Annual Conference of the Canadian Applied and Industrial Mathematics Society (CAIMS/SCMAI)

University of Regina
Regina, Saskatchewan, Canada
June 15-19, 2026

Scientific Organizing Committee:

Shaun Fallat (Chair), University of Regina
Alexandru Badescu, University of Calgary
Sean Bohun, Ontario Tech University
Mark Lewis, University of Victoria
Nilima Nigam, Simon Fraser University
Affan Shoukat, University of Regina
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Cristina Stoica, Wilford Laurier University
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Rebecca Tyson (EDI Advocate), University of British Columbia, Okanagan Campus

Local Organizing Committee:

Allen Herman, Chair (University of Regina)
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Sponsors:

Department of Mathematics and Statistics, University of Regina

Faculty of Science, University of Regina

Fields Institute

Pacific Institute for the Mathematical Sciences

President's Office, University of Regina

Centre de Recherches Mathématiques

Social Events:

- Stronger Together Lunch (Monday)
- M2PI Gala (Monday evening)
- Banquet (Wed, RIC Atrium)
- Conference Photo (Tuesday immediately before am coffee break)

Other Items of Note:

⋆ Registration will be available in Lobby of EA 106 beginning Sunday, June 14 (from 3-6 pm) and each day of the conference beginning 7:30 am until early afternoon (except Friday).
⋆ Daily bus service has been arranged from the local conference hotels to campus and back - please consult the conference webpage for more details.
⋆ CAIMS Annual General Meeting Business Meeting will take place Tuesday at 12 pm in EA 106 (lunch provided)

Annual Conference of the Canadian Applied and Industrial Mathematics Society (CAIMS/SCMAI)

Conference Schedule

Invited Plenary Lectures: [50 minutes in length + 10 minutes Q/A]
CT: Contributed Talk [25 minutes in length + 5 minutes Q/A]
MS·: Minisymposium Talk [25 minutes in length + 5 minutes Q/A]

CAIMS/SCMAI 2026 · Daily Conference Schedule · MONDAY

7:30am	Registration and Information Desk (lobby outside Education Bldg 106), open until 2pm. Morning Coffee Available					
8:15 am	Welcoming Remarks (EA 106)					
8:30am	Plenary (EA 106): **Philip Morrison** (Metriplectic Dynamics: The Geometrical Framework for Thermodynamically Consistent Dynamical Systems)					
9:30am	**Morning Coffee Break** (EA 106 Lobby)					
	CT ED 114	MS # 01 ED 191	MS # 03 EA 106.1	MS # 06 ED 193	MS # 09 CK 185	MS # 15 EA 106.2
10:00am	Budzinski		Lindsay	Broms (v)	Stastna	Hillen
10:30am	Lawrence	Shen	Tzou	Kawakami	Kevlahan	McNicol
11:00am	Fiaz		Wong	Li	Poulin	Willms
11:30am	Zhu (v)			Shum	Couchman	Campbell
12:15pm	**LUNCH BREAK: Stronger Together Luncheon (ED 191)**					
1:30pm	**NSERC Presentation (EA 106)**					
2:30pm	**Afternoon Coffee Break** (EA 106 Lobby)					
	CT ED 114	MS # 01 ED 193	MS # 03 EA 106.1	MS # 04 EA 106.2	MS # 09 ED 191	
3:00pm	Wu		Shevyakov	Zubkov (v)	Shamsukha	
3:30pm	Qu	Ridgway	Iyaniwura	Huraka (v)	Flynn	
4:00pm	Brandao (v)	Addai	Newby	Uz Zaman	Ahmed	
04:30pm	Plenary (EA 106): **Isabel Papadimitriou** (Syntax from data points: understanding the learning and representation of structural abstraction in language models),					
05:30pm	**DINNER BREAK** (Participants on their own)					
07:00pm	**M2PI Gala & Student Mixer** (RIC 119)					

KEY TO PARALLEL SESSIONS

CT	Contributed Talks
MS # 01	Advances in Agent-Based Models for Environmental and Health Systems
MS # 03	First Passage Phenomena in Brownian and Active Matter
MS # 04	Recent Advances in Geometric Numerical Methods
MS # 06	Computational Methods and Modeling of Fluid-Structure Interactions in Flows
MS # 09	Canadian Symposium for Fluid Dynamics
MS # 15	Differential Equations, Dynamical Systems and Applications in Mathematical Biology

NOTES FOR THE DAY

- The registration desk will be open in the lobby of EA 106 from 7:30am–2pm.
- Coffee breaks will be served in the lobby near EA 106.
- Building Abbreviations: ED=Education; CK=Centre for Kinesiology and Heath; CL=Classroom; RIC= Research and Innovation Centre.
- (v) means a virtual presentation via Zoom
- Changes from the printed schedules are in **bold blue**; cancellations are ~~struck out~~.

SPECIAL EVENTS FOR THE DAY

- Stronger together Luncheon
- M2PI Gala and Student Mixer

CAIMS/SCMAI 2026 · Daily Conference Schedule · TUESDAY

8:00am	Registration and Information Desk (lobby outside Education Bldg 106), open until 2pm.							
8:15 am	Morning Coffee Available							
8:30am	Plenary (EA 106): **Darren Crowdy** (Marangoni meets Burgers: new mathematics for surfactant dynamics in slow viscous flows)							
9:30am	**Conference Photo** (EA 106)							
9:35am	**Morning Coffee Break** (EA 106 Lobby)							
	CT ED 114	MS # 02 CK 185	MS # 03 EA 106.1	MS # 04 CK 187	MS # 06 ED 193	MS # 09 ED 191	MS # 12 ED 314	MS # 15 EA 106.2
10:00am	Belair	Bremer	Ward	MacDonald	Salac	Cai	Mailhot	Zhu
10:30am	Adesol	Gutleb (v)	D'Orsogna	Taylor	Sakakauskas	Gervais	Wang	Braverman
11:00am	Philip	Piyasundara (v)	Saghafifar	Fortunato	Quaife	Rezazadeh	Li	Chen
11:30am	Assefa	McKee		Montoya	McNicol	Shevyakov	Turcotte	Djuikem
12:15pm	**CAIMS Annual General Meeting - Boxed lunches (EA 106)**							
1:30pm	Plenary (EA 106): **Melissa Stadt** (Mathematical modelling of electrolyte homeostasis),							
2:30pm	**Afternoon Coffee Break** (EA 106 Lobby)							
	CT ED 114	MS # 02 EA 106.1	MS # 06 ED 193	MS # 09 ED 191	MS # 12 ED 314	MS # 15 EA 106.2		
3:00pm	Roussel	Lilly	Varchanis (v)	Joulaei	Stentoft	Heggerud		
3:30pm	Moosa	Melia	Zhou	Faramarzi	Boire	Ahmed		
4:00pm	Choi	Slevinsky	Young (v)	Protas	Xu	Nicola		
4:30pm	Trofimenkoff		Dalal	Goluskin	Bégin			
05:00pm	**DINNER BREAK** (Participants on their own)							
07:00pm	**Discussion Area** (The Study Bar & Grill)							

KEY TO PARALLEL SESSIONS

CT	Contributed Talks
MS # 02	Spectral and high order methods and special functions
MS # 03	First Passage Phenomena in Brownian and Active Matter
MS # 04	Recent Advances in Geometric Numerical Methods
MS # 06	Computational Methods and Modeling of Fluid-Structure Interactions in Flows
MS # 09	Canadian Symposium for Fluid Dynamics
MS # 12	Financial and Actuarial Mathematics: Theory and Applications
MS # 15	Differential Equations, Dynamical Systems and Applications in Mathematical Biology

NOTES FOR THE DAY

- The registration desk will be open in the lobby of EA 106 from 8am–2pm.
- Coffee breaks will be served in the lobby near EA 106.
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SPECIAL EVENTS FOR THE DAY

- CAIMS Annual General Meeting: All are invited, boxed lunch will be served.
- Conference Photo (EA 106)

CAIMS/SCMAI 2026 · Daily Conference Schedule · WEDNESDAY

8:00am	Registration and Information Desk (lobby outside Education Bldg 106), open until 12pm.					
8:15 am	Morning Coffee Available					
8:30am	Plenary (EA 106): **Brian Wetton** (Time Stepping Methods for Phase Field Models)					
9:30am	**Morning Coffee Break** (EA 106 Lobby)					
	CT ED 114	MS # 07 ED 318	MS # 08 ED 193	MS # 09 ED 191	MS # 11 EA 106.1	MS # 12 EA 106.2
10:00am	Lie	Moyles	Charlet (v)	MacLachlan	Monterde (v)	Saunders
10:30am	Hasan	Laison	Kongara (v)	Palma	Joshi (v)	Birghila
11:00am	Rogalsky		Wei	Leclerc	Lee	Pirvu
11:30am	Nikman	Tuffaha	Panday (v)	Mazzone	Parenteau	Simard
12:15pm	**LUNCH BREAK (Particpants on their own)**					
1:30pm	Plenary (EA 106): **Yuying Li** (Optimally Decumulate Using an NN Approach for Stochastic Optimal Control)					
2:30pm	**Afternoon Coffee Break** (EA 106 Lobby)					
03:00pm	**Poster Presentations** (ED 114)					
06:30pm	**Conference Banquet** (RIC Atrium)					

KEY TO PARALLEL SESSIONS

CT	Contributed Talks
MS # 07	Stochastic, Perturbative and Individual Effects on Population Modelling
MS # 08	Scientific Machine Learning for Weather Forecasting
MS # 09	Canadian Symposium for Fluid Dynamics
MS # 11	Theoretical Approaches to Computational Problems with Applications in Discrete Mathematics
MS # 12	Financial and Actuarial Mathematics: Theory and Applications

NOTES FOR THE DAY

- The registration desk will be open in the lobby of EA 106 from 8am–12pm.
- Coffee breaks will be served in the lobby near EA 106.
- Building Abbreviations: ED=Education; CK=Centre for Kinesiology and Heath; CL=Classroom; RIC= Research and Innovation Centre.
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SPECIAL EVENTS FOR THE DAY

- Poster Presentations (see Book of Abstracts for details on each poster)
- Conference banquet (for participants that confirmed at time of registration)

CAIMS/SCMAI 2026 · Daily Conference Schedule · THURSDAY

CAIMS
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[MOVE to Classroom Building to avoid Convocation]

8:00am	Registration and Information Desk (lobby outside Education Bldg 106), open until 12pm.						
8:15 am	Morning Coffee Available						
8:30am	Plenary (CL 126): **Adriana Dawes (v)** (Patterns of life: Quantifying biological symmetry across scales)						
9:30am	**Morning Coffee Break** (CL Main Hallway near CL 110)						
	CT CL 126	MS # 07 RIC 208	MS # 09 CL 125	MS # 10 CL 128	MS # 12 CL 127	MS # 13 RIC 119	MS # 17 CL 130
10:00am		Foxall	Mahfouz	Rayan	Ressor	Pathak	Mazzone
10:30am	Betti (v)	Shyntar	Sandoval	Sowa	Badescu		Shevyakov (v)
11:00am	Alisbaai	Douwes-Schulz	Sandoval/Essel	Johnston	Choulli	Bu	Saha
11:30am	Bidarvand	Lopez		Paddock	Swishchuk	Khedhiri (v)	Schmah
12:15pm	**Lunch Break (participants on their own)**						
1:30pm	Plenary (CL 126): **Wilten Nicola** (Computing with Neural Dynamics in Artificial and Biological Neural Networks)						
2:30pm	**Afternoon Coffee Break** (CL Main Hallway near CL 110)						
		MS # 09 CL 125	MS # 10 CL 128	MS # 11 CL 126	MS # 12 CL 127	MS # 13 RIC 119	MS # 17 CL 130
3:00pm			Dick	Khodamoradi (v)	Firoozi (v)	Moayeri	Khedhiri (v)
3:30pm		Montoya	Green	De Vera	Avci	Venn	Druzhkov
4:00pm			Monterde (v)	Maliuk	Alvarez	Patel	Stoica
4:30pm						Patil	
05:00pm	**DINNER BREAK** (Participants on their own)						
07:00pm	**Discussion Area** (The Study Bar & Grill)						

KEY TO PARALLEL SESSIONS

CT	Contributed Talks
MS # 07	Stochastic, Perturbative and Individual Effects on Population Modelling
MS # 09	Canadian Symposium for Fluid Dynamics
MS # 10	Mathematical Methods for Quantum Information and Quantum Technologies
MS # 11	Theoretical Approaches to Computational Problems with Applications in Discrete Mathematics
MS # 12	Financial and Actuarial Mathematics: Theory and Applications
MS # 13	Different PDE-Based Methods in Applied and Computational Mathematics
MS # 17	Dynamics and Symmetry

NOTES FOR THE DAY

- The registration desk will be open in the lobby of EA 106 from 8am–12pm.
- Coffee breaks will be served in CL Main Hallway near CL 110.
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CAIMS/SCMAI 2026 · Daily Conference Schedule · FRIDAY

CAIMS
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8:15 am	Morning Coffee Available			
8:30am	Plenary (CL 110): **Raymond Spiteri** (More Data + Heterogeneous Compute = Fractured Workflows: Why mathematical and computational structure matter more than ever)			
9:30am	**Morning Coffee Break** (CL Main Hallway near CL 110)			
		MS # 10 CL 128	MS # 11 CL 110	MS # 16 RIC 208
10:00am		Berezowski	Zilles	Corless
10:30am		Plosker	Shirazi	Hatzel
11:00am			Chan (v)	Jeffrey
11:30am			Breen (v)	Joby
12:15pm	**Closing Remarks and Departure (CL 110)**			

KEY TO PARALLEL SESSIONS

MS # 10	Mathematical Methods for Quantum Information and Quantum Technologies
MS # 11	Theoretical Approaches to Computational Problems with Applications in Discrete Mathematics
MS # 16	Computer Algebra in Applied Mathematics

NOTES FOR THE DAY

- Coffee break will be served in CL Main Hallway near CL 110.
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Conference Abstracts

Invited Plenary Lectures: [50 minutes in length + 10 minutes Q/A]
CT: Contributed Talk [25 minutes in length + 5 minutes Q/A]
MS·: Minisymposium Talk [25 minutes in length + 5 minutes Q/A]

Speakers ordered alphabetically by category (in order: Plenary lecturer; Minisymposia lecturer; Poster presenter; and Contributed lecturer) with Minsymposia appearing in numerical order as on the conference website.

Plenary Lectures.

Darren Crowdy, Imperial College London

[Tuesday, June 16; 8:30 am, EA 106]

Marangoni meets Burgers: new mathematics for surfactant dynamics in slow viscous flows

Marangoni meets Burgers: new mathematics for surfactant dynamics in slow viscous flows This talk will survey a number of new mathematical results on insoluble surfactant dynamics, and the resulting Marangoni effects, on the free surface of a viscous fluid. The main aim of the talk is to show the relevance of the complex Burgers equation to the dynamics of insoluble surfactants at arbitrary surface Peclet numbers – when surface diffusion and advection are both present – leading to a remarkable linearization of this nonlinear multiphysics problem having a number of mathematical, and physical, ramifications only so far partially explored. While the applications derive from fluid dynamics, the presentation should be of general interest to applied mathematicians.

Adriana Dawes, Ohio State University

[Thursday, June 18; 8:30 am, CL 126 (virtual)]

Patterns of life: Quantifying biological symmetry across scales

Symmetry is a fundamental characteristic of natural systems, and is often linked to survival, reproductive success, and evolvability. While symmetry is often intuitively obvious, biological symmetry is rarely perfect, making it challenging to define and compare quantitative measures, particularly across different systems. This lack of a common framework limits our ability to compare datasets, identify organizing principles, and standardize analyses across scales. To address this, we developed a flexible, entropy-based approach for quantifying symmetry we termed "Transformation Information" (TI). TI requires minimal user input and can be applied consistently across diverse biological structures and datasets. I will demonstrate its use in diverse contexts, including detecting convergent evolution in flowering plants, classifying biopolymer networks, and visualizing symmetry transitions during pattern formation, to illustrate how quantitative measures of symmetry can reveal underlying organizing principles in complex biological systems.

Yuying Li, University of Waterloo

[Wednesday, June 17; 1:30 pm, CL 126]

Optimally Decumulate Using an NN Approach for Stochastic Optimal Control

We present a data driven neural network (NN) learning framework for discovering optimal stochastic decumulation strategies in Defined Contribution (DC) pension plans. Our proposed NN based Policy Function Approximation (PFA) approach learns optimal dynamic policies directly from data.

Traditionally, computing finite-horizon discrete dynamic optimal controls relies on dynamic programming (DP) methods, such as partial differential equations (PDEs) or reinforcement learning. The DP approach requires maximizing a conditional high dimensional expectation to compute the value function at each rebalancing point, which is computationally intensive.

In contrast, our proposed method achieves computational efficiency by directly computing a low dimensional control policy through a single optimization problem.

We validate our approach by comparing computed optimal strategies against benchmark solutions derived from simulations of synthetic models. Furthermore, we demonstrate the application of our framework to both DC pension accumulation and decumulation strategies using inflation-adjusted CRSP data spanning 1926-2020.

*This talk is based on joint work with P. Forsyth (Univ of Waterloo), M. Chen (JP Morgan), M. Shirazi (Bank of Canada), and P. Van Staden (National Australia Bank, Melbourne)

Philip J Morrison, University of Texas at Austin

[Monday, June 15; 8:30 am, EA 106]

Metriplectic Dynamics: The Geometrical Framework for Thermodynamically Consistent Dynamical Systems

Classical descriptions of matter present many fluid mechanical, magnetofluid, and kinetic theory dynamical systems. These include, e.g., the Navier-Stokes-Fourier system, the Cahn-Hilliard-Navier-Stokes system for multiphase fluid flow, extended MHD, and various types of collisional kinetic theories for gaseous and plasma modeling. A desirable feature of such modeling is thermodynamic consistency, i.e., conservation of energy and production of entropy, in agreement with the first and second laws of thermodynamics. Metriplectic dynamics is a kind of dynamical system (finite or infinite) that encapsulates in a geometrical formalism such thermodynamic consistency. An algorithmic procedure (a recipe) for building such theories is based on the metriplectic 4-bracket, a bracket akin to the Poisson bracket that maps phase space functions to another. However, the 4-bracket maps 4 such functions and has algebraic curvature symmetries. Metriplectic 4-brackets can be constructed using the Kulkarni-Nomizu product or via a pure Lie algebraic formalism based on the Koszul connection. The formalism algorithmically produces many known and new dynamical systems, and it provides a pathway for constructing structure preserving numerical algorithms.

Wilten Nicola, University of Calgary **[CAIMS/PIMS Early Career Award Recipient]**

[Thursday, June 18; 1:30 pm, CL 126]

Computing with Neural Dynamics in Artificial and Biological Neural Networks

Computing with Neural Dynamics in Artificial and Biological Neural Networks How do neural systems compute? Rather than relying on static representations, both biological and artificial networks operate through complex and often plastic dynamics that must be understood with the tools of dynamical systems theory. In this talk, we show how the dynamics of neurons intermingle with the dynamics of synaptic connections to generate emergent macroscopic phenomena which can be analyzed with mean-field theories and other dynamical systems tools for analyzing network level behaviours. This is "bottom-up" approach is complimented with a "top-down" framework where these emergent dynamics are effectively controlled with novel real-time learning algorithms for performing useful computation in model circuits. Finally, we discuss how these model circuits can be translated into efficient hardware designs through neuromorphic computing architectures.

Isabel Papadimitriou, University of British Columbia

[Monday, June 15; 1:30 pm, EA 106]

Syntax from data points: understanding the learning and representation of structural abstraction in language models

How do language models learn abstract systems, like grammar, from gradient descent on many specific examples of language? This talk will go over some approaches in understanding the statistical language learning process, and how language models come to represent linguistic structure. I will focus on language model interpretability work, that looks at the learning trajectories and representation spaces of language models to ask: How do we know when an abstract system is represented in a continuous space? What learning constraints lead to abstract representations? And, what features of language make this learning possible?

Raymond Spiteri, University of Saskatchewan [**CAIMS Research Prize Recipient**]

[Friday, June 19; 8:30 am, CL 110]

More Data + Heterogeneous Compute = Fractured Workflows: Why mathematical and computational structure matter more than ever

The growth of data and computational power can easily be taken to imply that numerical algorithms and software architecture matter less in the quest to solve big problems. In practice, however, the opposite is often true: modern computing is increasingly heterogeneous, and scientific workflows are increasingly fractured across models, languages, hardware, schedulers, and data products. Expectations—for speed, fidelity, and reliability—seem to be the only things growing faster than data and compute.

Meeting these expectations calls for structure at two levels: in the mathematics of the algorithms and in the orchestration of the computations. This presentation is organized around two common procedures that are often adopted by default: operator splitting for simulating multiphysics systems and bulk-synchronous MPI for parallel execution. Both are powerful, and both can be made more so when algorithms and execution are co-designed for adaptivity, heterogeneous hardware, and irregular workloads.

We revisit operator splitting as an opportunity rather than a necessity. When designed with stability and error in mind, splitting becomes a structured way to compose physics and numerics. In this way, mathematics provides the way to build reliable composite integrators rather than a collection of ad hoc fractional steps.

We also revisit bulk-synchronous parallelism as a starting point rather than a destination. When designed with orchestration and irregularity in mind, execution becomes a structured way to compose kernels and data products. In this way, actors provide the means to build automated and robust computational workflows rather than a collection of ad hoc scripts and manual intervention.

Applications to cardiac electrophysiology and hydrology are used to illustrate how these ideas turn fractured workflows into routine simulation capability.

