium (~2D) displays a red (reduced) induction phase lasting several minutes, followed by “spontaneous” formation of “pacemaker” centers that oscillate between red and blue states and generate target patterns of concentric, outward-moving waves of oxidation (blue) in the red medium. The origin of these pacemaker centers is not yet completely understood. This talk will describe experimental results which lead to our current stochastic model for the origin of pacemaker centers, extending the Oregonator of Field, Kőrös and Noyes and recent work of the authors (J. Phys. Chem. A; 2006; 110; 5-7). In particular, we describe how an experimenter varies parameters in order to understand dynamics.

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Speaker: Tamas Wiandt (Rochester Institute of Technology)

Title: Liapunov functions for closed relations

Abstract:
A fundamental theorem by C. Conley ensures that any flow on a compact metric space decomposes into a chain recurrent part and a gradient-like part, i.e. there exists a continuous real-valued function which is decreasing along orbits not in the chain recurrent set. A similar result holds for continuous maps on compact metric spaces. Our aim is to further generalize this theorem to the setting of closed relations on compact Hausdorff spaces.