Applied Mathematics USRA Conference

Friday, August 16th, 2013
MC 5136B

Time	Speaker	Title
8:45-9:00	Coffee	
9:00-9:20	Ben Storer	Analytic Solutions to the Linear Shallow Water Equations in a Channel
9:20-9:40	Chris Sutherland	On the role of locality in epistemic model
9:40-10:00	Andrew Dhawan	Plasticity, phenotype heterogeneity, and the mathematical modeling of cancer stem cells
10:00-10:20	Alexei Borissov	Waves in the Solar Tachocline
10:20-10:40	Break	
10:40-11:00	Kevin Chow	Super convergence recovery for DG solutions.
11:00-11:20	Melanie Chanona	The Kleptomaniacal Moon: Angular Momentum Theft in the Earth-Moon System
11:20-11:40	John Dengis	Dissipative Encoder for Toric Code
11:40-12:00	Matt Beach	The Relational Quantum 3-Body Problem
12:00-12:45	Lunch	
12:45-1:10	Vedang Vyas & Moses Mung'Ayi	Investigating Genetic Switches to Control Cell-to-cell Communication between populations of Escherichia coli
1:10-1:30	Michael Rouben	Matter Bounce as an alternative to Inflation
1:30-1:50	Shane Lawrence	Numerical simulation of oxygen enhancement ratio in radiotherapy

Appendix

1. Analytic Solutions to the Linear Shallow Water Equations in a Channel

Presenter: Ben Storer

Abstract: We consider the linear shallow water equations for a single non-stratified layer in a semi-beta-plane channel. Since these dynamics encompass both a quasi-geostrophic model and an f-plane model we are able to observe Poincare, Kelvin, and Rossby waves as being solutions to the same system. The analytic solutions and an analysis of some properties are discussed.

2. On the role of locality in epistemic model

Presenter: Chris Sutherland

Abstract: Nonlocality was shown by Bell to be a striking and necessary feature of hidden variable models of quantum mechanics. Correct formulations of nonlocality are therefore of extreme importance in such models. Recently, the Pusey-Barrett-Rudolph theorem (PBR) claimed to have ruled out statistical interpretations of the quantum state. However, Schlosshauer and Fine showed that at the heart of the PBR argument lied a flawed notion of locality. I'll present a more natural, weaker formulation of the rule for composing two systems and show that under this principle, epistemic models are allowed.

3. Plasticity, phenotype heterogeneity, and the mathematical modeling of cancer stem cells

Presenter: Andrew Dhawan

Abstract: Within a number of malignancies, a critical subpopulation of cells that has been shown to drive tumor proliferation, known as cancer stem cells has been isolated using biomarkers such as CD44hi/24lo, CD133, and GD2. Tumor initiation using different proportions of neoplastic stem cells creates tumorspheres with similar steady state proportions of neoplastic stem cells, implying that within the dynamics of tumor growth, there is phenotype switching of tumor cells. Existing mathematical models either suppose that these phenotype transitions occur spontaneously, without a hierarchical mode of differentiation or that imperfection in the biomarker combined with a hierarchical model could also explain the experimentally observed results. In this talk we will present an ameliorated model that is biologically inspired, accounting for a hierarchy of differentiation, the process of dedifferentiation, and imperfection in the biomarker-based identification of a neoplastic stem cell population. In addition to presenting this model, we highlight the importance of including, along with steady state proportions of cell subpopulations, the tumorsphere formation rate. The model we use incorporates this quantity, and we show that just the steady state proportions of tumor cell subpopulations is not enough information to accurately quantify the cellular population dynamics.

4. Waves in the Solar Tachocline

Presenter: Alexei Borissov

Abstract: It has been observed with helioseismology that the core of the sun exhibits solid body rotation while the outer shell has a rotation gradient from the equator to the poles. The tachocline is a thin layer at the interface of these two different rotation profiles and is the source of many surface phenomena of the sun. We examine the dynamics of the tachocline, in particular the waves that propagate through the tachocline using a rotating shallow water model. We compare the results of numerical calculations with previously established asymptotic approximations to get a more accurate picture of the structure and propagation of both fast and slow solar waves.