Melissa Stadt, University of Waterloo [**CAIMS Cecil Graham Dissertation Prize Recipient**]

[Tuesday, June 16; 1:30 pm, EA 106]

Mathematical modelling of electrolyte homeostasis

Disruptions to electrolyte balance can lead to severe health consequences including arrhythmias, muscle dysfunction, and bone loss. The systems regulating electrolytes are complicated and interconnected, therefore a quantitative, mechanistic framework is critical for understanding these interactions to understand the system, predict risk, and guide interventions. This talk presents several mechanistic, whole-body compartmental models for key electrolytes potassium and calcium and their study through modelling analysis and simulations. Using simulations, sensitivity analyses, and scenario testing, we quantify the relative contributions of cellular, hormones, and renal regulation to long-term and postprandial potassium balance, explore whole-body implications of renal adaptations to high-potassium diets, characterize maternal adaptations required to meet fetal and neonatal calcium needs, and investigate how low-estrogen stats and common antihypertensive drugs can impact calcium balance and bone density. This work contributes quantitative foundations for understanding electrolyte homeostasis to predict the impacts of physiological changes and pharmacological interventions on electrolyte and bone homeostasis.

Minisymposia.

Minisymposium # 1 – Advances in Agent-Based Models for Environmental and Health Systems.

Obeng Appiagyei Addai, University of Saskatchewan

[Monday, June 15; 4:00 pm, ED 193]

Modeling Compound Flood and Disease Risk in an Agent-Based Urban System

Flood disasters are increasingly coupled with public-health stressors, yet many models treat hydrologic and epidemiologic impacts separately. We present a spatially explicit agent-based model of flood-disease interactions in an urban setting, designed to study cascading effects on households, services, and recovery. The model represents heterogeneous individuals and institutions (households, businesses, schools, shelters, healthcare, and government) with behavior driven by risk perception, coping capacity, and social context. Flood exposure evolves through baseline, warning, inundation, and recovery phases, while disease modules capture infectious, waterborne, vector-borne (stagnant water), and mold-related health pathways.

Beyond direct hazard impacts, the framework tracks service congestion, government support dynamics, economic disruption, and quality-of-life trajectories across demographic groups. Scenario experiments compare baseline, single-hazard, and compound-hazard conditions using replicated runs and uncertainty summaries. This allows us to quantify how timing, duration, and policy levers alter evacuation behavior, health burden, and recovery inequality.

The model is intended as a decision-support testbed for preparedness and response planning: identifying when compound shocks amplify vulnerability, which interventions are most robust under uncertainty, and how post-flood health effects can persist after water recedes. We discuss calibration choices, sensitivity to phase durations, and implications for resilient municipal planning.

Wesley J. M. Ridgway, University of Saskatchewan

[Monday, June 15; 3:30 pm, ED 193]

Multiscale Modelling of a Host-Pathogen System: From Agents to PDEs

Agent based models (ABMs) are widely employed in biological settings to study e.g. tumor growth, animal movement, and disease spread. ABMs are an attractive modelling choice as they allow individual behaviors to be encoded directly by imposing stochastic rules at the agent level. To extract meaningful statistics from ABMs, numerous independent simulations are required, which can be computationally expensive for systems with many agents. Additionally, it is often not possible to obtain analytical insight directly. In contrast, many PDE models are easier to analyze numerically and analytically, but agent-level behavior is difficult to incorporate.

In this talk, we consider a simple host-pathogen ABM consisting of discrete immune cells and bacteria with interactions governed by a set of stochastic rules. We systematically coarse grain this ABM into a semi-discrete reaction diffusion system where the agents are represented by a continuous field in space and time, but discrete in an internal state that encodes the agent-level rules. Our coarse graining approach is based on a method from the theory of reaction-diffusion processes, which effectively links reaction rate constants with the underlying motion of the agents.

Then by taking a suitable continuum limit of the semi-discrete system, we obtain a novel continuum PDE model that is structured in space, time, and the internal state. We show that the solutions of both the semi-discrete and continuum PDE models accurately estimate ABM ensemble averages at reduced computational cost. We discuss generalizations of our techniques to more realistic in-host infection models, with the goal of using coarse grained PDEs as an alternative tool in the analysis of these systems.

Samuel Shen, San Diego State University

[Monday, June 15; 10:30 am, ED 191]

iCHARM App: An optimized AI system to visualize, deliver, analyze, and interpret big climate data

Can we put the massive NOAA data at the fingertips of all users, including school children? Can we turn the NOAA data into economic powers? Can scientists visualize and analyze NOAA data without computer programming? To address these questions, with support from NOAA and NSF of the United States, we have developed a new AI and data science app, named iCHARM, as a Climate Hub for Analytical Research and Monitoring. iCHARM works like a video game and also uses the video psychology of instant gratification and easy learning. It has an optimized, fast database query system much like Amazon shopping. This presentation is a demo of this advanced AI app. A user can access iCHARM at https://icharm.app and visualize various types of weather events and climate phenomena, including the April 1-6, 2025, severe storms in the Tennessee Valley, USA. The seamless integration between iCHARM and our AI weather forecasts will also be implemented. Our iCHARM app features an interactive 3D globe with multiple projection options for flexible, in-depth global data exploration, including smooth zooming and rotation, hover functionality to view precise location-based data, time series analysis for any selected location, a time slider, and adjustable color scales

Authors: Samuel Shen, Jonathan Siegel, William Phong, Elliot Gambale, Will Ruff, Arthur Pasquinelli, Parisa Heidary, Cameron Mitchell, Kaylie Pham, Laura Hu, Christian Byars, Iman Khadir, and Shane Stevenson, Department of Mathematics and Statistics, San Diego State University, CA 92182, USA, Mitch Goldberg, NOAA-CESSRST, City University of New York, New York, NY 10031, USA

Minisymposium #2 – Spectral and high order methods and special functions.

James Bremer, University of Toronto [Tuesday, June 16; 10:00 am, CK 185]

Phase functions methods for the rapid evaluation of special functions

Phase functions provide an efficient way to represent rapidly varying solutions of a large class of ordinary differential equations. This class includes many equations satisfied by special functions of interest, and phase function methods have long been used in numerical schemes for evaluating certain special functions. However, the applicability of these techniques has generally been viewed as limited because of the high cost of computing phase functions numerically. In this talk, I will give an overview of several highly efficient numerical algorithms for computing phase functions and discuss their application to the evaluation of special functions and related quantities.

Timon S. Gutleb, University of Leeds [Tuesday, June 16; 10:30 am, CK 185 (virtual)]

Recent numerical advances for time-fractional PDEs with applications in medical ultrasound

Modelling frequency-dependent ultrasound absorption typically relies on fractional Laplacian formulations, which are efficient but restricted by global spatial coupling and a uniform absorption exponent. In this talk, I present a Fourier pseudo-spectral scheme based on a Caputo time-fractional loss model. By using a static-memory approximation to manage temporal history at a fixed cost, this approach allows the power-law exponent to vary spatially to represent different tissues. Compared to Laplacian models, this method achieves higher accuracy and supports larger time steps. It extends naturally to large-scale heterogeneous media, offering a practical route for high-fidelity modelling in realistic clinical scenarios. I will outline the numerical formulation and provide new analytic insights into related approximation schemes.

Kaitlynn Lilly, University of Washington [Tuesday, June 16; 3:00 pm, EA 106.1]

A Numerical Riemann-Hilbert Approach to the Computation of Transform Pairs

This research presents a unified methodology integrating spectral theory, Riemann-Hilbert problems, and inverse scattering theory to derive and implement transform pairs associated with time-evolution variable-coefficient partial differential equations (PDEs). The resulting hybrid analytical-numerical framework combines Riemann-Hilbert formulations, numerical ODE methods, and techniques for evaluating highly oscillatory integrals to compute both forward and inverse transforms. The method is demonstrated on transforms arising in the solution of the time-dependent Schrödinger and Dirac equations, producing accurate and stable results.

Kyle McKee, [Tuesday, June 16; 11:30 am, CK 185]

title

Owen Melia, Flatiron Institute

[Tuesday, June 16; 3:30 pm, EA 106.1]

GPU acceleration of high-order variable-coefficient direct solvers in 2D and 3D

GPU acceleration of high-order variable-coefficient direct solvers in 2D and 3D We consider how to exploit the massively-parallel execution available on general-purpose graphics processing units

(GPUs), applied to the hierarchical Poincaré–Steklov (HPS) family of algorithms for building fast direct solvers for linear elliptic partial differential equations. To take full advantage of the power of hardware acceleration, we propose two variants of HPS algorithms to improve performance on two- and three-dimensional problems. In the two-dimensional setting, we introduce a novel recomputation strategy that minimizes costly data transfers to and from the GPU; in three dimensions, we modify and extend the adaptive discretization technique of Geldermans and Gillman (2019) to greatly reduce peak memory usage. In this talk, I will describe these algorithms, present numerical results, and describe our open-source implementation. This is joint work with Daniel Fortunato, Jeremy Hoskins, and Rebecca Willett.

Chandramali Piyasundara Wilegoda Liyanage, University of Manitoba

[Tuesday, June 16; 11:00 am, CK 185 (virtual)]

Recent Advances in Space-Time Spectral Methods for PDEs in Irregular Geometry

Despite their high accuracy, classical spectral methods face a significant limitation in dealing with irregularly shaped domains. To address this challenge, we proposed a numerical method to approximate the solution of PDEs in irregular domains using space-time spectral collocation methods. The main idea is to embed the irregular domain in a regular one and extend the data from the physical domain to the larger regular domain. We assumed that the non-homogeneous term is only known in the physical domain and performed a non-periodic extension to the extended domain. The Alternating Non-periodic Extension method has been introduced for two-dimensional non-periodic extensions. The proposed approach is applied to PDEs defined on both non-simply connected and non-convex irregular domains, where spectral convergence is observed in each instance.

We further extend the Alternating Non-periodic Extension methodology to more challenging problems, including the coalescence of two drops governed by the Cahn–Hilliard equation. We are currently working on elliptic and parabolic interface problems where the interface is fixed in time and known, as well as the one-phase Stefan problem. We have also implemented delay PDEs on irregular geometries using the Alternating Non-periodic Extension method, where spectral convergence is observed in each case.

Richard Mikael Slevinsky, University of Manitoba

[Tuesday, June 16; 4:00 pm, EA 106.1]

Matrix equations and orthogonal polynomials

It is well known that matrices with low Hessenberg-structured displacement rank enjoy fast algorithms for certain matrix factorizations. We show how $n \times n$ principal finite sections of the Gram matrix for the orthogonal polynomial measure modification problem has such a displacement structure, unlocking a collection of fast algorithms for computing connection coefficients (as the upper-triangular Cholesky factor) between a known orthogonal polynomial family and the modified family. In general, the $O(n^3)$ complexity is reduced to $O(n^2)$, and if the symmetric Gram matrix has upper and lower bandwidth b, then the $O(b^2n)$ complexity for a banded Cholesky factorization is reduced to $O(bn)$. Next, we will extend this basic result to a matrix equation for the Sobolev–Gram matrix which has a number of terms proportional to the order of the corresponding Sobolev inner product. Finally, we will discuss the structure of Gram matrices of multivariate orthogonal polynomials. These multivariate Gram matrices are endowed with a block structure, and they satisfy a number of simultaneous matrix equations equal to the dimension of the domain.

Minisymposium #3 – First Passage Phenomena in Brownian and Active Matter.

Maria R D'Orsogna, California State University at Northridge

[Tuesday, June 16; 10:30 am, EA 106.1]

First Passage Properties of Velocity Jump Processes

First passage problems arise in many physical and biological applications, whereby reaching a target or state for the first time can trigger irreversible downstream events. Classical formulations typically assume diffusive, continuous dynamics, leading to analytical expressions for the mean first passage time (MFPT) to the target. Many real-world stochastic phenomena, however, are more accurately described by velocity jump processes (VJPs), characterized by persistent, directed motion interrupted by random velocity changes. Despite their ubiquity, the first passage properties of VJPs remain understudied. In this talk, we will present a general framework for estimating first passage properties of VJPs with fixed speed and random reorientations that follow a given angular distribution, such as the von Mises-Fisher, wrapped Cauchy, or elliptical distribution. Asymptotic expressions are derived for the MFPT to a target in the low Knudsen number regime, where the mean free path is small compared to the distance to the target. Explicit solutions are obtained for VJPs in two- and three-dimensional circular domains under radial symmetry. Remarkably, the MFPT scaling in the narrow capture problem can differ substantially from the classical diffusive prediction.

Sarafa Iyaniwura, Fred Hutchinson Cancer Center

[Monday, June 15; 3:30 pm, EA 106.1]

Optimal escape of chiral active matter

Chiral active particles (CAPs) are self-propelled agents with intrinsic rotational dynamics, giving rise to circular trajectories commonly observed in biological and synthetic microswimmers. Understanding how CAPs explore confined environments and locate targets is crucial for describing transport, search efficiency, and reaction processes in physical and biological systems. We study the escape dynamics of CAPs from one- and two-dimensional confined domains. In one dimension, we consider intervals with either two absorbing boundaries or one absorbing and one reflecting boundary. In two dimensions, we analyze escape from a disk containing one or two symmetric absorbing arcs. We characterize the escape time in the high-chirality regime using perturbation theory, and numerically compute the mean first passage time (MFPT) as a function of the particles initial orientation, self-propulsion speed, angular velocity, and domain geometry. Our results show that, depending on the parameters and geometry, the MFPT can exhibit either monotonic or non-monotonic behavior as a function of angular velocity, with a minimum at an intermediate spinning rate, revealing the existence of an optimal chirality that minimizes escape time. These theoretical results are corroborated by particle-based simulations and provide insight into the transport properties of confined chiral active matter, highlighting chirality as a key control parameter for transport and search in confined physical and biological systems.

Alan E Lindsay, University of Notre Dame

[Monday, June 15; 10:00 am, EA 106.1]

Advances in numerical computation and asymptotic analysis for cellular signaling problems

In this talk I will discuss recent advances in singular perturbation analysis for a class of cellular signaling problems. Cellular activity is modulated by noisy signaling dynamics at small localized surface receptors. One classic variant of these problems is the classic Berg-Purcell problem which seeks the steady state flux into a three dimensional cell with a number of localized reactive sites. Another is the mean first passage time (MFPT) problem which seeks the expected time for a diffusing molecule to reach one of many reaction sites either located internally or embedded on a manifold. In each of these cases, we show how to develop asymptotic expansions for these key quantities for general 3D domains. These expansions are developed in terms of the regular part of a Green's function which we develop a numerical routine to obtain. We demonstrate these new results for a variety of different signaling problems on a range of 3D domains.

Jay Newby,

[Monday, June 15; 4:00 pm, EA 106.1]

title

Fatemeh Saghafifar, University of British Columbia

[Tuesday, June 16; 11:00 am, EA 106.1]

Toward a First-Passage Theory for Biased Correlated Random Walks in Chemotactic Fields

First-passage times quantify how long it takes a moving agent to reach a target and are central to search, encounter, and reaction processes in active and biological systems. While many classic results focus on memoryless motion, real trajectories often exhibit persistence and directional bias, especially in gradient-driven settings such as chemotaxis. A framework is presented for studying mean first-passage times of biased correlated random walks in spatially varying fields. The analysis highlights how directional bias can qualitatively alter first-passage behavior compared with unbiased persistent motion, and it outlines regimes and approximations that connect persistent dynamics to effective, coarse-grained descriptions. The aim is to provide practical tools for predicting first-passage statistics in gradient-guided transport without relying on overly restrictive assumptions.

Alexey Shevyakov, University of Saskatchewan

[Monday, June 15; 3:00 pm, EA 106.1]

Brownian simulations and blow-up thresholds for particle systems with singular interactions

The talk concerns blow-up thresholds for finite particle systems with strong attracting interactions subject to additive noise, where thermal excitation competes against the attraction. When the strength of attraction exceeds a first critical threshold, particles collide almost surely infinitely many times, but separate after each collision (""non-sticky collisions""). Beyond a second critical threshold, all particles clump together in finite time with probability one and remain in this state indefinitely (""sticky collisions"") — a picture familiar from the study of one-dimensional Bessel processes. The blow-up thresholds for the underlying system of N interacting particles in R^d, $d \geq 2$, can be calculated analytically using Bessel process theory. Large-scale time-discrete Monte Carlo simulations for such systems with singular drift proved to be unexpectedly challenging and required the Compute Canada cluster. The computational difficulties encountered and the techniques that turned out successful will be discussed. This work is joint with Damir Kinzebulatov and Hakeem Hannoon.

Justin Tzou , University of New South Wales

[Monday, June 15; 10:30 am, EA 106.1]

The 2D narrow capture problem with Levy flights

For a particle undergoing Levy flight inside a rectangular domain with small targets, we formulate an elliptic problem for the mean first hitting time to the set targets. We show that how the particle interacts with the boundary of the search domain is encoded in the elliptic operator. Using a matched asymptotic approach, we calculate that the leading order mean hitting time diverges algebraically in the size of the small targets, exceeding the logarithmic divergence of Brownian search. For the correction term accounting for target placement, we employ an analytic-numerical method for accurately computing the regular part of a certain Greens function of the elliptic operator. Using this Green's function, we show that Levy flight search is less prone to shielding effects than it's Brownian counterpart.

Michael Ward , University of British Columbia

[Tuesday, June 16; 10:00 am, EA 106.1]

The Effective Reactivity for Capturing Brownian Motion by Partially Reactive Patches on a Spherical Surface

We analyze the trapping of diffusing ligands, modeled as Brownian particles, by a sphere that has many partially reactive boundary patches, each of small area and arbitrary shape, on an otherwise reflecting boundary. For such a structured target, the partial reactivity of each boundary patch is characterized by a Robin boundary condition, with a local boundary reactivity. For any spatial arrangement of well-separated patches on the surface of the sphere, the method of matched asymptotic expansions is used to derive explicit results for the capacitance of the structured target, which is valid for any patch reactivity. This target capacitance is defined in terms of a Green's matrix, which depends on the spatial configuration of patches, the local reactive capacitance of each patch and another coefficient that depends on the local geometry near a patch. The analytical dependence of the local reactive capacitance on the reactivity is uncovered via a spectral expansion over Steklov eigenfunctions. In the homogenization limit of a large number of identical uniformly-spaced patches, we derive an explicit scaling law for the effective capacitance and the effective reactivity of the structured target that is valid in the limit of small patch area fraction. From a comparison with numerical simulations, we show that this scaling law provides a highly accurate approximation over the full range of reactivities, even when there is only a moderately large number of reactive patches. (Joint work with Prof. Denis Grebenkov, Ecole Polytechnique)

Tony Wong, University of California, Los Angeles

[Monday, June 15; 11:00 am, EA 106.1]

First passage times to T cell activation

First passage times to T cell activation "Effective recognition of foreign antigens by the adaptive immune system relies on the activation of T cells by antigen-presenting cells (APCs) in lymph nodes. Diffusing T cells may encounter cognate APCs presenting matching antigen fragments, non-cognate APCs that do not, or may exit the lymph node before binding. We develop a stochastic model in which T cell–APC interactions proceed through a sequence of recognition steps represented by a multistage Markov chain. Activation occurs only upon reaching the terminal state associated with a cognate APC. We compute activation probabilities and mean first-passage times in the presence of abundant non- cognate APCs and show how kinetic proofreading with state resetting enhances specificity. This is a joint work with Ikchang Cho, Maria D'Orsogna, and Tom Chou.

Minisymposium #4 – Recent Advances in Geometric Numerical Methods.

Sofiia Huraka, University of Alberta

[Monday, June 15; 3:30 pm, EA 106.2 (virtual)]

Structure-preserving learning and prediction in optimal control of collective motion

Wide-spread adoption of unmanned vehicle technologies requires the ability to predict the motion of the combined vehicle operation from observations. While the general prediction of such motion for an arbitrary control mechanism is difficult, for a particular choice of control, the dynamics reduces to the Lie-Poisson equations. Our goal is to learn the phase-space dynamics and predict the motion solely from observations, without any knowledge of the control Hamiltonian or the nature of interaction between vehicles. To achieve this goal, we propose the Control Optimal Lie-Poisson Neural Networks (CO-LPNets) for learning and predicting the dynamics of the system from data. Our methods learn the mapping of the phase space through the composition of Poisson maps, which are obtained as flows from Hamiltonians that could be integrated explicitly. CO-

LPNets preserve the Poisson bracket and thus preserve Casimirs to machine precision. To illustrate the power of the method, we apply these techniques to systems of N=3 particles evolving on SO(3) group, which describe coupled rigid bodies rotating about their center of mass, and SE(3) group, applicable to the movement of unmanned air and water vehicles. Numerical results demonstrate that CO-LPNets learn the dynamics in phase space from data points and reproduce trajectories, with good accuracy, over hundreds of time steps. The method uses a limited number of points (approximately 200/dimension) and parameters (approximately 1000 in our case), demonstrating potential for practical applications and edge deployment.

Daniel Fortunato, Flatiron Institute

[Tuesday, June 16; 11:00 am, CK 187]

Fast high-order methods for surface PDEs

We introduce a fast direct solver for variable-coefficient elliptic partial differential equations on surfaces based on the hierarchical Poincaré–Steklov method. The method takes as input a high-order mesh of a surface and discretizes surface differential operators on each element using a high-order spectral collocation scheme. Elemental solution operators and Dirichlet-to-Neumann maps tangent to the surface are precomputed and merged in a pairwise fashion to yield a hierarchy of solution operators that may be applied in O(N log N) operations for a mesh with N elements. The resulting fast direct solver may be used to accelerate implicit time-stepping schemes, as the precomputed operators can be reused for fast elliptic solves on surfaces. We apply the method to a range of problems on both smooth surfaces and surfaces with sharp corners and edges, including the static Laplace–Beltrami problem, the Hodge decomposition of a tangential vector field, the computation of surface harmonics, wave scattering on an infinite manifold, and some time-dependent reaction–diffusion systems. Along the way, we showcase the method's implementation in Surfacefun, a user-friendly and open-source MATLAB package for numerically computing with functions on surfaces.

Colin B. Macdonald, University of British Columbia

[Tuesday, June 16; 10:00 am, CK 187]

An extrapolation technique for general boundary conditions within the closest point method

An extrapolation technique for general boundary conditions within the closest point method We generalize the closest point method to solve surface partial differential equations with general boundary conditions. The proposed extrapolation provides a unified framework for treating a broad class of inhomogeneous Neumann and Robin boundary conditions within the closest point method. The accuracy of the method is demonstrated through numerical convergence studies.

Tristan Montoya, University of Saskatchewan

[Tuesday, June 16; 11:30 am, CK 187]

Discontinuous spectral-element methods for hyperbolic systems on manifolds

We present a high-order discontinuous spectral-element formulation for hyperbolic systems of balance laws on curved manifolds, with a focus on two-dimensional surfaces embedded in three-dimensional Euclidean space. The methods are derived from a covariant formulation of the governing equations on the manifold itself, expressed in local coordinates induced by the mapping from the reference element to each physical element. Using a flux-differencing approach based on summation-by-parts operators, we obtain discretizations of arbitrary order that, in the case of the rotating shallow water equations, are mass conservative, well balanced, and either entropy conservative or entropy stable with respect to the total energy. This talk covers the fundamentals of the approach and its implementation within the Trixi.jl ecosystem, structure preservation for the rotating shallow water equations, numerical results for standard atmospheric test cases on the sphere, and extensions to more general manifolds and equations. This talk is based on joint work with Andrés Rueda-Ramírez and Gregor Gassner.

Seth Taylor, University of Saskatchewan

[Tuesday, June 16; 10:30 pm, CK 187]

Thermodynamically Constrained Information Geometric Regularization for Compressible Flows

Mitigating singularities associated with shock formation in compressible fluid flows is a long-standing problem in computational fluid dynamics. A recently proposed inviscid regularization of Cao and Schaefer offers a promising approach to this problem using an information geometric correction based on a mixed geometric structure combining the geometric mechanics of compressible flows with the information geometry of probability densities. In this talk, we describe our recent work on a thermodynamically constrained extension of this information geometric regularization. We describe the information geometric mechanics behind our approach and present numerical simulations demonstrating that our new compressible fluid models successfully mitigate the cusp singularities observed in previous inviscid regularizations while still maintaining their benefits. We further indicate some open directions for applied and theoretical research into information geometric mechanics for the systematic incorporation of information-theoretic structure into multi-scale models of physical phenomena.

Tareq Uz Zaman, Simon Fraser University

[Monday, June 15; 4:00 pm, EA 106.2]

Preserving multiple conserved quantities for the Korteweg–de Vries equation

Many evolutionary partial differential equations possesses multiple conservation laws and preserving such quantities is essential for accurate long-time predictions. The Korteweg–de Vries (KdV) equation is one such nonlinear dispersive model possessing an infinite hierarchy of conservation laws. We investigate a class of structure-preserving semi-discretizations in space for the KdV equation which inherit a finite number of discrete conservation laws. For both Petrov–Galerkin finite element and Fourier–Galerkin spectral semi-discretizations, we derive compatibility conditions under which the resulting ODE system inherits a prescribed set of discrete conservation laws from the underlying PDE. To preserve multiple conserved quantities across time, we employ the Minimal ℓ^2-Norm Discrete Multiplier Method (MN-DMM) of Schulz and Wan (2025) for the proposed semi-discretizations. Numerical results on solitons illustrate accurate preservation of conserved quantities, as well as stable and accurate long-time dynamics over nonconservative schemes.

This work is joint with Andy T.S. Wan of the Department of Applied Mathematics, University of California, Merced, USA.

Maksym Zubkov,

[Monday, June 15; 3:00 pm, EA 106.2 (virtual)]

Algebraic geometry of rational neural networks

In this talk, we will explore (neuro)algebraic geometry, an emerging field analogous to algebraic statistics that uses algebraic geometry to study the theory of deep learning. We fix a feedforward neural network architecture with a rational activation function and associate an algebraic (neuro)variety to the given architecture. I will present recent results showing how the study of neurovarieties arising from shallow rational neural networks connects to several classical questions in algebraic geometry, including Chow varieties, secant varieties of Veronese and Grassmann varieties, Weyl's conjectures, and other related topics. On the other hand, moving beyond shallow architectures brings a rich collection of classical algebro-geometric objects into focus, whose study may help us better understand the geometry underlying deep learning theory. More broadly, the talk will illustrate how algebro-geometric tools complement the more familiar statistical and probabilistic approaches to the mathematical foundations of deep learning.

Minisymposium #6 – Computational Methods and Modeling of Fluid-Structure Interactions in Flows.

Anna Broms, Imperial College London

[Monday, June 15; 10:00 am, ED 193 (virtual)]

Brownian Hydrodynamics of Rigid-Body Suspensions with the Method of Fundamental Solutions

Stokesian particulate flows arise in a wide range of natural and industrial settings. When particles are sufficiently small, thermal fluctuations play a dominant role, and their motion is governed by the overdamped Langevin equation—a fully coupled stochastic differential equation whose efficient numerical simulation remains challenging, particularly when full hydrodynamic coupling between particles is required.

Boundary integral equations (BIEs) and the closely related method of fundamental solutions (MFS) provide accurate and efficient solvers for the underlying Stokes equations, avoiding volumetric meshing by discretizing only particle surfaces. In dynamic deterministic simulations, the so-called Stokes mobility problem must be solved at each time step, corresponding to the application of a large, dense mobility matrix coupling all particles. In the Brownian setting, one must also compute terms involving both the square root and the divergence of the mobility matrix to satisfy so-called fluctuation–dissipation balance. This requires a discretization that preserves symmetry; standard BIE and MFS formulations do not, and are therefore unsuitable for consistent stochastic dynamics.

We present an MFS-based formulation that restores this symmetric structure. We also identify a modified boundary value problem with fluctuating velocity data such that the resulting rigid body motions satisfy fluctuation–dissipation balance. This avoids explicit formation of the mobility matrix and enables stochastic forcing to be generated at low cost. Combined with a fast, linearly scaling solver for the modified mobility problem, this leads to efficient time integration. Joint work with Eric Keaveny, Imperial College London.

Aashi Dalal, University of Ottawa

[Tuesday, June 16; 4:30 pm, ED 193]

A Robin-Robin splitting method for the Stokes-Biot fluid-poroelastic structure interaction model

We develop and analyze a splitting method for fluid-poroelastic structure interaction. The fluid is described using the Stokes equations and the poroelastic structure is described using the Biot equations. The transmission conditions on the interface are mass conservation, balance of stresses, and the Beavers-Joseph-Saffman condition. The splitting method involves single and decoupled Stokes and Biot solves at each time step. The subdomain problems use Robin boundary conditions on the interface, which are obtained from the transmission conditions. The Robin data is represented by an auxiliary interface variable. We prove that the method is unconditionally stable and establish that the time discretization error is $O(\sqrt{T}\Delta t)$, where T is the final time and Δt is the time step. We further study the iterative version of the algorithm, which involves an iteration between the Stokes and Biot sub-problems at each time step. We prove that the iteration converges to a monolithic scheme with a Robin Lagrange multiplier used to impose the continuity of the velocity. Numerical experiments are presented to illustrate the theoretical results.

Sho Kawakami, New Jersey Institute of Technology

[Monday, June 15; 10:30 am, ED 193]

Boundary integral analysis of nested nearly spherical domains in Stokes flow

Fluid–structure interactions between droplets and their environment are fundamental to many viscous-
dominated soft matter and biophysical systems. Utilizing a boundary integral formulation, we extend analytical solutions for the evaluation of single-layer and double-layer operators on a sphere perturbatively to nearly spherical domains. Combined with displacement theorems for Stokes flows, this approach enables the derivation of analytical solutions for nested, nearly spherical objects, including those in eccentric configurations. As a novel application, we examine the flows produced by a finite-size active particle within a droplet. These analytical results are incorporated into numerical experiments to explore the coupling between particle motion, droplet deformation, and center-of-mass translation. Finally, the framework is applied to examine fluid flows in thin films on particle surfaces.

Shuwang Li, Illinois Institute of Technology

[Monday, June 15; 11:00 am, ED 193]

A boundary integral scheme for computing the dynamics of rigid particles in unsteady stokes or linear viscoelastic fluids

We present a numerical study of the flow due to oscillating three-dimensional rigid particles in either a linear viscoelastic fluid or a viscous Newtonian fluid. Using the viscous–viscoelastic correspondence between creeping flows of viscous and linear viscoelastic materials, we obtain flow quantities in the frequency domain by solving linear partial differential equations via an accurate boundary integral method. We investigate the stresses on the particle surfaces and the velocity fields near the particles. We discuss the flow characteristics under a various conditions including Newtonian and linear viscoelastic fluids, different Weissenburg and frequency numbers, different particle separation distances and particle sizes.

Gordon R. McNicol, University of Waterloo

[Tuesday, June 16; 11:30 am, ED 193]

Self-excited oscillations in a finite-length collapsible channel flow with a heavy wall

Flow through a flexible-walled channel serves as a prototypical model for fluid-structure interaction. Such flows can, under certain conditions, exhibit spontaneous self-excited oscillations reminiscent of several physiological instabilities, where the corresponding growth rate and frequency is often strongly dependent on the mass of the compliant wall. To elucidate this dependency, we consider a model for laminar high-Reynolds-number flow through a long finite-length planar channel, where a segment of one wall is replaced by a membrane of finite mass that is held under longitudinal tension. We use a combination of a two-dimensional long-wavelength model and a reduced one-dimensional model to investigate the critical flow conditions required for the onset of self-excited oscillations for flow driven by an imposed upstream pressure. We quantify the asymptotic structure of these oscillatory normal modes in the limit where both the wall mass and longitudinal tension become large, showing that the leading-order wall motion is a standing wave resulting from a balance between these two contributions independent of the flow. This oscillatory wall motion drives flow along the channel, which is then superimposed with other flow components necessary to satisfy the global boundary conditions using an eigenfunction matching technique. The normal stress arising from this flow balances the first-order correction to restoring forces in the wall, but is notably out of phase with the leading-order wall motion, allowing the flow to do work on the wall and drive the instability.

Bryan Quaife, Florida State University

[Tuesday, June 16; 11:00 am, ED 193]

Dynamics of an active drop under imposed shear

Simulations of nemato-hydrodynamics on the surface of a viscous drop reveal a complex interplay among nematic ordering, activity-driven flows, and interfacial deformations, giving rise to a wide range of self-organized dynamical behaviors (Firouznia and Saintillan, 2025, Physical Review Research). We examine the influence of externally imposed shear on these dynamics. We first analyze how weak shear affects the spatial organization of topological defects in the surface nematic field, focusing on regimes of small deformation. We then quantify how these defect dynamics couple to drop deformation and drive migration of the active drop. Our results provide quantitative insight into the physical mechanisms by which an active drop migrates in a flowing environment.

William Snow Sakalauskas, Worcester Polytechnic Institute

[Tuesday, June 16; 10:30 am, ED 193]

Simulating Growth-Induced Instabilities with Hessian-Informed Vertex Methods

Tissue growth induces morphogenesis and breaks symmetry in situations such as such as the annular growth found in guts tubes and brain convolution. Most previous work numerically solving growth–elasticity systems to replicate these effects has relied on higher-order elements to find critical points, but these only allow for smooth solutions. Additionally, they often use local methods like Newton's method for the discretized system, which can miss multiple solutions generated by the nonlinear system. We adopt more robust force-based vertex methods with gradient descent (applied to the energy functional) to find bifurcations and new minima as growth continues. We perturb the solutions found by gradient descent in directions of the non-positive spectrum of the Hessian in order to find new solutions. This allows us to find multiple stable local minima for certain annular growth problems. Considering the growth of gut tube cross-sections constrained externally with free interior boundaries, we simulate the shape development from initial wrinkling to folding and crease formation. We study the convergence behavior of these solutions as the discretization is refined, and improve computational efficiency to allow for finer discretization. This is achieved through momentum-based methods and/or analysis of the Hessian. Our results suggest that the classical growth–elasticity models may have limited reproducibility in describing biological growth processes.

David Salac, University at Buffalo

[Tuesday, June 16; 10:00 am, ED 193]

Modeling of multi-component compressible flows with applications to hybrid rocket engines

Unlike traditional rockets, hybrid rocket engines combine the energy density of a solid rocket engine with the safety of on using liquid components. In such as hybrid system the fuel, such as paraffin wax is a solid cylinder while the oxidizer is stored separately as either a liquid or gas. The two are not brought together until combustion is needed.

Of of the most critical portions of a hybrid rocket engine is the ablation of the fuel into small droplets, which then burn and in turn produce the thrust. This is a complex process involving high-speed, compressible, multiphase flows. In this work we outline recent progress in the modeling of this processes using direct numerical simulations using ABLATE, a massively parallel numerical simulation tool developed as part of the DOE PSAAP III funded center, CHREST. The underlying methods, sample results, and comparison with experiments will also be presented.

Henry Shum, University of Waterloo

[Monday, June 15; 11:30 am, ED 193]

Modelling of photocatalytic microparticles driven by rotating magnetic fields

Microrobots have the potential for many biomedical and industrial applications, carrying out tasks such as targeted drug delivery, micromanipulation, and environmental monitoring. Experiments have demonstrated that hematite microparticles can be used as simple microrobots as they can be controlled by externally imposed magnetic fields and exhibit photocatalytic activity. We model the relevant physical and chemical aspects in this system and use numerical methods to simulate their motion in viscous fluids. In particular, a boundary element method is used to solve the equations of Stokes flow. Incorporating phoretic effects and short-range interactions with a wall, we characterize distinct regimes of behavior with and without a rolling magnetic field.

Stylianos (Stelios) Varchanis, Flatiron Institute, Simons Foundation

[Tuesday, June 16; 3:00 pm, ED 193 (virtual)]

A stabilized finite element formulation for simulating ordered arrays of immersed flexible fibers with applications in cellular mechanics

We present a new computational tool for the simulation of aligned assemblies of thin, bendable, but inextensible fibers immersed in a linear Stokes fluid. Such systems are of great importance in cellular mechanics because they arise in many intracellular (e.g., cytoskeleton-cytoplasm interactions) and extracellular (e.g., ciliary locomotion) microscale biological processes. The fiber bed is represented as an anisotropic poroelastic medium that obeys the Euler-Bernoulli beam theory and is hydrodynamically coupled to the viscous fluid through local-slender body theory. We develop two methodologies to solve the resulting fluid-structure interaction problem: (1) a classical approach where the solid is solved in the Lagrangian frame, and the fluid is solved using an Arbitrary-Lagrangian-Eulerian (ALE) method, and (2) a novel approach where the solid equations are expressed in the Eulerian frame and the fiber-fluid system is solved together using an ALE method. In both cases, the resulting set of equations is approximated using a Petrov-Galerkin stabilized finite element method specifically designed for the fiber-fluid interaction problem. Equal-order continuous finite elements are used for the spatial discretization of the deforming physical domain, and finite differences are used for temporal discretization. Both approaches are shown to be numerically stable and convergent at the expected order; and additionally, the pure ALE method can resolve extreme fiber deformations without the need for mesh reconstruction. Finally, our methods are validated by direct comparisons to discrete fiber simulations in two benchmark tests: (a) the shearing of an anchored fiber bed and (b) the emergence and evolution of cell-spanning vortices in cellular geometries.

Yuan-Nan Young, New Jersey Institute of Technology

[Tuesday, June 16; 4:00 pm, ED 193 (virtual)]

Soft-Lubrication Drainage and Rupture in Particle-Driven Vesicles

The deformation and rupture of a lipid vesicle due to the forced normal approach of an inclusion are essential for optimizing the design of magnetic giant unilamellar vesicles [magGUVs, Malik et al., Nanoscale 17, 13720 (2025)], with implications for active colloid-membrane interactions and cellular-scale chemical delivery. Here, we investigate vesicles propelled by a force-driven rigid inclusion and reveal a robust elastohydrodynamic mechanism: the inclusion outpaces the vesicle, sustaining a thinning film that drains symmetrically and self-similarly, largely independent of initial shape. For soft membranes and small inclusions, coupling drives a monotonic tension increase that can exceed the lysis tension. Evaluating the maximal tension over a delivery distance, we map an operating window in vesicle reduced area and size relative to the inclusion.

Han Zhou, University of Pennsylvania

[Tuesday, June 16; 3:30 pm, ED 193]

Modeling, Computation and Analysis of Open Membranes

Lipid bilayer membranes with open boundaries arise in many biophysical processes, including pore formation, vesicle rupture, and parasite egress. In this talk, I present a mathematical and computational framework for simulating their dynamics in viscous Stokes flow. The model couples a three-dimensional bulk fluid, a two-dimensional membrane surface, and a one-dimensional free edge via an energy variational formulation. Under axisymmetry, the system reduces to a one-dimensional mixed-dimensional boundary integral problem. We develop a hybrid boundary element–finite element method with local mesh refinement to resolve edge singularities. To better understand the solution structure, we also study a simplified elliptic problem with open boundaries, establishing well-posedness and characterizing the edge singularity. Numerical results demonstrate accurate resolution of multiscale fluid–membrane interactions and edge dynamics.

Minisymposium #7 – Stochastic, Perturbative and Individual Effects on Population Modelling.

Dirk Douwes-Schultz, University of Calgary

[Thursday, June 18; 11:00 am, RIC 208]

Hidden Markov Individual-level Models of Infectious Disease Transmission

Individual-level epidemic models are increasingly being used to help understand the transmission dynamics of various infectious diseases. However, fitting such models to individual-level epidemic data is challenging, as we often only know when an individual's disease status was detected (e.g., when they showed symptoms) and not when they were infected or removed. We propose an autoregressive coupled hidden Markov model to infer unknown infection and removal times, as well as other model parameters, from a single observed detection time for each detected individual. Unlike more traditional data augmentation methods used in epidemic modeling, we do not assume that this detection time corresponds to infection or removal or that infected individuals must at some point be detected. Bayesian coupled hidden Markov models have been used previously for individual-level epidemic data. However, these approaches are only appropriate when most detected individuals have multiple detection times, greatly limiting their applicability.

In contrast, we incorporate autoregression into the observation model, allowing us to analyze outbreaks where only symptom-onset times are available, which is very common. We illustrate the advantages of our method over existing approaches by fitting two examples: an experiment on the spread of tomato spot wilt virus in pepper plants and an outbreak of norovirus among nurses in a hospital ward.

Eric Foxall, University of British Columbia, Okanagan campus

[Thursday, June 18; 10:00 am, RIC 208]

Reproductive value for branching processes with time-varying parameters

The reproductive value function of a linear population model, when it exists, is an eigenfunction for the eigenvalue corresponding to the growth or decay rate of the population, and describes the relative contribution of different types of individuals to the long-term success of the population. For models with time-varying parameters, the correct generalization of the reproductive value notion is a function of space and time that is invariant under the model dynamics. We discuss conditions for its existence and explore some of the properties that can be studied with its help, such as the convergence, in ratio, of the measures that give the descendants of individuals as a function of their initial type.

Elda Laïson, Université de Montréal

[Wednesday, June 17; 10:30 am, ED 318]

Tracking Mpox-related stigma: Classification and time-series modelling for digital public health surveillance

The 2022 mpox outbreak showed how fast outbreak risk and stigma can fuse and reshaping trust, prevention uptake, and the public narrative. We increasingly lean on social media for surveillance, but stigma is rarely measured with enough conceptual detail to be useful at scale. In this work, we developed and validated a framework to detect and classify distinct functions of mpox-related stigma in large-scale public discourse. We then tested whether stigma and counter-stigma follow identifiable temporal patterns in relation to cases and public attention signals. Preliminary findings suggest that the lag between the resurgence of cases, stigmatising discourse and delayed counter-stigma indicates an opportunity for public health interventions.

Diego Tenoch Morales Lopez, Western University

[Thursday, June 18; 11:30 am, RIC 208]

Predicting the fate of rare mutations that modify the mutation rate and spectrum

The rate of de novo mutations varies across species and is predicted to be dependent on parameters such as population size, the average generation time, and how far the population is from the fitness peak. Mutations that modify the mutation rate itself often emerge in bacterial evolution experiments, either increasing or decreasing the mutation rate of ancestral lineages. Previous theoretical approaches have delineated the conditions necessary for these modifiers of mutation rate to spread in the population, either by hitchhiking with beneficial mutations or by reducing the load of deleterious mutations. One implicit assumption in previous work is that the fractions of beneficial and deleterious mutations are identical in the modifier and ancestral lineages (which differ only in how often new mutations arise). Recent empirical work, however, has highlighted the fact that modifications of the mutation rate are often accompanied by changes in mutation bias, such that different types of mutations occur at different rates. This can dramatically alter the availability of beneficial and deleterious mutations for the modifier lineage. In this talk, I will present a stochastic model and computer simulations which explore the effect of mutations that modify both the mutation rate and the mutation bias, demonstrating how these two effects simultaneously play a role in the evolution of microbes.

Iain Moyles, York University

[Wednesday, June 17; 10:00 am, ED 318]

A Basic Reproduction Number for Pair Formation Models with Co-Infection

The basic reproduction number is a standard tool in disease modelling for determining the conditions under which a disease free equilibrium goes unstable and produces an epidemic. One popular procedure for determining this is the next generation matrix method. When this method is applied to models with pair formation, it is able to determine the stability threshold for the disease free equilibrium, but does not accurately compute the basic reproduction number. In this talk we show how to reconcile this by adapting the method to pair formation models. We extend this to the case where there are multiple diseases to consider via co-infection. We demonstrate that our modified next generation method recovers the basic reproduction number in a mathematical model of coinfection with mpox and HIV.

Alexandra Shyntar, University of Alberta

[Thursday, June 18; 10:30 am, RIC 208]

Calcium Signalling in Glioblastoma Networks of Different Topologies and Possible Treatments

Glioblastoma cells can form connected networks using tumor microtubes. Recently, it was discovered that through these connections glioblastoma cells can form a cell network which allows propagation of calcium waves. Additionally, there is a rare cell type called periodic cells which can sustain consistent intracellular calcium transients and are likely to have KCa3.1 pumps. In this work, we adapt an ordinary differential equation model for intracellular as well as intercellular calcium signaling and account for periodic cells. We apply our model to small-world, scale-free and random networks and test how communication is inhibited through random removal of cells, random removal of tumor microtubes, and inhibition of KCa3.1 pumps. All three network types were more vulnerable to random cell damage than to random TM damage. However, to fully degrade the calcium signalling network, random removal of cells is not enough and all periodic cells must be eradicated confirming experimental observations.