5. Super convergence recovery for DG solutions

Presenter: Kevin Chow

Abstract: It is known that under mild conditions, it is possible to extract from a discontinuous Galerkin (DG) solution, a solution of higher order accuracy. In this talk, we will go through a basic introduction to DG methods, and then apply it to our model problem, the linear advection equation $u_t + au_x = 0$. We will then discuss post-processing the solution, with emphasis on the techniques introduced by Cockburn, et al. Finally, we present numerical and symbolic results that demonstrate this higher order accuracy.

6. The Kleptomaniacal Moon: Angular Momentum Theft in the Earth-Moon System

Presenter: Melanie Chanona

Abstract: The nature of Earth-moon interactions result in a complex astrophysical system. Due to subtle effects of the tidal gravitational field of the moon, the Earth's spin angular momentum is actually decreasing over time. But conservation of angular momentum requires that this be compensated for by altering the moon's orbit. I present a novel method of analyzing this interaction using a quasilocal approach that produces a highly general conservation law. Through the use of rigid quasilocal frames (RQFs), we can achieve physically relevant equations by taking a more natural approach to gravitational energy, and we maintain the ability to make accurate predictions. This is demonstrated by considering the example of the Earth-moon system and calculating the recession of the moon to be 3.8cm/year - exactly the experimental result.

7. Dissipative Encoder for Toric Code

Presenter: John Dengis

Abstract: I consider the problem of encoding logical information into the ground states of the toric code Hamiltonian using local, time-independent interactions with a memoryless environment. I will give a brief introduction to Kitaev's toric code and to memoryless open quantum systems. I will then proceed to detail the construction of such an encoder and demonstrate that such an encoder can convert product states into the topologically ordered ground states of the toric code.

8. **The Relational Quantum 3-Body Problem**

Presenter: Matt Beach

Abstract: In a quantization of the scale-invariant 3-body problem there is an ambiguity in the value of the dimensionless `Planck's constant' on shape space. This values determines the relative weight between the kinetic and potential terms in the Schrödinger equation. By treating the universal wavefunction as a function of hbar, one can hope to identify a preferred value on shape space. The techniques developed also apply to another model, the scaled 3-body problem with Newtonian gravity. Likewise, the universal wavefunction can be plotted as a function of dimensionless `time' in this theory. The quantum mechanical evolution of both models will be discussed.

9. **Investigating Genetic Switches to Control Cell-to-cell Communication between populations of Escherichia coli**

Presenters: Mosses Wanyoni and Vedang Vyas

Abstract: For this year’s competition, UWaterloo’s team for International Genetically Engineered Machine (iGEM) competition investigates communication between different populations of Escherichia coli, a commonly found species of bacteria. We developed a population dynamics model, and with the use of numerical tools in MATLAB, analyzed it to observe the dynamics of message transmission between different populations of E.coli. Using results from the Endy group, we implemented a switch dynamics model, and tested robustness and leakiness of various designs in MATLAB. Both switch dynamics and population dynamics are insightful in hypothesizing lab results, and we are continuously refining our model through results from literature.

10. Matter Bounce as an alternative to Inflation"

Presenter: Michael Rouben

Abstract: To date, Inflation has been the most successful and popular theory in cosmology. However it is not without its flaws. In this talk I will discuss the Matter Bounce as a different approach to early universe cosmology. I will highlight the key differences in the theories and show some features of the specific Cuscuton model which does not generate any divergent degrees of freedom.

11. Numerical simulation of oxygen enhancement ratio in radiotherapy

Presenter: Shane Lawrence

Abstract: Hypoxia, the lack of oxygen, is a feature of many solid malignant tumors which strongly influences response to conventional treatments like radiotherapy. The lower efficiency of radiotherapy in hypoxic conditions is often quantified by the so-called oxygen enhancement ratio (OER). The OER is defined as the ratio of the radiation dose at a given hypoxic condition and the radiation dose in fully oxygenated condition that results in the same survival. We apply a modified linear-quadratic model to numerically calculate the overall survival of cancer cells and the OER for various distributions of oxygen in one- and two-dimension. We discuss how these results may help in designing efficient radiotherapy protocol, while reducing the risk of second cancer.