Marwa Tuffaha, York University

[Wednesday, June 17; 11:30 am, ED 318]

Global Lessons from Local Policies: Counterfactual COVID-19 Outcomes Across Jurisdictions

We use an age-structured infection and immunity model to evaluate counterfactual COVID-19 outcomes under alternative non-pharmaceutical interventions (NPIs) and vaccination strategies across multiple jurisdictions. After calibrating to observed data, we simulate scenarios varying the timing and strength of NPIs, vaccine rollout, and booster uptake. Our results show strong interactions between population immunity and human compliance to policies, with boosters timing playing a critical role in mitigating severe outcomes, even with partial booster coverage. The framework enables consistent cross-jurisdictional comparison and is readily extendable to additional regions, providing actionable insights for future pandemic response planning.

Minisymposium #8 – Scientific Machine Learning for Weather Forecasting.

Julie Charlet, University of British Columbia

[Wednesday, June 17; 10:00 am, ED 193 (virtual)]

Regional Weather Forecasting with Graph Transformers using the Anemoi Framework

We implement and evaluate a Graph Transformer model for medium-range weather forecasting in British Columbia, Canada using the Anemoi Python framework. The model employs an encoder-processor-decoder architecture and integrates global forcings into a high-resolution domain using a stretched-grid approach. It is pre-trained on 43 years of ERA5 reanalysis data and fine-tuned with 3 years of dynamically downscaled ERA5 data at 3km grid spacing (ClimatEx).

Predictions produced at a 6 hour temporal resolution are evaluated against the training dataset and surface observations from 260 stations. Performance is benchmarked against WRF-RDPS, a state-of-the-art numerical model with identical spatial resolution. We also evaluate the possibility of transfer learning by performing inference using a similar Graph Transformer model trained for the Scandinavian peninsula.

Although development is ongoing, initial results indicate that while the model slightly underperforms relative to WRF-RDPS, it effectively captures most spatial and temporal patterns. The model trained for the Scandinavian peninsula demonstrates variable-specific transfer learning abilities, performing well for wind but not for temperature and 6 hour accumulated precipitation. These findings confirm the necessity of region-specific fine-tuning. Our results help to identify the strengths and limitations of stretched-grid models to guide their incorporation into daily forecast products.

Charith Kongara, Concordia University

[Wednesday, June 17; 10:30 am, ED 193 (virtual)]

Accuracy and Stability of Graph Neural Networks for Turbulent Flows

Graph Neural Networks (GNNs) have emerged as powerful tools for spatiotemporal modeling in Computational Fluid Dynamics (CFD), highlighted by large-scale successes such as Google DeepMind's GraphCast for weather forecasting. These models excel in scalable predictions, but often prioritize breadth over depth in capturing core fluid dynamics phenomena and struggle to be direct surrogates for numerical CFD solvers. Specifically, GNNs struggle to maintain solution stability during extended autoregressive forecasting horizons, which are essential for recursive timestepping in turbulent flow evolution. This limitation arises from error accumulation in long- term predictions, limiting their ability to fully replace computationally intensive traditional solvers.

This study systematically assesses how feature engineering and training strategies extend GNN stability and accuracy for turbulent flows. The primary objective is to identify modifications that preserve physical consistency over prolonged forecasting periods. Using high-fidelity ground truth data generated from our in-house numerical CFD solver, we test several GNN configurations. Input features vary from conserved variables to augmented sets incorporating spatial derivatives, which encode local gradient information between graph nodes that represent grid points. Training schedules contrast standard approaches with introducing autoregressive model predictions in the training data, including emphasis on single-step predictions followed by minimal recursive fine-tuning.

Experiments compare these setups against CFD benchmarks across single-step and multi-step time horizons. Results show that spatial derivatives provide the strongest stability gains, reducing drift in velocity fields by capturing propagation effects more effectively. The optimal training schedule mimics GraphCast: approximately 97% of efforts focus on single-step predictions to master core dynamics, with autoregressive tasks introduced only at the end for about 3% of total simulation time. This yields superior long-term performance compared to uniform schedules, though all configurations confirm GNN strengths in short-term forecasting and degradation in performance as the forecast horizon is increased.

Shoyon Panday, Environment and Climate Change Canada (ECCC)

[Wednesday, June 17; 11:30 am, ED 193 (virtual)]

PARADIS-ENS: A CRPS-Optimized Machine Learning Ensemble Forecasting Model

Ensemble forecasting consists of multiple predictions that characterize uncertainty and provide probabilistic forecasts. By improving predictive skill, it enables more effective risk assessment, decision-making, and early warnings for high-impact events. While operational ensemble forecasting has advanced significantly since the 1990s, ensemble prediction systems based on traditional numerical weather prediction (NWP) models remain computationally expensive. In recent years, machine-learned weather prediction models have emerged as promising alternatives to physics-based approaches. Although early efforts in AI-based weather modeling primarily focused on deterministic models, recent developments in AI-based ensemble methods have demonstrated competitive performance. Here, we introduce PARADIS-ENS, an efficient machine-learned ensemble prediction model that extends the PARADIS model developed at ECCC. PARADIS-ENS is trained by optimizing the Continuous Ranked Probability Score (CRPS) using 29 years of 6-hourly ECMWF ERA5 reanalysis data. The model operates at 1° spatial resolution, incorporating seven atmospheric variables across 13 pressure levels, along with seven surface variables. In this study, we evaluate the performance of PARADIS-ENS across multiple metrics and compare it with leading machine learning–based ensemble forecasting systems.

Siqi Wei, Environment and Climate Change Canada (ECCC)

[Wednesday, June 17; 11:00 am, ED 193]

PARADIS: A physics inspired neural network for weather forecasting

Recent machine learning architectures for global weather forecasting often rely on a monolithic approach where all processes—advection, diffusion, and reaction—are implicitly represented by a single large network. This is particularly problematic for long-range advection. In this talk, I will introduce PARADIS, a physics-inspired neural network that decouples the entire system in an operator-splitting fashion. We consider three major components—advection, diffusion, and reaction—mirroring the fundamental physical processes in atmospheric evolution. We implement a neural semi-Lagrangian operator to perform the advection, depthwise-separable spatial mixing for diffusion, and pointwise interactions for local source terms and vertical dynamics.

Evaluated on ERA5 benchmarks, PARADIS achieves state-of-the-art forecast skill, matching or exceeding the performance of leading traditional and machine-learning baselines on standard metrics while maintaining excellent spectral fidelity.

Minisymposium #9 – Canadian Symposium for Fluid Dynamics.

Tashmid Ahmed, University of Alberta

[Monday, June 15; 4:00 pm, ED 191]

Merging of Four Finite-Source Plumes on a Square Grid

By combining turbulent plume theory and potential flow theory, this work examines the dynamics of plume merger for four plumes arranged on a square grid. Importantly, in contrast to the seminal study by Rooney (J. Fluid Mech., 796, 2016), we consider plumes from finite-area sources. This seemingly minor detail introduces mathematical complications and has nontrivial implications for plume merger, e.g. we demonstrate the existence of a transition region in which plumes are in contact but not yet fully merged. By including this transition region, we model the full evolution of plume cross-sectional shapes from circular just above the source to quatrefoil through the early stages of merger and back to circular in the far field. Associated with these changes of shape are nontrivial and, in some cases, non-intuitive variations of key plume parameters such as vertical velocity and local Richardson number. Our analysis provides a helpful bookend to the study of Li & Flynn (Phys. Rev. Fluids, 5, 2020), which considered two infinite rows of plumes and so examined a 2-by-infinity arrangement of sources as compared to the 2-by-2 arrangement of interest here. The establishment of such bounds (2-by-2 and 2-by-infinity) facilitates the application of our study to real industrial systems, e.g. to an analysis of the atmospheric plumes discharged by cooling towers arranged in a "back-to-back" configuration.

Mingyao Cai, Carleton University

[Tuesday, June 16; 10:00 am, ED 191]

A investigation of the interaction between internal gravity waves and surface water waves

We examine a coupled model of the internal gravity wave and surface water waves. The model is based on an anelastic approximation for internal gravity waves and shallow water equation for surface water waves. This configuration is relevant for the situation such as generations of atmospheric waves by Tsunami or gravity waves , or the situation where coupled atmospheric ocean interactions. We consider different configurations including a situation where multiple surface waves interact and generate gravity wave modes, which in turn interact with each other and with the background atmospheric flow. The numerical solutions show the effects of the nonlinear wave interactions on the background atmospheric flow, and the effects on the background wind and temperature, resulting from these interactions. The coupled model could also describe a situation where the interaction of arbitrary numbers of waves collides at the observer. Joint work with L. Campbell.

Miles Couchman, York University

[Monday, June 15; 11:30 am, CK 185]

STRATA: Extreme Resolution and Extreme Events in Stratified Turbulence

We discuss the STRATA database, a growing public repository of direct numerical simulations (DNS) of stratified turbulence and associated visualization and analysis tools, spanning multiple forcing schemes and flow parameters (e.g. buoyancy Reynolds, Froude, Prandtl and Richardson numbers). Two datasets are explored here as case studies. The first dataset is comprised of high-resolution 3D snapshots of stratified turbulence driven by background vertical shear, with the largest simulation containing 4 trillion grid points. These data are discussed in the context of experimental and observational measurements, with our DNS providing unprecedented resolution of the vast range of length scales influencing the flow. The second dataset is a time series of stratified turbulence triggered by Taylor-Green vortices. We quantify the changing morphology of extreme events in the flow over time, yielding insight into the transition to a layered state.

Mohsen Faramarzi, Laval University

[Tuesday, June 16; 3:30 pm, ED 191]

Slumping flows in buoyant miscible viscoplastic fluid injection

We study the slumping of a buoyant, miscible viscoplastic fluid injected through an eccentric inner pipe into a lighter Newtonian fluid in an inclined, closed-end geometry, under high Péclet numbers and within the Boussinesq approximation. Using camera imaging, ultrasound Doppler velocimetry (UDV), CFD simulations, and a lubrication-based semi-analytical model, we characterize concentration, velocity, and stress fields, as well as interfacial dynamics and the evolution of unyielded plugs. The dynamics depend on the Reynolds, Froude, and Bingham numbers, as well as buoyancy, viscosity ratio, and inclination angle. Two main regimes emerge: arrested and unhalted, with the latter further divided into two sub-regimes: uniform slumping, characterized by a near-constant front speed, stratified flow, and uniform axial plug growth, and bulged slumping, characterized by front deceleration, inlet pressure buildup, and plug expansion toward the pipe center and lower wall. CFD and UDV results reveal self-similar axial profiles in the uniform regime, whereas the bulged regime exhibits decaying velocities and enlarging plugs. Yield stress promotes plug growth, buoyancy enhances stratification, and inertia primarily affects the early stages of propagation. Near the front, high velocity gradients delay plug formation; the plug remains approximately constant in the uniform regime but decreases in the bulged regime. The semi-analytical model captures the main trends in stress fields, yield surfaces, and the transition in plug formation with interface height, showing good qualitative agreement with the CFD results.

Morris R. Flynn, University of Alberta

[Monday, June 15; 3:30 pm, ED 191]

Plume merger from area sources

The evolution of vertically-ascending turbulent plumes has been the subject of significant theoretical study for 80 years. Despite this long record of investigation, relatively little is known about plume merger, much less when the merging plumes in question originate from sources of finite dimension. A theoretical treatment of this problem will be presented that requires the judicious application of turbulent plume theory and potential flow theory. By combining these approaches, predictions can be made for the vertical variation of numerous quantities of interest including the plume vertical velocity, volume flux, momentum flux, etc. In addition, if the plume contains water vapor (as in the case of the moist air discharged from cooling towers), one can track the vertical variation of relative humidity and so predict the severity of fog formation at different heights.

Funding acknowledgment: NSERC, International Cooling Tower Inc.

Alain Gervais, University of Waterloo

[Tuesday, June 16; 10:30 am, ED 191]

Numerical playground: Linear internal waves in radial geometry with nonuniform stratification

Internal gravity waves propagate within stably stratified fluids, in which the background mass density increases with depth. Starting from a mathematically rich toy problem, we obtain a separable solution to the linear PDE governing small-amplitude internal waves in radial geometry with arbitrary background stratification and vertical momentum forcing, representing an idealized cylindrical lake with a pycnocline. We find that nonuniform stratification couples the eigenvalues of the separated horizontal and vertical ODEs, resulting in 'families' of two-parameter eigenfunction solutions that are not necessarily orthogonal, as would be the case in the limit of uniform stratification. Seeking resonant wave evolution, we force a single vertical eigenmode and show that a spectrum of eigenmodes is excited in response, which suggests the possibility of energy transfer between physical scales. The analytical solution is implemented numerically. The output from one simulation is analyzed using the classical EOF approach to identify a hierarchy of spatial structures and their time evolution. Results are compared and contrasted with those obtained using tensor decomposition-based approaches (HOSVD, CP-decomposition, star-M SVD). We conclude with a discussion of potential applications.

David Goluskin, University of Victoria

[Tuesday, June 16; 4:30 pm, ED 191]

Quartic Lyapunov functions for global stability analysis beyond the energy method

Verifying global stability of simple fluid flows is a classic challenge in fluid dynamics. Standard results all rely on Lyapunov functions – quantities that must decrease monotonically for all possible perturbations – but with a very specific form: quadratic integrals whose time evolution is unaffected by nonlinearity. The only such quantity in general is the energy of perturbations, although in certain systems other quadratic quantities can be used also. This approach, which goes back to Reynolds and Orr, is called the energy method. Its results are overly conservative in many systems because it cannot verify global stability in flows where the energy of perturbations can grow transiently, even if they must eventually decay when evolving nonlinearly. I will present a new class of quartic Lyapunov function that can verify global stability in certain parameter regimes where the energy methods fails due to transient energy growth. I will sketch the computer-assisted analysis required to show that such quartic quantities indeed decay monotonically for all admissible initial conditions. The general approach is applicable to essentially any fluid model. For an explicit example, I will show quantitative results from its application to 2D plane Couette flow, where it verifies stability at Reynolds numbers larger than the energy stability threshold.

Amir Joulaei, Université Laval

[Tuesday, June 16; 3:00 pm, ED 191]

Modelling viscoplastic fluid transport over air-filled grooves

Superhydrophobic (SH) surfaces with micro-grooved structures have been extensively studied for drag reduction, but their influence on viscoplastic fluid transport requires more investigations. This study investigates pressure-driven Poiseuille flow of viscoplastic fluids over transverse air-filled grooved surfaces, focusing on the interplay between groove geometry, flow inertia, and viscoplastic rheology, characterized by the Bingham number. By combining a semi-analytical model with high-resolution two-phase numerical simulations, we examine interface deformation dynamics, central plug behavior, and pressure drop across a wide range of groove aspect ratios, from shallow ($d \sim 10^{(-3)}$) to deep ($d \sim 1$) grooves. To model air flow inside shallow grooves, lubrication theory is employed where computational costs limit full simulations, while deeper or more complex geometries are fully resolved numerically. Results reveal distinct interface morphologies, including the flat, curved, depinned, or contacting the bottom wall, controlled by groove geometry, Reynolds number, Capillary number, and Bingham number. Correlations are derived to predict critical conditions for depinning, plug deformation, and pressure drop. Based on both the semi-analytical framework and the numerical simulations, we show that in the creeping-flow regime the liquid/air interface remains essentially flat and pinned at the groove edges over a wide range of parameters. Under these conditions, the multiphase problem can be significantly simplified. Specifically, the air-filled grooves can be modeled through a Navier-slip law condition at the liquid/air interface, enabling single-phase modeling and simulations that capture the dominant flow physics. The results demonstrate that the presence of the SH surfaces enhances the penetration of velocity gradients into the center of channel, thereby promoting plug breakage. This effect becomes particularly pronounced when both channel walls are considered as SH surface, as the relative alignment or misalignment of the grooved patterns on opposing walls strongly influences the symmetry of the velocity field and the stress distribution within the plug. In addition to wall alignment, asymmetry in groove geometry itself is shown to play a key role in determining the morphology of the central plug, leading to markedly different deformation and breakage scenarios. These observations motivate the introduction of the concept of an equivalent slippery motion, whereby channels with different groove geometries can exhibit comparable drag-reduction performance while displaying different plug morphology regimes, including cases with intact or broken central plugs. Given the computational intensity of the simulations, we further employ convolutional neural networks (CNNs) to evaluate their predictive performance. The trained CNN is then utilized to optimize SH wall geometries to maximize velocity field asymmetry.

Nicholas Kevlahan, McMaster University

[Monday, June 15; 10:30 am, CK 185]

WAVETRISK dynamically adaptive global atmosphere model coupled to dry physics

General circulation models (GCMs) of the atmosphere couple a layer-based dynamical core for fluid dynamics that are primarily two-dimensional with a physics model for processes like radiation and convection that are primarily one-dimensional. In this talk we describe the dry physics model of Hourdin (1992), which includes a soil column, radiation, vertical diffusion and convective adjustment. The climatology of the dry physics coupled with the wavetrisk-atmosphere dynamical core is described. We show that the dynamically adaptive version of wavetrisk-atmosphere can be stably and accurately coupled to the dry physics without scale-aware parameterizations or modifications to the dynamics-based adaptivity criteria. The turbulence generated by wavetrisk-dry physics GCM is characterized by longitude-latitude projections of vorticity, three-dimensional vorticity isosurfaces and vertical profiles of energy spectrum power laws, which vary between -2.8 in the boundary layer to -5.2 in the stratosphere for the rotational mode.

Etienne Leclerc, University of Victoria

[Wednesday, June 17; 11:00 am, ED 191]

A Dynamical Perspective on Convective Quasi-Equilibrium Theory: Why Convective Parametrization Should be Prognostic

Cumulus parametrization is a leading source of error in climate models, owing to the intrinsic difficulty of predicting small spatiotemporal-scale convective phenomena from large-scale data. Mass flux schemes which employ the quasi-equilibrium assumption form the most commonly-used class of cumulus parametrizations. The present work restates the quasi-equilibrium assumption in the language of dynamical systems using prognostic energy-cycle equations. Criteria for the dynamical validity of the quasi-equilibrium assumption are established. The quasi-equilibrium solution must be dynamically stable, and disturbances must decay on scales which are faster than the large-scale evolution time scale. A small-enough cloud area fraction and a fast-enough turbulent kinetic energy dissipation time scale are shown to be necessary and sufficient for the stability of the quasi-equilibrium solution, while time scale-separation of convection paradoxically requires the reverse. Using both the original formulation of Arakawa & Schubert (Interaction of a cumulus cloud ensemble with the large-scale environment, J. Atmos. Sci., 31 (3), 1974) and an extended version that includes shallower cloud types, validity of the quasi-equilibrium assumption is tested. The quasi-equilibrium assumption is shown to be valid within only a small range of parameter regimes, owing to cloud-cloud coupling and the progressive transition from shallow to deep convection. Parameter values taken from the literature yield a dynamically stable quasi-equilibrium whose daily or even weekly convective adjustment time scales are too slow to justify the quasi-equilibrium assumption. Diagnostic quasi-equilibrium closures (or simple relaxations thereof) therefore cannot be dynamically valid in general. Prognostic convection closures which take into account the effects of subgrid variability due to convective processes are therefore needed.

Scott MacLachlan, Memorial University of Newfoundland

[Wednesday, June 17; 10:00 am, ED 191]

Finite element simulations of smectic liquid crystal films

Smectic liquid crystals are a paradigmatic example of a layered fluid that form an ideal testbed to verify, through physical experiments and numerical simulations, predictions from theoretical models. Like all liquid crystalline phases, they have the ability to easily form topological defects that can be manipulated by surface patterning to produce optically active materials. Understanding and controlling the formation of these defects, however, is complicated by the lack of direct measurements of their state in films that are typically only few hundred nanometers thick. In this talk, I will present our work on developing a finite-element simulation framework for thin films of smectic liquid crystals and its relation to recent experimental data.

Mikael Mahfouz, McGill University

[Thursday, June 18; 10:00 am, CL 125]

Numerical Investigation of the Scalar Fields Downstream of Two Concentrated Sources in Turbulent Channel Flow

The effect of initial scalar field symmetry in turbulent mixing remains incompletely understood yet has direct relevance to applications ranging from pollutant dispersion to industrial chemical processing. In this talk, we present the results of Direct Numerical Simulations (DNSs) of passive scalar mixing downstream of two concentrated line sources in fully developed turbulent channel flow at a friction Reynolds number of $\mathrm{Re}\tau = 190$. Two configurations are compared: a symmetric case with two identical scalar sources, and an antisymmetric case pairing a source with a sink of equal magnitude. Results show that the symmetry of the initial scalar conditions has an important influence on mixing efficiency. The antisymmetric configuration demonstrates enhanced mixing, achieving approximately an order of magnitude lower unmixedness at the channel centerline by the end of the domain, compared to the symmetric case. We attribute this increased mixing to stronger scalar gradients near the injection plane in the antisymmetric configuration. This intensifies scalar variance production and accelerates its subsequent decay. These trends are quantified through normalized RMS temperature fluctuations and the unmixedness parameter. These findings highlight the importance of the scalar field initial conditions in determining turbulent mixing dynamics and provide insight relevant to applications such as pollutant dispersion and chemically reacting flows.

Giusy Mazzone, Queen's University

[Wednesday, June 17; 11:30 am, ED 191]

Motions of a viscous fluid with a prescribed flow rate

We consider the flow of a viscous incompressible fluid subject to a prescribed flow rate in domains with boundaries. Objective of our work is to determine whether and to which extent the presence of boundaries influences the motion of the fluid. This study is motivated by some fluid-solid interaction problems arising in the design of energy harvesting systems.

Tristan Montoya, University of Saskatchewan

[Thursday, June 18; 3:30 pm, CL 125]

Actor-based orchestration for heterogeneous simulation workflows

Large-scale parallel computing workflows for fluid dynamics and related scientific and engineering applications require efficient and fault-tolerant orchestration of many simulation tasks across available computational resources. The actor model of concurrent computation provides a flexible paradigm for such orchestration, wherein tasks are executed by independent actors that communicate through asynchronous message passing. This talk discusses the design and development of a software framework that coordinates the execution of simulation tasks within multi-component scientific computing workflows. Its implementation employs the C++ Actor Framework (CAF) for task scheduling, message passing, and failure handling, together with a dynamic plugin system compatible with the Basic Model Interface (BMI), enabling interoperability across different simulation tools, components, and programming languages. We demonstrate the cross-discipline applicability of the proposed framework and assess resource utilization during workflow execution through case studies involving hydrologic simulations across multiple independent catchment domains and ensembles of high-order computational fluid dynamics simulations.

This talk is based on joint work with Raymond Spiteri.

Diego Peña Palma , University of Victoria

[Wednesday, June 17; 10:30 am, ED 191]

GPU Accelerated Bayesian Inference for Stochastic Multicloud Models

The Stochastic Multicloud Model (SMCM) is an important method for representing the missing variability in general circulation models (GCMs) due to unresolved features of organized tropical convection. While the SMCM improves the simulation of climate phenomena, its effectiveness depends on the calibration of cloud convective timescales from observational data. In De La Chevrotière et al., 2014, the calibration problem is formulated within a Bayesian context to derive posterior distributions over these parameters. The computational bottleneck lies in evaluating the likelihood function, which requires solving a large system of Kolmogorov differential equations for every data point in a time series. In the original implementation, even with parallelization combined with efficient algorithms for sparse matrix exponentials such as the uniformization or Krylov subspace methods, using the PETSc suite on CPU clusters, memory and processing requirements become prohibitive for large scale applications. This talk presents an acceleration of the SMCM calibration by transitioning both the uni- formization method and Krylov subspace methods to GPU architectures. By leveraging GPU optimized sparse matrix-vector operations to speedup the linear algebra operations, the Bayesian technique will be applied to a variety of observations and numerical simulation data of clouds and rain types, to obtain a compressive coverage of varying convection regimes over all possible climatic conditions over land and oceans, and from the tropics to high-latitudes.

Francis Poulin, University of Waterloo

[Monday, June 15; 11:00 am, CK 185]

Stability in the Beaufort Gyre

The Beaufort Gyre (BG) is the Arctic Ocean's largest freshwater reservoir, and its stability has important implications for halocline structure, freshwater storage, and the Arctic climate system. To assess the role of intrinsic dynamics in controlling BG variability, we begin by examining an idealized barotropic representation of the gyre using quasi-geostrophic theory and nonlinear numerical simulations. These analyses show unequivocally that barotropic instability cannot meaningfully occur in the Beaufort region: predicted growth rates are extremely weak, and the most unstable wavelengths are far larger than the gyre itself. The excellent agreement between linear theory and fully nonlinear simulations reinforces this conclusion and demonstrates that barotropic processes cannot generate mesoscale variability or contribute to the observed eddy field within the gyre.

Because the barotropic pathway is dynamically closed, we also explore an idealized baroclinic Beaufort Gyre to assess whether vertical structure might support more realistic instabilities. Preliminary simulations indicate that baroclinic modes grow more rapidly and have unstable wavelengths that can fit within the gyre, suggesting that baroclinic instability may be a viable mechanism for eddy generation. However, these early findings remain tentative and require further theoretical and numerical refinement. Together, this combined theoretical–numerical framework will help clarify the role of baroclinic instability in regulating the evolving dynamics of the Beaufort Gyre in a rapidly changing Arctic.

Bartosz Protas, McMaster University

[Tuesday, June 16; 4:00 pm, ED 191]

Searching for Singularities in Navier-Stokes and Euler Flows Using Variational Optimization Methods

This investigation concerns a systematic computational search for potentially singular behavior in 3D Navier-Stokes and Euler flows. In the former case, the enstrophy $\mathcal{E}(t)$ serves as a convenient indicator of the regularity of solutions — as long as this quantity remains finite, the solutions are guaranteed to be smooth and satisfy the equations in the classical sense. Another well-known conditional regularity result are the Ladyzhenskaya-Prodi-Serrin conditions stating that the quantity $\mathcal{L}_{q,p} := \int_0^T \|\mathbf{u}(t)\|_{L^q(\Omega)}^p \, dt$, where $2/p + 3/q \leq 1$, $q > 3$, must remain bounded if the solution is smooth on the interval $[0, T]$. In the case of the Euler flows, Kato's theorem asserts local existence of smooth solutions in the Sobolev space H^m, $m > 5/2$. However, there are no a priori bounds on these quantities valid for arbitrarily long times and hence the global regularity problem for both the 3D Navier-Stokes and Euler system remains open. To quantify the maximum possible growth of these quantities, which quantify the regularity of solutions, we consider families of variational PDE optimization problems in which initial conditions are sought subject to certain constraints so that these quantities in the resulting Navier-Stokes or Euler flows are maximized. These problems are solved computationally using a large-scale adjoint-based gradient approach. By solving these problems for a broad range of parameter values we demonstrate that in the Navier-Stokes flows the maximum growth of $\mathcal{E}(T)$ and $\mathcal{L}_{q,p}$ appears finite. Thus, even in such worst-case scenarios, the two quantities remain bounded for all times and there is no evidence for singularity formation. On the other hand, the behavior of the extreme Euler flows found by maximizing their H^3 norm at a sufficiently long time T is consistent with the possibility of singularity formation.

Elham Rezazadeh, Carleton University

[Tuesday, June 16; 11:00 am, ED 191]

Resonant Waves in a Rectangular Tank with Periodic Bottom Topography

Resonance is a fundamental phenomenon that manifests across both natural and engineered systems, from earthquakes amplifying structural vibrations in buildings to mechanical oscillations in engines. While previous research has examined resonant forcing in rectangular tanks and the evolution of periodic long surface waves over bottom topography in unbounded domains, the influence of periodic bottom configurations on free surface evolution in bounded domains remains incompletely understood. In this talk, we will investigate the interplay between periodic bottom topography and resonantly forced oscillations of fluid in a shallow rectangular tank of finite length. Beginning from the governing equations for an inviscid fluid, we will outline how perturbation methods and multiple-scale techniques yield a forced evolution equation that captures the combined influence of the finite geometry, the oscillatory forcing, and the variable bottom topography. We will then present numerical results obtained from this model and describe how the topography affects the resonant response.

Manuel O. Sandoval, Concordia University

[Thursday, June 18; 10:30 am, CL 125]

Data-Driven Reduced-Order Modeling of the Unsteady Wake Dynamics of Unequal-Height Tandem Finite Wall-Mounted Cylinders

This study presents a data-driven reduced-order model (ROM) for the unsteady wake dynamics of finite wall-mounted cylinders (FMWCs) in single (SC) and tandem configuration (TC). The SC had an aspect ratio AR=h/d=7.0, where h is the cylinder height and d the diameter, while the TC had an upstream cylinder (UC) with AR=5.3, partially sheltering a downstream cylinder (DC) of AR=7.0, with spacing ratio s/d=4.0, where s is the center-to-center distance. Instantaneous flow fields were collected using time-resolved particle image velocimetry (TR-PIV) measurements from the symmetry plane and three horizontal planes, along the span of the FWMCs. Proper orthogonal decomposition (POD) was used for dimensionality reduction, with the selected first 200 POD modes capturing 60-80% of the total turbulent kinetic energy. Long short-term memory (LSTM) and bidirectional LSTM (BLSTM) recurrent neural networks were used for learning and predicting temporal coefficients grouped by 10 consecutive modes, lowering the required trained networks. Transfer learning (TL) was implemented from the mid-height to the horizontal planes near the wall and free end, reducing the computational training cost and the prediction error. Both LSTM and BLSTM accurately predicted the POD temporal coefficients with minimal error in the ROM reconstructed instantaneous and time-averaged flow fields, increasing root-mean-square errors of the coefficient predictions for higher-order modes, and higher reconstruction errors for TC compared to SC. The LSTM exhibited marginally larger errors, especially for TC regions associated with higher-order modes with localized smaller-scale turbulent structures, although the computational cost was nearly half of BLSTM.

Manuel O. Sandoval and Ebenezer E. Essel, Concordia University

[Thursday, June 18; 11:00 am, CL 125]

Influence of Cross-Sectional Aspect Ratio on the Unsteady Wake of Finite Wall-Mounted Rectangular Cylinders in a Thick Turbulent Boundary Layer

This study examines the influence of cross-sectional aspect ratio (CR) on the unsteady wake dynamics of rectangular finite wall-mounted cylinders (FWMCs) in a thick turbulent boundary layer (TBL), using improved delayed detached eddy simulations (IDDES). Five different test cases ($CR = l/d = 1.0, 2.0, 2.5, 3.0$, and 4.0) were simulated by varying the cylinder streamwise length, l, while the width, d, height, h, and TBL thickness, δ, were fixed, yielding a height-aspect ratio, $h/d = 7.0$, Reynolds number based on d, $Re = 5540$, and TBL submergence ratio, $\delta/h = 1.2$. The thick TBL promoted earlier reattachment of the separated shear layers and significantly reduced the mean drag while increasing lift for $CR \geq 2.5$ compared to a uniform flow or thin TBL. Over the free end, increasing CR resulted in mean reattachment for $CR \geq 2.0$, with the reattachment length becoming independent of CR for $CR \geq 2.5$, and intensified turbulent kinetic energy due to an earlier onset of Kelvin-Helmholtz instabilities. Except for the unattached case ($CR = 1.0$), lower Strouhal numbers near the base, weak broadband frequencies near mid-height, and higher Strouhal numbers near free end indicated a cellular shedding pattern. The thick TBL strengthened the base vortices, resulting in a quadrupole wake structure for $CR = 1.0$ that transitioned to a dipole wake structure for $CR = 2.0$ and 2.5, and a no-pole wake structure for $CR \geq 3.0$. The wake transition was accompanied by a shift from alternating von Kármán vortex shedding to symmetric shedding and a reduced reverse-flow area and pumping intensity behind the cylinder.

Bharat Shamsukha, University of Waterloo

[Monday, June 15; 3:00 pm, ED 191]

The Enstrophy Budget in the Convective Boundary Layer

Turbulence, the phenomena of random and chaotic fluid motion over a wide range of length scales, is a key property of the Earth's atmosphere. Turbulence acts to cascade kinetic energy from its generation at large scales, down to its dissipation at small scales. However, turbulence is hard to reproduce in numerical models of the atmosphere due to its effects at all scales. We present a study of the mean square vorticity, or enstrophy, to investigate the physical mechanisms driving this cascade within the Earth's convective boundary layer (CBL). Analysis of turbulence in the CBL is necessary to better understanding the formation of eddies and weather phenomena in the lowest layer of the atmosphere and also to understand how turbulence is represented numerically. The Weather Research and Forecasting Model (WRF) is used to perform large eddy simulation of an idealized CBL. We simulate a rectangular prism with periodic boundary conditions, heated by a mean constant temperature flux at the surface, in order to mimic the solar heating of the Earth's surface. Then, we calculate the terms in the enstrophy budget to investigate the roles of vortex stretching, baroclinic vorticity generation and eddy viscosity in the energy cascade. With thorough analysis of this idealization, we present our findings on the enstrophy budget in the boundary layer to better understand the physical mechanisms at work in atmospheric turbulence.

Alexey Shevyakov, University of Saskatchewan

[Tuesday, June 16; 11:30 am, ED 191]

Exact spherical vortex-type equilibrium flows in fluids and plasmas

Hill's classical spherical vortex solution is re-derived using Galilei symmetry and the Bragg–Hawthorne equations in spherical coordinates. The well-known correspondence between equilibrium Euler equations and static magnetohydrodynamic equations is then exploited to construct a generalized vortex-type solution corresponding to both dynamic fluid equilibria and static plasma equilibria with a nonzero azimuthal vector field component, satisfying physical boundary conditions. Separation of variables in the Bragg-Hawthorne equation yields further new families of fluid and plasma equilibria with nested toroidal flux surfaces, featuring boundary vorticity sheets and current sheets respectively. The instability of the original Hill's vortex under certain radial perturbations of the spherical flux surface is proven analytically and illustrated numerically. This work is joint with Jason Keller.

Marek Stastna , University ofWaterloo

[Monday, June 15; 10:00 am, CK 185]

Super exponential instability of radiatively driven convection

Classical hydrodynamic instability considers how perturbations to a given state of fluid flow grow or decay. In normal mode analysis, the background flow is typically assumed to be steady and the perturbations are assumed to be a complex exponential. In the late winter/early spring many Canadian lakes remain ice covered and below the temperature of maximum density. At the same time, the increased strength of solar radiation drives under ice convection. Since the ice eventually melts, and the lake stratifies the underlying process has an inherent secular component. We consider several formulations of the instability problem, and demonstrate that properly accounting for the changing background state yields perturbations that grow super-exponentially. In some cases, this yields a semi-analytical solution using the classical Airy equation. We generalize to increasingly more realistic situations, implementing novel numerical solutions along the way, and demonstrate that the super-exponential result remains robust. It thus appears that snapshot based stability analyses of this situation could under-estimate under-ice convection.

Minisymposium #10 – Mathematical Methods for Quantum Information and Quantum Technologies.

Madeline Berezowski, University of Saskatchewan

[Friday, June 19; 10:00 am, CL 128]

Spectral Analysis of Generalized Bosons

Ray operators are a certain type of linear operator. Sums of constant ray operators are unitarily equivalent to a multiplication operator followed by projection. This is analogous to the well-known Toeplitz operators, which are also unitarily equivalent to multiplication-then-projection operators. The spectra of Toeplitz operators are related to the operator's symbol function and can be nicely approximated by finite dimensional Toeplitz matrices via a concept known as the pseudospectrum. While radially constant operators are not amenable to pseudospectral techniques, approximate eigenvalues can be used effectively. We have found the spectrum for certain radially constant operators, which are related to their own symbol functions. Interpreting these operators as sums of generalized bosonic ladder operators in the number theoretic Bose-Hubbard model allows for deeper insight into the spectrum. This talk represents work done in collaboration with Artur Sowa (University of Saskatchewan).

Rainer Dick, University of Saskatchewan

[Thursday, June 18; 3:00 pm, CL 128]

The role of quantum foundations and scattering in quantum technology

The development and deployment of second-generation quantum devices reinvigorates research in quantum foundations from a genuine practical perspective. Superpositions of spin states in magnetic fields, or superpositions of oscillator eigenstates in oscillating systems, can correspond to actual quasi-classical evolution of the system or to Schrödinger-cat-like states. We examine the importance of elastic versus inelastic scattering channels for the creation of quasi-classical states or Schrödinger-cat states. We also point out that inelastic scattering yields dynamic quantum state collapse within canonical quantum theory. This is afforded through the convolution of initial states of the probed system with localized detector states.

Robert Green, University of Saskatchewan

[Thursday, June 18; 3:30 pm, CL 128]

Many-Body Operator Methods for Quantum Spectroscopy: Krylov Subspace Approaches to Spectral Functions

Spectroscopic experiments on quantum materials probe dynamical properties that are naturally expressed as correlation functions of interacting many-body systems. In this talk, I will present an operator-based framework for computing such spectra, in which experimentally measured intensities are formulated as spectral measures associated with many-body Hamiltonians. This perspective recasts spectroscopy as the evaluation of matrix elements of resolvents of large, sparse operators acting on exponentially large Hilbert spaces.

I will discuss practical implementations based on cluster Hamiltonians relevant to transition metal systems, emphasizing the structure of the underlying operator algebra and the role of basis transformations in capturing hybridization and local interactions. From a computational standpoint, I will focus on Krylov subspace methods, including Lanczos recursion and continued fraction expansions, which enable efficient approximation of spectral functions without full diagonalization.

Particular attention will be given to how interaction terms transform under changes of basis, and how this impacts both the numerical stability and physical interpretation of the resulting spectra. These considerations highlight broader mathematical challenges, including the representation of operators in high-dimensional spaces and the extraction of physically meaningful spectral features from approximate numerical data.

Nathaniel Johnston, Mount Allison University

[Thursday, June 18; 11:00 am, CL 128]

Approximating quantum states by states of low rank

Given a positive integer k, it is natural to ask for a formula for the distance between a given density matrix (i.e., mixed quantum state) and the set of density matrices of rank at most k. This problem has already been solved when "distance" is measured in the trace or Frobenius norm. We solve it for all other unitary similarity invariant norms. We also present some consequences of our formula. For example, in the trace and Frobenius norms, the density matrix that is farthest from the set of low-rank density matrices is the maximally-mixed state, but this is not true in many other unitary similarity invariant norms.

Hermie Monterde, University of Regina

[Thursday, June 18; 4:00 pm, CL 128 (virtual)]

Open problems on continuous quantum walks

Over the past two decades, there has been a surge of research work on the topic of quantum walks, which are mathematical objects that describe the propagation of quantum states in graphs represented by a quantum spin networks. In this talk, we survey the state of the art in the area and present some interesting open problems.

Connor Paddock, University of Calgary

[Thursday, June 18; 11:30 am, CL 128]

Undecidability, entanglement, and values of nonlocal games

Determining the power of multiprover interactive proofs led to many revelations in theoretical computer science, such as the PCP theorem and are connected to fundamental open problems like the unique games conjecture. In the quantum setting, we now know that provers sharing entanglement in interactive proofs have unfathomable computational power, MIP*=RE. On the other hand, the quantum value for unique games can be well approximated using semi-definite programming. These divergences between the classical and the entangled theory of MIPs suggest why a quantum PCP theorem remains so elusive, and that we still understand little of what makes entanglement so powerful computationally. Towards these broader goals, a number of recent works suggest when the quantum and classical theories are consistent, and when they appear to be at odds. In this talk, I will discuss them alongside some of own results in this area, and future directions.

Sarah Plosker, Brandon University

[Friday, June 19; 10:30 am, CL 128]

The quasiorthogonality measure of commutative algebras

Two unital $*$-subalgebras $\mathcal{A}$ and $\mathcal{B}$ of M_n cannot be orthogonal since they both contain the identity. However, they can be thought of as *quasi*-orthogonal in a natural way: if $\mathcal{A}\cap\{I\}^\perp$ and $\mathcal{B}\cap\{I\}^\perp$ are orthogonal in the trace inner product. This motivates several equivalent formal definitions of quasiorthogonality. We establish a connection between the quasiorthogonality of commutative algebras and complex Hadamard matrices. We build on this connection by introducing the notion of a 'quasiable' matrix, which allows us to derive a new matrix-theoretic technique to compute the quasiorthogonality measure between pairs of commutative algebras. This approach can be extended to the general non-commutative case. This is joint work with Sooyeong Kim, David Kribs, Edison Lozano, and Rajesh Pereira.

Steven Rayan, Centre for Quantum Topology and Its Applications (quanTA) / Department of Mathematics and Statistics, University of Saskatchewan

[Thursday, June 18; 10:00 am, CL 128]

Quantum Computing in Negative Curvature

I will present a number of mathematical and experimental results in which I have been involved over the past seven years where quantum computing is deployed in systems that display some form of negative curvature. This deployment captures the features of currently-available noisy intermediate scale quantum (NISQ) devices, including gate synthesis and entanglement on physical lattices, but also features continuous variable modalities and advanced error correction that are not normally part of, say, superconducting setups. As such, I will situate these developments in the framework of the pursuit of fault-tolerant, scalable quantum computing.

Artur Sowa, University of Saskatchewan

[Thursday, June 18; 10:30 am, CL 128]

Geometric and Exogeometric Architectures for Qubit, Fermion, and Boson Sites

I will discuss arrays of bosonic, fermionic, and qubit sites from the standpoint of harmonic analysis. As is well known, qubits and fermions admit a common description via the Jordan–Wigner transform. Recent work has further developed geometric models of such systems, formulated in terms of the metric structure on the unit interval, with its natural coordinate and dyadic scales.

In contrast, arrays of bosonic sites are naturally situated within analytic number theory, with structures governed by Dirichlet series. These systems do not admit a geometrization comparable to that of their qubit and fermionic counterparts, and appear to rely on fundamentally different organizing principles.

I will present an approach that places these systems within a common exogeometric framework, in which bosonic and qubit/fermionic structures can be compared and related. The scope of this perspective will be illustrated through several recent results obtained in collaboration with physicists and mathematicians.

In many respects, comparisons between qubits and fermions on one side and bosons on the other resemble comparisons between cats and dogs. Long story short, I will show that there are mathematical arrangements that allow fermionic cats to sit on bosonic dogs' mats.

Minisymposium #11 – Theoretical Approaches to Computational Problems with Applications in Discrete Mathematics.

Jane Breen, Ontario Tech University

[Friday, June 19; 11:30 am, CL 110 (virtual)]

Perturbation formulas for Kemeny's constant

Kemeny's constant is an interesting and useful quantifier describing the global average behaviour of a Markov chain. A natural question is to determine the sensitivity of Kemeny's constant to perturbations in the transition probabilities. While originally motivated by the computational problem of developing a condition number for Kemeny's constant, the theoretical approaches developed in this context may also provide insight into determining the most influential transitions in a Markov chain, and highlighting the role of the combinatorial structure of the transition matrix in the mixing properties of the Markov chain.

Ada Chan, York University

[Friday, June 19; 11:00 am, CL 110 (virtual)]

Continuous-time quantum walk on cycles

The transition matrix of the continuous-time quantum walk on X with Hamiltonian H is e^{itH}, where H is a Hermitian matrix associated with a graph X. In existing literature, the adjacency matrix and the Laplacian matrix of X are the most commonly used Hamiltonians, where only the interactions between adjacent vertices are modeled.

In this talk, we consider the natural embedding of the cycle C_n as a regular polygon in $\mathbb{R}^2$ and model the interaction of two vertices based on their Euclidean distance in the embedding. We compare the behaviours of the quantum walks on C_n using different Hamiltonians.

Homer Franz De Vera, University of Manitoba

[Thursday, June 18; 3:30 pm, CL 126]

Computing minimum possible Kemeny's constant for a given partial stochastic matrix using sparse matrices

A finite, discrete-time, time-homogeneous Markov chain on n states may be studied in terms of its matrix of transition probabilities T which is an $n \times n$ matrix indexed by the n states and whose (i, j)-entry is the probability for the chain to transition from state i to state j. An irreducible Markov chain gives rise to Kemeny's constant $\mathcal{K}(T)$, a value that counts the expected number of time-steps from a random initial state to a random destination state. As such, Kemeny's constant may be taken as a measure of the average travel time between the states of a Markov chain or average travel time in a network if the chain is viewed as a random walk on a graph. For example, Kemeny's constant has been used to analyze road traffic networks, epidemic spread modelling, etc.

Kemeny's constant $\mathcal{K}(T)$ may be computed entirely from the eigenvalues of T. More precisely, $\mathcal{K}(T) = \sum_{j=2}^{n} \frac{1}{1-\lambda_j}$ where $1 = \lambda_1, \lambda_2, \ldots, \lambda_n$ are the eigenvalues of T. Suppose we have a *partial stochastic matrix* P where some entries are specified and the rest are unspecified, and such that there exists a *completion*, i.e., a choice of values for the unspecified entries so that the resulting matrix is stochastic. We compute the minimum possible Kemeny's constant among the set of completions using the previously established result that the minimum is attained by a completion which is as sparse as possible, that is, in every row of the partial stochastic matrix, at most one unspecified entry is chosen to be nonzero in the completion. In particular, we investigate the case when P is a partial stochastic matrix such that the entries in one single column are specified while the rest are unspecified. This is a work in progress with Steve Kirkland.

Neha Joshi, Arizona State University

[Wednesday, June 17; 10:30 am, EA 106.1 (virtual)]

Feasible Fusions in Association Schemes

Association schemes provide highly structured algebraic frameworks for describing similarity and relationships within discrete systems. A central problem in this area is the study of feasible fusions, which simplify relational structures while preserving their essential algebraic properties. My doctoral research focused on feasible fusions of Johnson and generalized Hamming schemes.

In this talk, I will introduce the basic ideas behind association schemes and fusion schemes, discuss examples from my research, and explore connections to clustering, network compression, spectral methods, and graph-based learning. I will also briefly discuss how similar ideas arise in my current work, where students in mathematics, computer science, and data science investigate methods for organizing and compressing large-scale data while preserving meaningful structure. These connections illustrate how concepts developed in algebraic combinatorics can provide useful perspectives on modern computational challenges.

Kamyar Khodamoradi , University of Regina

[Thursday, June 18; 3:00 pm, CL 126 (virtual)]

The Computational Complexity of Almost Stable Clustering with Penalties

We investigate the complexity of stable (or perturbation-resilient) instances of k-Means and k-Median clustering problems in metrics with small doubling dimension (these metrics include Euclidean spaces of constant dimension). While these problems have been extensively studied under multiplicative perturbation resilience in low-dimensional Euclidean spaces (e.g., by (Friggstad et al., 2019)), we adopt a more general notion of stability, termed "almost stable', introduced by Balcan et al. in 2016 as (α, ε) -perturbation resilience. Additionally, we extend our results to k-Means and k-Median with penalties, where each data point is either assigned to a cluster centre or incurs a penalty.

We show that certain special cases of almost stable k-Means and k-Median (with penalties) are solvable in polynomial time. To complement this, we also examine the hardness of almost stable instances and $(1 + 1/poly(n))$-stable instances of k-Means and k-Median(with penalties), proving super-polynomial lower bounds on the runtime of any exact algorithm under the widely believed Exponential Time Hypothesis (ETH).

Adrian Lee, University of Guelph

[Wednesday, June 18; 11:00 am, EA 106.1]

A report on the results of the ongoing investigation of the Weak Closure Algorithm (WCA)

The non-Hamiltonian cycle decision problem is co-NP complete for which the existence of a polynomial time algorithm is unknown. In 2017, Gismondi and Lee developed a heuristic algorithm (O(n8)) called the weak closure algorithm (WCA) that investigated this problem using a total of 461 snarks that are known to be non-Hamiltonian. This algorithm successfully decided these snarks to be non-Hamiltonian. In this presentation, a follow up report of an ongoing investigation of the WCA testing a total of 459,986 3-regular graphs with vertex counts ranging from 4 to 18; and also 153,000 out of 510,489 3-regular graphs with 20 vertices is presented. All non-Hamiltonian graphs were verified non-Hamiltonian, and, no Hamiltonian graph was decided non-Hamiltonian (Hamiltonian graphs cause the WCA to exit Undecided) via Maple 2023. All tested graphs were generated by GENREG, an open-source software developed by Meringer in 1999.

Hermie Monterde, University of Regina

[Wednesday, June 18; 10:00 am, EA 106.1 (virtual)]

Threshold graphs with simple eigenbases

A graph has a simple eigenbasis if its associated Laplacian matrix has an eigenbasis consisting of vectors with entries from the set $\{-1, 0, 1\}$. Matrices with structurally simple eigenbases are known to present significant computational advantages and offer a more straightforward eigenvector analysis. Consequently, graphs with simple eigenbases are interesting from a computational point of view. In this talk, we discuss threshold graphs with simple eigenbases. This is joint work with Leonardo de Lima, Renata Del-Vecchio, and Heber Teixeira.

Valerii Maliuk, University of Regina

[Thursday, June 18; 4:00 pm, CL 126]

Computing the q-Analogue of Zero Forcing for Specific Classes of Trees

The q-analogue of certain conventional zero forcing parameters is an important graph parameter (relating to certain propagation-type colorings of vertices in a graph) that is not well understood in general. In this paper, we establish additional results on the computation of q-analogue zero forcing numbers for trees, paying particular attention to caterpillar trees and the development of algorithmic strategies for producing optimal related colorings for such trees and an extension to binary trees. In addition, we provide a useful general result for the q-analogue zero forcing number of a tree and a related bound for general graphs.

Johnna Parenteau, University of Regina

[Wednesday, June 17; 11:30 am, EA 106.1]

An Inverse Strictly Interlaced Spectral Data Problem for Graphs

Given two sequences $\{\lambda_1, \lambda_2, \ldots, \lambda_n\}$ and $\{\mu_1, \mu_2, \ldots, \mu_{n-1}\}$;, it is well known for any tree, there exists a matrix $A \in S(G)$ and a vertex v, so that $\lambda_1 < \mu_1 < \lambda_2 < \mu_2 < \cdots < \cdots < \mu_{n-1} < \lambda_n$. This result was later extended to all connected graphs using the Implicit Function Theorem by Monfared and Shader. In this talk, we prove an analogous result for hollow matrices.

Mahsa Nasrollahi Shirazi, University of Winnipeg

[Friday, June 19; 10:30 am, CL 110]

Erdős-Ko-Rado Type Problems for Perfect Matchings and Partitions

Many problems in extremal combinatorics ask for the largest family of discrete objects satisfying a prescribed intersection condition. Classical results such as the Erdős-Ko-Rado theorem show that extremal families often have a highly structured "star" form.

In this talk, I will discuss several intersection problems involving perfect matchings and uniform set partitions, including recent results on the size and structure of largest intersecting families. I will describe a common framework based on graph reformulations, spectral methods, and symmetry techniques such as equitable partitions and quotient graphs. I will also discuss recent work on the robustness of these extremal structures under random perturbations.

Sandra Zilles, University of Regina

[Friday, June 19; 10:00 am, CL 110]

Learning from contrastive examples

Machine learning can greatly benefit from providing learning algorithms with pairs of contrastive training examples - typically pairs of instances that differ only slightly, yet have different class labels. Intuitively, the difference in the instances serves as a means of explaining the difference in the class labels. This presentation proposes a theoretical framework in which the effect of various types of contrastive examples on learning is studied formally. The focus is on the sample complexity of learning concept classes and how it is influenced by the choice of contrastive examples. We illustrate our results with geometric concept classes and classes of Boolean functions.

Minisymposium #12 – Financial and Actuarial Mathematics: Theory and Applications.

Alexander Alvarez, University of Prince Edward Island

[Thursday, June 18; 4:00 pm, CL 127]

From Pricing to Causality: A Structural Bridge via Discrete-Time Markets

Discrete-time financial models are used to price uncertain payoffs under structural constraints using tools such as dynamic programming and no-arbitrage conditions. This talk presents a parallel framework for causal inference, where the goal is to evaluate the effect of interventions under partial identification. We show that interventional quantities can be viewed as prices of contingent claims, while confounding in causal models plays the role of market incompleteness. In this setting, bounds on causal effects arise naturally as superhedging and subhedging prices, and can be computed via a backward recursion analogous to that of discrete-time derivative pricing. The emphasis is on the structural connection itself, highlighting how familiar ideas from financial mathematics provide a new lens through which to view causal problems.

Mustafa Avci, Athabasca University

[Thursday, June 18; 3:30 pm, CL 127]

A Variable-Exponent Diffusion Framework Extending the Cox–Ingersoll–Ross Model

This work introduces a new stochastic model in which the diffusion coefficient incorporates a state dependent variable exponent function $p(\cdot)$, providing a flexible extension of the classical Cox–Ingersoll–Ross (CIR) framework widely used in volatility modeling. By allowing the diffusion behavior to adjust with the state of the process, the proposed model captures richer volatility dynamics than the traditional square root diffusion, enabling greater adaptability to empirical features observed in financial markets. We establish rigorous results on existence, uniqueness, and higher order moment properties of the solutions. Numerical experiments demonstrate the model's validity and computational efficiency. Finally, we present a detailed comparison of the model under both Ito and Stratonovich interpretations.

Alexandru Badescu, University of Calgary

[Thursday, June 18; 10:30 am, CL 127]

Option Pricing with Recurrent Variance Risk Aversion

This paper develops an option pricing framework that jointly fits returns, realized volatility, and option prices, while capturing the regime- and maturity-dependent shape of the pricing kernel. The framework is built around a variance-dependent stochastic discount factor in which the variance risk aversion coefficient is modelled by a recurrent neural network (RNN). Using S&P 500 index options, we show that the RNN-based specification substantially improves the cross-sectional fit relative to benchmarks, with the largest gains for deep out-of-the-money and short-maturity contracts. The implied pricing kernel exhibits pronounced time variation, becoming U-shaped during periods of market stress and displaying a downward-sloping term structure consistent with stronger pricing of short-horizon volatility risk. Outside periods of elevated market stress, however, it is typically inverted U-shaped for all but the shortest maturities.

Jean-François Bégin, Simon Fraser University

[Tuesday, June 16; 4:30 pm, ED 314]

Beyond volatility of volatility: Decomposing the informational content of VVIX

This study investigates the informational content of the VVIX, traditionally viewed as a proxy for the S&P 500 index's volatility of the volatility (VOV). We show that this interpretation is incomplete: the VVIX also embeds a long-run variance (LRV) component. To establish this result, we first demonstrate that regressions of squared VVIX on VOV proxies gain substantial explanatory power once LRV measures are incorporated. We then develop a tractable theoretical framework linking VVIX to three risk drivers—the instantaneous variance, LRV, and VOV—and show that the VVIX loads on both VOV and LRV. Our empirical analysis reveals that VVIX dynamics are dominated by LRV in calm markets, but by VOV during financial stress. We further show that these variance components explain option returns in distinct markets: S&P 500 index option straddles load on the instantaneous variance and LRV, while VIX option straddles load on the VOV. Taken together, our results redefine the role of the VVIX, establishing it as a measure of both VOV and LRV uncertainty, with important implications for how it should be read and used by finance practitioners.

This study is joint work with Étienne Bacon and Geneviève Gauthier.

Corina Birghila, University of Lethbridge

[Wednesday, June 17; 10:30 am, EA 106.2]

Portfolio selection with ambiguity aversion and model ambiguity

We study the mean-variance portfolio selection problem when both ambiguity attitude and model ambiguity of a decision maker are present. We consider an alpha-maxmin criterion that describes the mixture of ambiguity aversion and ambiguity seeking attitude of the decision maker. The uncertainty around the partial information about the underlying distribution of asset returns is captured by the Gelbrich ambiguity set, characterized by a reference mean and variance-covariance matrix. Extreme distributions in the ambiguity set associated with the minimal and maximal mean-variance portfolio values are obtained in closed form. Depending on the risk aversion coefficient alpha, the optimal portfolio can be obtained via convex programming or difference of convex functions programming. A numerical example illustrates the efficiency frontier of the portfolio and the sensitivity of the frontier to model uncertainty.

François-Michel Boire, University of Ottawa

[Tuesday, June 16; 3:30 pm, EA 314]

Modeling Systemic House Price Risk

Economists and policy makers have become increasingly aware of the role of house price risk in driving financial fragility. This paper develops a semiparametric framework to model and assess downside risk in the U.S. housing market. First, we use panel quantile regressions to capture heterogeneous effects of supply, demand, and non-fundamental factors across the distribution of state-level house price changes. Second, we estimate the quantile regression jointly with a copula-based structure to capture cross-state dependence. Finally, we construct a measure of systemic housing risk using a weighted composition of state-level price indices, allowing us to compare tail exposures and quantify cross-state contributions to aggregate risk.

Tahir Choulli, University of Alberta

[Thursday, June 18; 11:00 am, CL 127]

Novel Esscher Pricing Concepts for various Risks in Finance and Insurance

Our principal leitmotif herein lies in pricing various claims within an informational setting that covers both life insurance and finance. This framework is represented by the triplet (S, F, T). Herein F is the "public"" flow of information which is available overtime to all agents, S is the discounted price process of d-tradable assets, and T is an arbitrary random time whose occurrence might not be observable via F. This framework covers the credit risk theory setting where T represents the default time of a firm/client, the life insurance setting where T models the death time of an insured, and other areas of finance to cite a few. For the resulting stopped model (S^T, G), where G is the flow that contains $\mathbb{F}$ and makes T an observable random time when it occurs, we address the pricing problem using Esscher concept. Given that T brings various informational risks, certainly these risks cannot be priced by the classical Esscher pricing method even if T is subject to assumptions such as immersion. Besides the informational risks generated by the randomness of τ, there is risk intrinsic to the stocks' jump caused by the shock of T. Again, the classical Esscher fails somehow to deal with this risk even without any information discrepancy at all. This led us to rethought radically the concept of Esscher pricing, and introduce the second-order Esscher pricing notion for general continuous-time models to deal with the risks coming from assets' jumps. Then we introduce a novel Esscher notion to quantify the informational risks afterwards. The second-order Esscher extends the classical notion of Esscher that is used in finance and actuarial sciences. Besides this novel notion, our contributions herein is multifold. We characterize its second-order Esscher densities via pointwise equations using the statistical parametrization of the model under consideration. We show that the bounds of the Esscher stochastic pricing interval, Y^{inf}, Y^{up} , are solutions to two constrained reflected linear backward stochastic differential equations, or equivalently reflected BSDEs with singular non Lipschitz generator. Besides applying this second-order Esscher to risk management and show how the second order catch features that the classical Esscher fails to achieve, we show that the second-order allows us to quantify markets's fear/stress more accurately. Our informational Esscher pricing concept allows us to obtain explicit pricing formulas for several vulnerable complex claims, and quantify the prices for various informational risks.

This talk is based on the following joint works with Alla Elazkany (University of Alberta) and/or Michele Vanmaele (Ghent University, Belgium): 1. T. Choulli and Ella Elazkany (2026):

Novel Esscher (2026): Novel Esscher for informational risk and valuation of vulnerable claims. Preprint. 2. T. Choulli, Ella Elazkany and Michele Vanmale (2025): The second-order Esscher with applications: Risk management and fear quantification.Preprint. 3. T. Choulli, Ella Elazkany and Michele Vanmale (2025): The second-order Esscher martingale densities for continuous-time market models: Frontiers of Mathematical Finance, Vol. 6, 2025, pp. 16-66.

Dena Firoozi, University of Toronto

[Thursday, June 18; 3:00 pm, CL 127]

Infinite-Dimensional LQ Mean Field Games with Common Noise: Small and Arbitrary Finite Time Horizons

We extend the results of (Liu and Firoozi, 2025), which develops the theory of linear-quadratic (LQ) mean field games (MFGs) in Hilbert spaces, by incorporating a common noise. This common noise is modeled as an infinite-dimensional Wiener process affecting the dynamics of all agents. In the presence of common noise, the mean-field consistency condition is characterized by a system of coupled forward-backward stochastic evolution equations (FBSEEs) in Hilbert spaces, whereas, in its absence it is represented by coupled forward-backward deterministic evolution equations. We establish the existence and uniqueness of solutions to the coupled linear FBSEEs associated with the LQ MFG framework for small time horizons and prove the epsilon-Nash property of the resulting equilibrium strategy. Furthermore, we establish the well-posedness of these coupled linear FBSEEs for arbitrary finite time horizons. Beyond the specific context of MFGs, our analysis also yields a broader contribution by providing, to the best of our knowledge, the first well-posedness result for a class of infinite-dimensional linear FBSEEs, for which only mild solutions exist, over arbitrary finite time horizons.

Dongchen Li, York University

[Tuesday, June 16; 11:00 am, ED 314]

Screening via Investment Guarantees under Risk Attitude Heterogeneity

Investment contracts with partial guarantees, such as variable annuities, constitute a multi-trillion dollar market. From the perspective of a monopolistic seller, we attribute the emergence of such contracts to a previously unexplored endogenous driver: the strategic utilization of the guarantee level as a screening mechanism to maximize expected profits in the presence of asymmetric information regarding investor risk attitudes. We characterize the optimal menu of contracts in closed-form and identify the distribution of risk attitudes and the seller's relative screening costs as the key determinants of product design. Our results also provide an explanation for key stylized facts, including cross-country market gaps and the relative scarcity of the partial guarantee market compared to the bond and mutual fund sectors.

Mélina Mailhot, Concordia University

[Tuesday, June 16; 10:00 am, ED 314]

Nested Archimedean distorted copula for hail claim hazard in Alberta

The objective of this project is to provide return level maps for hail claim frequencies for the province of Alberta. A nested Archimedean copula model is used, with zero-inflated negative binomial GLM margins. Based on theoretical results related to the distortion of copulas, we are able to adapt the spatiotemporal model, which is compared to well-known models, such as INLA and models using spatiotemporal stochastic processes. Distorting multivariate distributions is a useful approach for introducing flexibility and capturing model uncertainty. In this presentation, we investigate the extremal domain of attraction problem for Morillas-type distorted copulas. We establish not only conditions under which such copula-to-copula transformations alter the respective asymptotic behaviour, but also discuss conditions under which the distorted copulas remain in the same domain of attraction as the initial undistorted copula. The application of such a model provides information on the evolution of time dependent locations and the relation with their climatic covariates. It turns out the methodology, using distorted copulas, outperforms existing techniques.

Traian Pirvu, McMaster University

[Wednesday, June 17; 11:00 am, EA 106.2]

Calibration of Spread Option Pricing with Liquidity Impact

This works implements a calibration procedure for pricing spread options with liquidity risk. The pricing methodology developed in Pirvu and Zhang (2024) is employed. The calibration procedure is based on nonlinear regression. This method provides close estimations of model parameters using synthetic market data. Our calibration results reveal that more volatile market data leads to higher liquidity impact parameters

Mark Reesor, Wilfrid Laurier University

[Thursday, June 18; 10:00 am, CL 127]

Integrating Climate Risk into Legacy Credit Risk Models

Banks have devoted significant resources into the development and implementation of their existing or legacy portfolio credit risk (PCR) models. We propose a method to integrate climate risk into legacy credit risk models that i) provides simple modification(s) of existing models; ii) results in intuitive, interpretable adjustment(s); iii) uses the original legacy PCR model parameters (e.g., factor loadings and default correlation); iv) enables model calibration in an easily-communicated fashion; v) facilitates sensitivity analysis to climate risk factors, allowing for risk attribution; and vi) allows for a wide variety of adjustments.

The proposed method re-weights the distribution(s) of some account-level components of legacy PCR models using distortion functions. We show that our framework includes the methodology proposed by the United Nations Environment Program (UNEP) Financial Initiative (FI) and the Bank of Canada-Office of the Superintendent of Financial Institutions (BoC-OSFI). Using the 1-factor threshold model as an example, we explore the distorted models' properties at both the account and portfolio levels and calibrate a distorted model to a set of climate scenarios.

This is joint work with W. Mnif, M. Drmac, and A. Zeldenrijk

David Saunders, University of Waterloo

[Wednesday, June 17; 10:00 am, EA 106.2]

Equilibrium Exploratory Optimal Stopping with Non-Exponential Discounting

We consider a continuous-time reinforcement learning approach to the problem of optimal stopping of a diffusion process with non-exponential discounting. We study an equilibrium approach to this time-inconsistent problem, and compare the solutions (stopping regions and stopping policies) derived from a time-consistent setting with exponential discounting and a time-inconsistent setting with non-exponential discounting. An algorithm to learn the optimal stopping policy is also presented, together with examples on the pricing of American options. This is joint work with Yuling Chen and Bin Li from the University of Waterloo.

Clarence Simard, Université du Québec à Montréal

[Wednesday, June 17; 11:30 am, EA 106.2]

A simple approach to the Løkka-Zervos dichotomy for absolutely continuous dividend strategies

We consider a dividend maximization problem that incorporates a penalty for ruin and the possibility of injecting capital. Under an arithmetic Brownian model, we analyze dividend strategies constrained to be absolutely continuous and linearly bounded by the surplus. We demonstrate that the resulting value function exhibits a structural property which provides a clear view of the dichotomous quality of the optimal strategy.

Lars Stentoft, Western University

[Tuesday, June 16; 3:00 pm, ED 314]

In estimation, the key is the volatility index, not the returns

This paper proposes a new methodology to estimate a subclass of square-root stochastic autoregressive volatility (SR-SARV) models using volatility index (vli) and returns data. The approach, denoted A-C-VIX-Ret, is based on fitting the vli via a M-estimator, while approximating returns; and it is shown to be vastly superior to the standard approach of fitting returns via likelihood with an approximation on the vli, denoted A-Ret-VIX. We focus on SR-SARV(1) models with a Chi-square, 1 df distribution for the conditional variance, as this accommodates most GARCH models in the literature. This type of models leads to infinite likelihood for infinitely many points, hence an ill-posed likelihood, a problem our approach overcomes while ensuring consistency. Our main focus is on the HN-GARCH of Heston & Nandi (2000), and the time series of S&P 500 Index returns and VIX data from CBOE. Our analyses demonstrate that the volatility index holds more information on the parameters than the returns, leading to A-C-VIX-Ret improving the quality of estimation compared to A-Ret-VIX, as seen by RMSE reductions of up to 90%. For robustness, we apply and compare the methodologies on two alternative choices of models, several volatility indexes, and stock data sets obtaining similar results.

Anatoliy Swishchuk, University of Calgary

[Thursday, June 18; 11:30 am, CL 127]

Applications of Marked Hawkes Process in Finance and Insurance

We introduce two models for a risky asset in finance and for risk process in insurance based on compound marked Hawkes process (CMHP). Using the diffusion approximation of the CMHP, we show how to solve Merton optimization problems in finance and insurance, and how to calculate the ruin probabilities on finite and infinite time horizons. Numerical examples will be presented as well.

Roxane Turcotte, Université du Québec à Montréal

[Tuesday, June 16; 11:30 pm, ED 314]

Semi-parametric modeling of risk exposure with monotonicity constraint

Generalized additive models (GAM) and generalized additive models for location, scale, and shape (GAMLSS) allow the inclusion of smoothing functions in the modeling of model parameters. This allows for a much more flexible structure between an explanatory variable and a response variable since linearity is no longer imposed as in the case of a generalized linear model (GLM). This type of model makes it easier to analyze the relationship between variables. However, when working with data associated with a practical context, such flexibility is not always desirable, since certain form constraints may be necessary. In the case of car insurance data, risk exposure should always be an increasing function, since the greater the risk exposure, the higher the probability of an accident, and this increase should be reflected in the premium. In this work, shape constraints to model risk exposure measured by mileage have been included in GAM and GAMLSS models. We use data from a Canadian company to illustrate the proposed approaches. We discuss the relevance of mileage as a measure of risk exposure and how the measure should be included in the modeling.

Yumin Wang, University of Manitoba

[Tuesday, June 16; 10:30 am, ED 314]

Variable Annuity Pricing with Limited Attention

We study the role of limited attention in the pricing of variable annuities. In contrast to the existing literature, which typically assumes continuous monitoring, we introduce an attention friction where policyholders observe their account only intermittently. At each decision date, observation occurs with an exogenous probability p, and surrender decisions are made only when observation takes place. We show that limited attention reduces the frequency of policyholder surrender behavior, which in turn lowers the fair insurance fee and helps reconcile the gap between standard model-implied fees and those observed in the market. Furthermore, by allowing the attention probability to vary with time, our model generates spike-shaped surrender patterns consistent with the market observation, highlighting limited attention as a potential mechanism behind this empirical feature.

Wei Xu, Toronto Metropolitan University

[Tuesday, June 16; 4:00 pm, ED 314]

Local Risk Minimization for American Options under Stochastic Early Exercise and Transaction Costs

We study the discrete time dynamic hedging problem faced by an American-option writer under proportional and fixed transaction costs, allowing for randomized exercise behavior by the holder within a local risk-minimization (LRM) framework. We solve the resulting LRM problem using a willow tree backward induction algorithm that delivers the initial option value and hedge ratio, as well as the full surface of optimal hedging positions and option values across rebalancing dates and underlying price states. Numerical experiments show that transaction costs materially increase LRM prices and substantially shift hedge positions. Simulation-based tests further indicate that exercise uncertainty, the structure of transaction costs, and model specification jointly shape hedging-error distributions and tail risk. The algorithm is broadly applicable across continuous and discrete time stochastic models, and can be extended to non-Markovian settings such as rough volatility dynamics.

Minisymposium #13 – Different PDE-Based Methods in Applied and Computational Mathematics.

Kewen Bu, Simon Fraser University

[Thursday, June 18; 11:00 am, RIC 119]

Inverse spectral problem of refractive index with low regularity

We study the inverse spectral problem of recovering the refractive index n in the interior transmission problem from the full set of special transmission eigenvalues. Our main result is a uniqueness theorem for n under low-regularity assumptions. First, we present a counterexample showing that if n is discontinuous then the full set of special transmission eigenvalues does not determine n uniquely. We then prove that, under an admissibility hypothesis $n \in M$, the refractive index is uniquely determined by the special transmission eigenvalues together with modest partial information when n is either piecewise C^2 or C^1 with Lipschitz continuous derivative.

Nourelhouda Khedhiri, FACULTY OF SCIENCE OF TUNIS EL MANAR-TUNISIA

[Thursday, June 18; 11:30 am, RIC 119 (virtual)]

Rigorous Derivation of an Energy-Transport model coupled with Poisson equation

The paper deals with the rigorous derivation of an Energy-Transport (ET) model coupled with the Poisson equation.The ET model was formally obtained as a diffusion approximation of a nonlinear Boltzmann equation. Our main contribution is to establish a mathematically rigorous justification of this approximation, addressing potential issues related to degeneracy and saturation effects. In particular, we remove the restrictive assumption $0 < 0 < \beta \leq f^{\alpha} \leq 1 - \beta$. By carefully analyzing the entropy and entropy dissipation structure, we derive uniform estimates and rigorously justify the ET model coupled with the Poisson equation. The proof is based on the compactness properties of the collision operator and its linearization.

Mahdi Moayeri, University of Saskatchewan

[Thursday, June 18; 3:00 pm, RIC 119]

A temporal operator-splitting template library in deal.II with application to larger-scale ignition problems

Operator splitting (OS) is a practical strategy for time integration of multi-physics PDEs. It decomposes a model into simpler subproblems that can be advanced with specialized sub-integrators, rather than using a single monolithic method. In this talk, we will present tost.II, a temporal operator-splitting template library built on top of the deal.II finite element library. tost.II provides a flexible mechanism for systematically implementing a wide range of OS methods by allowing users to define any number of operators in any order and to select a sub-integrator at each stage of a splitting scheme. We will then introduce an efficient computational workflow to explore ignition thresholds in 2D slow-fast systems. In this workflow, we use tost.II and the actor model for concurrent computation to perform efficient and adaptive parameter sweeps with dynamic task scheduling. The goal is to make the computation of ignition thresholds tractable at scale while simultaneously enabling controlled experimentation with suitable numerical solvers for stiff slow-fast dynamics.

Harshil Pathak, Simon Fraser University

[Thursday, June 18; 10:00 am, RIC 119]

Impact of Helical Fibres on Soft Bodied Animals: A Computational Study

Skeletal muscles are capable of producing large mechanical deformations over short timescales, driven by the nonlinear activation of embedded muscle fibres. In many soft-bodied organisms, such as worms, muscle fibres are organized in longitudinal, circular, and cross-linked helical arrangements. In this talk, we employ a three-dimensional finite element model that captures elastic deformations of skeletal muscle. The model is implemented in Flexodeal, a finite element framework for simulating dynamic and quasi-static muscle contractions based on the Hill-type muscle model. We extend Flexodeal by incorporating spatially varying fibre orientations and activation patterns, enabling the simulation of realistic helical and circular fibre architectures. All simulations are performed using a dynamic model that includes inertial effects. Using these capabilities, we investigate the physiological question of the critical helical angle by varying the helical fibre angle from 0 degrees (longitudinal) to 90 degrees (circular). Additionally, we study impact of fibre angles on strain energy densities. Our simulations reveal physiologically consistent emergent behaviors.

Farhatbanu Hasmatali Patel, Memorial University of Newfoundland

[Thursday, June 18; 4:00 pm, RIC 119]

Hankel Transform Analysis of Overlapping Schwarz Methods in Infinite Axisymmetric Domains.

This talk focuses on transform-based analysis of domain decomposition methods for partial differential equations posed in infinite axisymmetric domains. While Fourier techniques are widely used in Schwarz analysis, the Hankel transform remains comparatively underexplored despite its natural suitability for cylindrical geometries. Using the Hankel transform, overlapping Schwarz methods can be reduced to decoupled one-dimensional modal equations, enabling explicit derivation of convergence factors and detailed analysis of each Hankel mode. The session will emphasize convergence behaviour, theoretical insights, and the strengths and limitations of Hankel-based spectral approaches for infinite-domain problems.

Kshitij Patil, Simon Fraser University

[Thursday, June 18; 4:30 pm, RIC 119]

Exterior Steklov Eigenvalues

We address some questions on the spectral geometry of the generalized Steklov-Helmholtz eigenvalue problem on exterior domains in the plane with Lipschitz boundaries. General wave numbers in the first quadrant of the complex plane are considered. Numerical results lead to various conjectures relevant to the spectral geometry of the problem.

Daniel Venn, Simon Fraser University

[Thursday, June 18; 3:30 pm, RIC 119]

Separable Basis Functions for Symmetric Meshfree Methods

We examine meshfree methods that use separable basis functions, particularly on surfaces. For problems involving scattered data, radial basis functions are useful tools but are often computationally infeasible to use globally due to the use of large, dense matrices. However, if separable basis functions are used instead, a variety of computational techniques become available for quickly producing approximate solutions to global problems. We demonstrate such techniques for interpolation problems and partial differential equations on surfaces.

Minisymposium #15 – Differential Equations, Dynamical Systems and Applications in Mathematical Biology.

Shohel Ahmed, University of Alberta

[Tuesday, June 16; 3:30 pm, EA 106.2]

Modelling Foraging Behavior in Ecological Dynamics

Foraging behavior is highly flexible, with individuals adjusting feeding strategies in response to food availability, predation risk, and physiological state. This study develops mechanistic frameworks to explore how such behavioral flexibility influences population dynamics and ecosystem functioning. We first examine consumer-resource systems in which feeding intensity responds to resource density and population pressure, generating feedback between foraging effort and resource depletion. We then incorporate continuous variation in consumer behavioral phenotype, recognizing that individuals differ in boldness rather than conforming to a single average behavioral type. By capturing this spectrum of behavioral variation, the framework highlights how individual differences shape resource use and species interactions. Together, these approaches demonstrate how behavioral flexibility and individual variation can regulate population stability, alter species coexistence, and enhance ecosystem resilience under environmental change.

Elena Braverman, University of Calgary

[Tuesday, June 16; 10:30 am, EA 106.2]

On the influence of diffusion strategies on the average population levels and competition outcomes

In 2006, Lou proved that, once the intrinsic growth rate r in the logistic model is proportional to the spatially heterogeneous carrying capacity K ($r = K^1$), the total population under the regular diffusion exceeds the total of the carrying capacity. He also conjectured that the dependency of the total population on the diffusion coefficient is unimodal, increasing to its maximum and then decreasing to the asymptote which is the total of the carrying capacity. DeAngelis et al (2016) argued that the prevalence of the population over the carrying capacity is only observed when the growth rate and the carrying capacity are positively correlated, at least for slow dispersal. Guo et al (2020) justified that, once r is constant ($r = K^0$), the total population is less than the cumulative carrying capacity. Together with filling up the gap for when $r = K^\lambda$ for any real λ, we define a diffusion strategy as the tendency to have a distribution proportional to a certain positive prescribed function, once a diffusion coefficient grows infinitely, and explore the interplay of harvesting and dispersal strategies and their influence on the outcome of the competition for two resource-sharing species. While achieving extinction by excessive culling of the undesired species is simple and efficient, keeping biodiversity is a more complicated task. Proposing such heterogeneous harvesting that the two populations become an ideal free pair allows to guarantee coexistence.

Sue Ann Campbell, University of Waterloo

[Monday, June 15; 11:30 am, EA 106.2]

Turing Instability of a Closed Nutrient-Phytoplankton-Zooplankton-Detritus Model with Nutrient Recycling

We study a diffusive nutrient-phytoplankton-zooplankton-detritus (NPZD) model with nutrient recycling. We show that the detritus compartment is equivalent to having a distributed time delay in the recycling with a specific delay kernel. The closed nature of the system allows the formulation of a conservation law of biomass that governs the ecosystem. We give general conditions for the existence and stability of equilibria. If the diffusion rates for all species are identical, then Turing instability is not possible as diffusion predominantly has a stabilizing effect; however, if sufficient nutrient is present, complex spatio-temporal dynamics, both transient and long lasting, may occur. We show that these patterns are linked to Hopf bifurcations. If the diffusion rates are different we show that Turing instability is possible, and derive conditions on the diffusion rates for the instability to occur. We study the effect of the diffusion rate of the nutrient and the total biomass on the development of the instability. This is joint work with Francis Poulin and Xiangye Xu.

Yuming Chen, Wilfrid Laurier University

[Tuesday, June 16; 11:00 am, EA 106.2]

Periodic dynamics in a time-switching advection-diffusion model for competing Aedes mosquitoes

We consider a time-switching advection-diffusion system modeling the competition between *Aedes albopictus* and *Aedes aegypti* mosquitoes in heterogeneous environments. The switching mechanism is induced by periodic releases of sterile *Aedes albopictus* mosquitoes, which are active only during their sexual lifespan within each release period. By defining a minimal release amount and four critical release period thresholds, we establish the periodic dynamics of the system, providing new insights into optimal control strategies of mosquitoes. Specifically, the trivial steady state is globally asymptotically stable if sterile releases are sufficiently frequent and abundant, which ensures eradication of both *Aedes* species. For less frequent sterile releases, we prove the global asymptotic stability of the two semi-trivial periodic solutions and demonstrate the existence of a coexisting periodic solution, indicating cases where mosquito control fails. Numerical simulations are presented to validate the theoretical findings.

Clotilde Djuikem, University of Manitoba

[Tuesday, June 16; 11:30 am, EA 106.2]

Within-host immunology to age-of-infection epidemiology via a virtual cohort

We develop a methodology that provides a one-directional link between within-host individual heterogeneity and population-level disease transmission dynamics. The framework consists of several steps. A within-host model is first analyzed numerically to identify the pathogen and immune parameters that produce the greatest variability in host responses. These influential parameters are then used to generate a synthetic population of individuals, from which temporal immune-response profiles are obtained. The resulting profiles are ranked by severity of clinical outcome, from mild infection to death, according to time since infection. This ranking is subsequently used to parameterize an age-of-infection structured epidemiological model for investigating transmission dynamics at the population level. The methodology is illustrated through a within-host model of SARS-CoV-2 infection coupled with an SIR epidemiological model.

Christopher Heggerud, University of Manitoba

[Tuesday, June 16; 3:00 pm, EA 106.2]

Modelling the different ways ecological change can happen and how systems respond.

In theoretical population biology, the study of steady-states, persistence and other long-term dynamics are often made the focal point. Undoubtably this focus has led to many key biological insights, but certain questions pertaining to dynamics that occur on much shorter, and ecologically relevant timescales are often overlooked. In particular, the way systems respond to perturbations is understudied. In this talk, I will give my interpretation of the various phenomena that lead to ecological change and discuss models that respond to non-trivial parameter changes in interesting and unpredictable ways.

Thomas Hillen, University of Alberta

[Monday, June 15; 10:00 am, EA 106.2]

Oncolytic Virotherapy: Analysis and Optimization

Oncolytic viruses (OVs) are designed to selectively target and destroy cancer cells while sparing normal, healthy tissue. Several viruses for oncolytic virotherapy are currently developed. Of particular interest is the interactions of the virus with the immune response, as a virus infection triggers an immune response, which in turn can prevent the virus from spreading. In this talk we consider various mathematical models for oncolytic virotherapy. We show the occurrence of interesting spatial patterns such as invasion fronts and spiral waves. Moreover, we fit the model to data for reovirus and we optimize for dose scheduling and for combinations with immuno therapies. We find the best outcome if CAR-T cell therapy is followed by oncolytic virotherapy with one or two days delay.

Gordon McNicol, University of Waterloo

[Monday, June 15; 10:30 am, EA 106.2]

Vitamin C as a nitrosation inhibitor: a modelling study across dietary patterns and water quality

Rising dietary and drinking-water intake of nitrate and nitrite presents a significant public health concern. After ingestion, a portion of nitrate enters the enterosalivary circulation, where oral bacteria reduce it to nitrite. When swallowed, nitrite enters the acidic gastric environment, where it can react to form N-nitroso compounds (NOCs), many of which are suspected carcinogens. However, epidemiological evidence for this link remains mixed, likely due to the protective effects of antioxidants such as vitamin C, which is present in many high-nitrate foods (e.g. leafy vegetables). To better understand and quantify these complex interactions, we develop a dynamic, compartmental quantitative systems pharmacology (QSP) model of human nitrate and nitrite metabolism and gastric chemistry. The framework tracks nitrate and nitrite fluxes across the stomach, intestine, plasma, and saliva, incorporates postprandial changes in gastric volume and pH, and includes mechanistic nitrosation pathways with vitamin C inhibition. Using this model, we evaluate NOC formation under different dietary and water-quality contexts, demonstrating the protective effect of dietary vitamin C and investigating the role of vitamin C supplementation in suppressing NOC formation. Our simulations suggest, across all dietary contexts, supplementation is most effective when administered shortly after each meal. These findings provide a mechanistic basis for understanding how diet, drinking-water nitrate and nitrite, and vitamin C supplementation interact to shape endogenous NOC formation, with potential implications for nutritional guidelines and risk mitigation in vulnerable populations.

Wilten Nicola, University of Calgary

[Tuesday, June 16; 4:00 pm, EA 106.2]

Mean Field

Firing rate fluctuations in neural populations are observed experimentally over multiple time scales in both single neurons, across trials, and across populations. In this work, we examine how firing rate fluctuations are generated in networks of coupled integrate-and-fire neurons based on the initial distribution of voltages in uncoupled and coupled networks with and without slowly varying inputs. We analytically derive an approximation for the evolution of the instantaneous population rate or flux as a function of the initial voltage distribution through a Fokker-Planck system. This novel mean-field system, Unlike earlier mean-field approaches based on asynchronous steady-state solutions to the Fokker-Planck system, is based on the transport solution to the Fokker-Planck equation assuming that the time-varying dynamics are slow, and the neurons are in the excitation driven regime. The system of mean-field equations we derive here captures the fluctuations of the firing as a function of the initial voltage distribution accurately for coupled and uncoupled networks of neurons.

Allan R. Willms, University of Guelph

[Monday, June 15; 11:00 am, EA 106.2]

Tick spread in southern Ontario based on land classification and deer behaviour

Blacklegged ticks (deer ticks) can carry several pathogens, including Borrelia bacteria that causes Lyme disease in humans. As suggested by their common name, the primary vector by which deer ticks are spread is the white-tailed deer. The Southern Ontario Land Resource Information System's land classifications are utilized in order to model the movement of white-tailed deer and the consequential spread of deer ticks in southern Ontario. The model is a probability-based discrete dynamical system. Tick location data from Public Health Ontario for the years 2015 to 2025 are used to both calibrate the model and assess its accuracy.

Huaiping Zhu,

[Tuesday, June 16; 10:00 am, EA 106.2]

Dynamical models for mosquito population dynamics with temperature

Temperature is a primary driver of mosquito development during the aquatic stage. In this talk, I will present a two-stage model that uses a general distributed-delay kernel to represent how the daily temperature profile determines the development rates and maturation into adults. This formulation links environmental variability directly to stage transition, allowing maturation to depend on temperature history rather than a single averaged temperature (delay). Building on the two-stage framework, I will introduce a matrix population model and analyze its dynamics to characterize how daily temperature drives mosquito abundance. The results provide a mechanistic bridge from temperature data to actionable predictions of adult mosquito abundance. I will also illustrate model applications including model performance using weekly Culex mosquito surveillance data from the Peel Region, Ontario.

Minisymposium #16 – Computer Algebra in Applied Mathematics.

Rob Corless, Western University

[Friday, June 19; 10:00 am, RIC 208]

Structured Backward Error for the WKB method

The classical WKB method (also known as the WKBJ method, the LG method, or the phase integral method) for solving singularly perturbed linear differential equations has never, as far as we know, been looked at from the structured backward error (BEA) point of view. This is somewhat surprising, because a simple computation shows that for some important problems, the WKB method gives the exact solution of a problem of the same structure that can be expressed in finitely many terms. This kind of analysis can be extremely useful in assessing the validity of a solution provided by the WKB method. In this talk we show how to do this and explore some of the consequences, which include a new iterative algorithm to improve the quality of the WKB solution. We also mention a new hybrid method where the potential is approximated by Chebyshev polynomials, which can be implemented in a few lines of Chebfun.

Michelle Hatzel, Western University

[Friday, June 19; 10:30 am, RIC 208]

Bohemian Symmetric Matrices and Maximal Spread Conjecture

Last year, a computational proof by Neil Calkin, Robert Corless, Laureano Gonzalez-Vega, Rafael Sendra and Juana Sendra proved the Fallat–Xing conjecture for matrices up to n=7. The proof establishes the absolute upper bounds for the spectral spread of bounded symmetric a,1-matrices. In the cases where a=0, the authors proved the conjecture up to the 8 x 8 symmetric matrices.This talk presents some experiments on symmetric Bohemian matrices relevant to the conjecture and proofs.

David Jeffrey, Western University

[Friday, June 19; 11:00 am, RIC 208]

Perturbation theory with computer algebra

Perturbation theory has been a central topic in Applied Mathematics for many years. Even in this age of computation, it provides information and comprehension that supplements numerical results. Indeed, May 2026 sees the publication of a new monograph on the subject. The extensive algebraic manipulation which often accompanies a perturbation analysis is facilitated by computer algebra. This talk uses several computations in particle interactions to illustrate and discuss the interplay between symbolic computation, asymptotic analysis and perturbation theory.

Johan Joby, Western University

[Friday, June 19; 11:30 am, RIC 208]

An asymptotic expansion of the inverse gamma approximation and spider polynomials

Spider polynomials are a set of polynomials whose distribution of roots look like a spider on the complex plane. They are derived from the asymptotic expansion of the inverse gamma function. This talk aims to show the asymptotic expansion of the gamma function, how one can derive an asymptotic expansion of the inverse gamma function, its connections to spider polynomials and how the computer algebra system Maple was used to make generating functions for spider polynomials.

Minisymposium #17 – Dynamics and Symmetry.

Konstantin Druzhkov, University of Saskatchewan

[Thursday, June 19; 3:30 pm, CL 130]

Invariant reduction of Poisson brackets

I will show that, under suitable conditions, finite-dimensional systems describing invariant solutions of PDEs inherit local Hamiltonian operators through the mechanism of invariant reduction, which applies uniformly to point, contact, and higher symmetries. The inherited operators endow the reduced systems with Poisson bivectors that relate constants of invariant motion to symmetries. The induced Poisson brackets agree with those of the original systems, up to sign.

Nourelhouda Khedhiri, FACULTY OF SCIENCE OF TUNIS EL MANAR-TUNISIA

[Thursday, June 19; 3:00 pm, CL 130 (virtual)]

Rigorous Derivation of an Energy-Transport model coupled with Poisson equation

The paper deals with the rigorous derivation of an Energy-Transport (ET) model coupled with the Poisson equation. The ET model was formally obtained as a diffusion approximation of a nonlinear Boltzmann equation. Our main contribution is to establish a mathematically rigorous justification of this approximation, addressing potential issues related to degeneracy and saturation effects. In particular, we remove the restrictive assumption $0 < 0 < \beta \leq f^{\alpha} \leq 1 - \beta$. By carefully analyzing the entropy and entropy dissipation structure, we derive uniform estimates and rigorously justify the ET model coupled with the Poisson equation. The proof is based on the compactness properties of the collision operator and its linearization.

Giusy Mazzone, Queen's University

[Thursday, June 19; 10:00 am, CL 130]

Asymptotic stability of evolution equations in Banach spaces

I will present a linearization principle for the stability analysis of a class of nonlinear evolution equations on a Banach space. We assume that the set of equilibria forms a finite dimensional manifold of normally stable and normally hyperbolic equilibria. In addition, the linearized operator is the generator of an analytic semigroup (not necessarily stable). We show that if a solution to our evolution equation exists globally in time and remains ""close"" to the manifold of equilibria at all times, then the solution must eventually converge to an equilibrium point at an exponential rate.

I will present an application of the above abstract result to the equations governing the motion of a fluid-filled heavy rigid body. In particular, we show that weak solutions to the governing equations eventually converge to a steady state with an exponential rate, no matter one chooses the initial data.

Archishman Saha, University of Ottawa

[Thursday, June 19; 11:00 am, CL 130]

On some Stochastic Perturbations of Hamiltonian Systems

We consider stochastic perturbations of the Kepler problem in the angular direction that preserve the deterministic dynamics in the radial direction. We generalize this perturbation to stochastic perturbations of Hamiltonian systems by noise arising from collective Hamiltonians. We show that these systems can be described as a coupling between deterministic and stochastic dynamics. We also show that they preserve many symmetry-related features of the deterministic system, even though the stochastic equations of motion are not symmetric in general. This is part of a joint work with Tanya Schmah (University of Ottawa) and Cristina Stoica (Wilfrid Laurier University).

Tanya Schmah, University of Ottawa

[Thursday, June 19; 11:30 am, CL 130]

Collective Hamiltonian Systems

We consider perturbations of a G-symmetric Hamiltonian H by *collective* terms of the form $f \circ J$, where J is an equivariant momentum map for the G action. In general this breaks the symmetry, however the perturbed dynamics can be reconstructed in two stages from the symmetry-reduced unperturbed motion.

An interesting special case is the *mirror collective Hamiltonian* $f^L \circ J_R + f^R \circ J_L$ on T^*G where G is a Lie group and J_L and J_R are the momentum maps of left and right translations. One example is a rigid body with constant spatial torque. Another is a continuum model with applications to image registration, generalising the widely used Large Deformation Diffeomorphic Metric Mapping (LDDMM) framework. This work is joint with Archishman Saha and Cristina Stoica.

Alexey Shevyakov, University of Saskatchewan

[Thursday, June 18; 10:30 am, CL 130 (virtual)]

On Breaking Waves and Exact Solutions of a Family of Nonlinear Wave Equations

A family of nonlinear wave equations arising in diverse physical contexts is studied. By decomposing solutions into left- and right-going waves, an exact coupled system of first-order quasilinear PDEs is derived, with the coupling term governing nonlinear interactions between the two waves. Using this system, unidirectional travelling wave solutions are obtained exactly via the method of characteristics, and bidirectional waves are studied using perturbation methods. Nonlinear PDEs of this form are known for forming singularities in finite time, where the spatial derivative of the solution develops jump discontinuities. The structure and formation time of breaks in travelling wave solutions, as well as the persistence and behaviour of the weak solution after the first break, are shown to be revealed by the first-order coupled system. An exact solution method is proposed that correctly captures the shock dynamics by adhering to the fundamental principle of equal areas. The method is implemented numerically in a new MATLAB package, yielding solutions that transition seamlessly into weak solutions after wave breaking, with jump discontinuities represented to machine precision. The solver is validated against an implementation of the method of lines and against Clawpack v5, showing agreement up to and well beyond the breaking time. Two applications are considered: a nonlinear shear wave model from hyperelasticity and the wave equation governing a nonlinear string. While the weak solutions satisfy the defining conservation law, they are shown to generally violate conservation of auxiliary quantities, such as mechanical energy and momentum, that are preserved by smooth solutions. This work is joint with Shawn McAdam.

Cristina Stoica, Wilfrid Laurier University

[Thursday, June 19; 4:00 pm, CL 130]

Continuation of Hamiltonian dynamics from the plane to constant-curvature surfaces

We investigate the deformation of symmetry on cotangent bundles from the Euclidean plane to two-dimensional constant-curvature surfaces and the continuation of local dynamics aspects in Hamiltonian systems.

For a fixed curvature sign, the curved problem is set up either on the sphere or on the hyperbolic plane, both with radius recovering flat space in the zero limit of a small parameter. The symmetry of these spaces is taken into account by using ther contraction of Lie algebras from so(3) or so(2,1) to se(2). We use Riemannian exponential coordinates centred at the North pole together with the pull-back the associated momentum map and the symplectic form. Within this geometric setting we use a local slice construction and prove the persistence from flat to curved spaces of non-degenerate relative equilibria and relative periodic orbits of general cotangent bundle Hamiltonian systems. We apply the resulting framework to the Newtonian n-body problem.

Posters.

[Wednesday, June 17; 3:00-5:00 pm, ED 114]

Naznin Sultana Akhi, University of Regina

Estimating Time-Varying Transmission Rates with Causality-Enhanced Physics-Informed Neural Networks

In Epidemic Research, understanding how quickly an infectious disease is spreading is one of the fundamental goals. And to do so we need to estimate the time varying transmission rate $\beta(t)$ in infectious disease modeling which governs how fast the disease spread through a population, controls the rise and fall of waves, how severe outbreaks become, and if the interventions are working. However, estimating the time varying $\beta(t)$ from epidemic data is one of the most challenging aspects because we have unreported incidence or hospitalizations and that's why identifying $\beta(t)$ by the inverse problem theory becomes unstable because different parameter combinations can generate similar curves where many of these compartments are unobserved. Recently, Physics Informed Neural Networks (PINNs) emerged as a promising approach to integrate theoretical compartmental models with observational data, allowing hidden states and model parameters to be learned simultaneously. PINNs control the NN solutions by matching predicted epidemic curves to the observed case counts, and most of the time this is inadequate to infer the time varying transmission rate uniquely, as a result, we get unstable and unrealistic value of $\beta(t)$, consequently, the estimates of the unobserved compartments are also unreliable. In this work, we introduce Causality-Enhanced Initial Conditions (CEIC) framework in our PINN model where we use a weighting strategy that places more emphasis on the earlier time-dynamics, so that the model learns the initial behavior accurately before computing later time points. This is important because epidemic progression is inherently sequential, and errors at earlier times can spread and mislead later predictions. We evaluated our proposed framework using Canadian Covid-19 incidence data from 2020 to 2023 in a SEIR model, where the neural network outputs the compartments along with $\beta(t)$, and epidemiological parameters σ and γ vary over time according to dominant variants (Alpha, Delta, Omicron, BA.5). We only used reported incidence data in our model, and it recovers realistic trends for the transmission rate $\beta(t)$ across multiple waves along with all the hidden compartments by maintaining the physical constraints. Overall results suggest that incorporating the causality into PINN training improves parameter identifiability and a more reliable epidemic model.

Ryan Bilous, Canadian Mennonite University

When Timing Matters: Mechanism-Dependent Treatment Windows in a Dynamical Model of Seizures

Status epilepticus is a neurological emergency in which benzodiazepine therapy — the standard first-line treatment — loses effectiveness with delay and may fail for mechanistically distinct reasons. We adapt a Wilson–Cowan excitatory–inhibitory neural mass model to ask whether the effective treatment window is universal, or whether it depends on the mechanism sustaining seizure activity.

Three mechanisms are compared within a common dynamical framework: hyperexcitation, inhibitory depletion, and depolarizing GABA. The novel contribution is to keep the model autonomous, treat benzodiazepine efficacy as a bifurcation parameter, and convert the seizure-eliminating threshold to a critical treatment delay via a separate efficacy-decay law.

For hyperexcitation and inhibitory depletion, seizure activity corresponds to a stable high-activity attractor removed through a saddle-node bifurcation once benzodiazepine efficacy exceeds a critical value. The hyperexcitation model yields a window of approximately 14.35 minutes, within the 5–20 minute initial therapy phase recommended by the American Epilepsy Society; inhibitory depletion compresses this to 9.31 minutes — still within that range, but with substantially less margin. In the depolarizing-GABA model, chloride dysregulation can reverse the inhibitory pathway so that GABAergic activity reinforces excitation rather than suppressing it; if that reversal exceeds the maximum available drug effect, no finite treatment window exists within the model.

These results show that benzodiazepine failure is not always a matter of timing: while delay compresses the rescue window in Models 1 and 2, the depolarizing-GABA mechanism can render seizure termination pharmacologically unreachable under the assumed efficacy cap.

Tristan Brier, Université de Montréal

Improving Virtual Population Generation for Quantitative Systems Pharmacology (QSP)

Quantitative systems pharmacology (QSP) models aim to capture biological complexity and variability to inform drug development. A key strategy involves generating virtual populations (VPop) representing parameter sets that reflect physiologically plausible biological states and reproduce observed variability in clinical outcomes. VPop are used to simulate inter-individual differences in drug response, optimize dosing strategies, and support model-informed drug development (MIDD). However, generating high-quality VPop remains challenging due to the nonlinear and often non-identifiable nature of QSP models. Existing approaches for VPop generation generally struggle with low acceptance rates, poor parameter diversity, suggesting limited coverage of biologically relevant regions of the parameter space. In this study, we introduce the DREAM(ZS) algorithm, a widely used multi-chain adaptive MCMC, to the QSP field. We evaluate its performance and compare it to that of the Metropolis-Hastings (MH) method proposed by Rieger et al., using the van de Pas cholesterol metabolism model as a case study. Our objective was to assess the ability of DREAM(ZS) to overcome known limitations of traditional MH approaches as a sampling method for VPop generation. We evaluated the quality of the generated plausible populations and Vpop using metrics of parametric diversity, goodness of fit to clinical cholesterol data, and sampling efficiency. Our results demonstrate that DREAM(ZS) offers a broader parameter space coverage, restores correlation structures, and produces more diverse populations while maintaining or improving goodness of fit. This work highlights DREAM(ZS) as a promising and flexible alternative for VPop generation in QSP, expanding the methodological approaches for in silico trial simulation and MIDD.

Yueyang Du, University of Victoria

A Kinetic Model of Consumer Resource System with Density- and Resource-Dependent Movement

Animals share multiple motivations to move, such as finding food and mate, avoiding competition or predation. Previous studies have often assumed that the changes in the reorientation rate due to these interactions between individuals can also account for the changes in speed in response to the same interactions. However, empirical evidence suggests that the speed and reorientation rate can be controlled independently in response to conspecific and resource density. This project presents a consumer-resource model in which the movement of consumers follows the above rules. The existence of solutions to the system is shown. Pattern formation and the existence of travelling solutions are discussed.

Matthaeus Dyck, Canadian Mennonite University

Modeling the Effectiveness of RNAi Control: Invasive Zebra Mussels in Lake Winnipeg

Zebra mussels (Dreissena polymorpha) are a highly invasive species placing significant ecological and economic strain on Lake Winnipeg, including damage to hydroelectric infrastructure through dense colonization of water intake systems. Their spread between waterbodies is driven primarily by recreational boating, but once established, their reproductive capacity is so high that no control strategy has proven effective at scale. RNA interference (RNAi) has recently been proposed as a targeted molecular strategy because it can suppress gene expression involved in reproduction and development with high species specificity. We develop and analyze a two-dimensional ordinary differential equation model for larval and adult density to investigate how effective RNAi must be to suppress or eliminate populations, and how this changes under continued boating-driven introduction.

The model incorporates reproduction, maturation, mortality, density-dependent crowding, boating-driven external introduction, and RNAi suppression of reproduction and maturation. Without boating, sufficiently strong RNAi produces a transcritical bifurcation driving the population to extinction, though the required suppression threshold is very high, underscoring the practical difficulty of eradication through biocontrol alone.

When boating is included, extinction is always unstable regardless of RNAi efficacy: any introduction, however small, grows to a persistent positive population. Increasing RNAi reduces equilibrium population size but cannot eliminate the invasion. These results suggest that eradication requires not only extremely strong biological suppression, but concurrent elimination of boat-driven introduction.

Kezia Heppner, Canadian Mennonite University

Food Insecurity and Type 2 Diabetes: A Mathematical Model of Glucose–Insulin–β-Cell Dynamics

Type 2 diabetes is a progressive disorder of glucose regulation involving hyperglycemia, insulin resistance, impaired insulin secretion, and loss of functional pancreatic β-cell mass. Food insecurity is increasingly recognized as a contributor through its effects on diet quality, eating patterns, psychosocial stress, and inflammation — a relationship of particular importance in Manitoba, where food insecurity and type 2 diabetes disproportionately affect First Nations and rural communities. We adapt the Topp glucose–insulin–β-cell model to examine how food insecurity influences long-term diabetes progression. The three-dimensional model is reduced to a two-dimensional glucose–β-cell system via a quasi-steady state assumption on insulin, justified by timescale separation between rapid insulin dynamics and slower β-cell adaptation. Food security enters as a control parameter acting on glucose input, insulin-mediated glucose removal, and β-cell death. Equilibrium, stability, phase-plane, and bifurcation analyses reveal two qualitatively distinct dynamical regimes. In one, a saddle-node bifurcation produces bistability, where long-term outcomes depend on both food-security level and initial metabolic condition. In the other, a transcritical bifurcation exchanges stability between boundary and interior equilibria. Across both regimes, higher food security is associated with lower equilibrium glucose and greater β-cell preservation, while lower food security shifts the system toward hyperglycemia and β-cell decline. These results suggest that food insecurity may shape diabetes progression not only by worsening average metabolic conditions, but by altering the stability landscape itself.

Johnna Parenteau, University of Regina

Detecting "Matchings" Using Companion Testing

It is well-known that any polynomial can be modeled as a graph, and the roots of the polynomial determine certain properties of the graph. What happens when these properties are altered? Does altering the graph change the roots of its associated polynomial? While it is unknown how to predict the exact value of the new roots that are created via vertex deletion, the multiplicities of certain common roots can be predicted using a novel test called the Vandermonde Eigenvector Test (VET), which we will discuss in relation to the weighted matching polynomial.

Jacob Serpico, University of Alberta

Global lake tipping vulnerability under sustained agricultural exposure

Intensive agriculture drives lake eutrophication, degrading water quality and biodiversity through harmful algal blooms, hypoxia, and costly regime shifts. It remains unclear whether agriculture triggers sudden change through expansion or instead accumulates vulnerability under long-standing land cover. Between 2003 and 2022, we combined trophic state and nearshore land cover data for 859 lakes worldwide to detect 125 abrupt, persistent tipping events. We then use interpretable models to separate chronic agricultural exposure from rapid expansion, and compare simple driver-based forecasts with classical early warning signals. Near-term tipping risk is dominated by a lake's baseline trophic state and its long-term surrounding cropland; small increases above that baseline raise the 12-month tipping risk by 16%, whereas early warning signals add little predictive power. These findings show that sustained agricultural pressure narrows the safe operating space for freshwater ecosystems and provide a versatile framework for managing other vulnerable social-ecological systems.

Asher Warkentin, Canadian Mennonite University

The Role of Turbidity in a Common Carp-Yellow Perch Model in Manitoba

Common Carp (Cyprinus carpio) are invasive benthivorous fish that alter freshwater ecosystems by resuspending sediment, increasing turbidity, and reducing habitat quality for native species. In Manitoba, Common Carp are established in several waterbodies, including Lake Manitoba, where their ecological effects may contribute to pressure on native fish communities. This project uses a two-dimensional ordinary differential equation model to examine how turbidity-mediated habitat degradation influences the competitive dynamics between invasive Common Carp and native Yellow Perch.

We adapt a published three-species fish-population model into a two-species competition framework incorporating logistic growth, interspecific competition, harvest, and a turbidity term representing the indirect negative effect of Carp on Perch. After nondimensionalizing the system, we derive nullclines, four equilibria, local stability conditions, and bifurcation structure as turbidity increases.

The model admits extinction, Perch-only persistence, Carp-only persistence, and coexistence equilibria, with stability depending on the relative strength of growth, harvest, competition, and turbidity-mediated impacts. Using parameters chosen to represent the south basin of Lake Manitoba, we find that increasing turbidity drives a transcritical bifurcation at approximately $\gamma = 0.00102$. Below this threshold, both species coexist at a stable positive equilibrium; above it, the coexistence equilibrium loses biological feasibility and the system shifts to a stable Carp-only state.

These results suggest that Carp-driven turbidity can act as a threshold mechanism pushing native fish communities from coexistence toward exclusion – and that habitat modification, not only direct competition, must be accounted for in models of invasive species management.

Contributed Talks.

OLOPADE ISAAC ADESOLA, FEDERAL UNIVERSITY WUKARI

[Tuesday, June 16; 10:30 am, ED 114]

A Mathematical Epidemiological Model for Dengue Fever Transmission Incorporating Integrated Public Health Interventions

This work formulates and analyzes a deterministic compartmental model for the spread of dengue fever, incorporating three key intervention strategies: environmental sanitation, early detection of cases, and hospitalization. The model reflects how improved sanitation reduces mosquito breeding opportunities, early detection enhances timely medical response, and hospitalization limits disease severity and potential transmission. A threshold quantity, the reproduction number, is derived to assess whether the infection will persist or decline over time. The qualitative analysis shows that when this threshold is below one (Ro¡1), the infection cannot sustain itself in the population, whereas values above one (Ro¿1) indicate possible persistence of the disease [1]. The results also demonstrate that increased sanitation efforts reduce the vector population, early detection shortens the duration of infectiousness, and hospitalization decreases both complications and the likelihood of further spread. The sensitivity analysis is conducted on the reproduction number to determine the parameters that most strongly influence disease transmission [2]. The findings indicate that factors such as mosquito biting rate, vector recruitment, and transmission probabilities tend to increase disease spread, while improved sanitation, faster detection of infected individuals, and effective hospitalization contribute significantly to reducing transmission. Numerical experiments are performed to support the analytical results and to evaluate the combined impact of the control measures [3]. The simulations suggest that a coordinated application of sanitation, early detection, and hospitalization can substantially reduce infection levels, potentially leading to effective control of dengue fever.

Shaza Alsibaai, Queen's University

[Thursday, June 18; 11:00 am, CL 126]

Mathematical Modeling of Cell Cycle Dynamics with Quiescence and Interphase Delay

The cell cycle is a tightly regulated biological process governing cell growth and division. In this talk, I will present two mathematical models of cell cycle dynamics that incorporate both cell quiescence and a time delay associated with interphase. We consider two formulations: a constant-delay model, representing a fixed interphase duration, and a state-dependent delay model, in which the duration increases with the number of mitotic cells due to competition for limited resources.

For the constant-delay model, we show that the system is linear and that when the death rate of mitotic cells exceeds twice their proliferation rate ($\mu_1 > 2b_1$), the trivial equilibrium is the unique biologically feasible steady state and is asymptotically stable. When $\mu_1 < 2b_1$, a critical threshold τ for the interphase duration emerges. In this regime, the trivial equilibrium remains the only biologically feasible equilibrium; it is asymptotically stable for $\tau > \tau$ (extinction) and unstable for $\tau < \tau$ (unbounded growth). At the critical value $\tau = \tau$, the system admits a continuum of equilibria.

We then investigate the state-dependent delay model numerically and show that, for a range of parameter values, the system admits a positive, non-trivial equilibrium. This demonstrates that incorporating state dependence, even in a linear form, can induce bounded population dynamics absent in the constant-delay case. These results highlight the qualitative impact of delay structure on cell cycle behavior and provide insight into mechanisms regulating cellular proliferation.

Woldegebriel Assefa Woldegerima, York University

[Tuesday, June 16; 11:30 am, ED 114]

Conflict-Gated Gradient Scaling: Resolving gradient pathology in physics-informed epidemiological models

Physics-Informed Neural Networks (PINNs) are increasingly used in mathematical epidemiology to bridge the gap between noisy clinical data and compartmental models. However, training these hybrid networks is often unstable due to competing optimization objectives. As established in recent literature on "Gradient Pathology," the gradient vectors derived from the data loss and the physical residual often point in conflicting directions, leading to slow convergence or optimization deadlock. While existing methods attempt to resolve this by balancing gradient magnitudes or projecting conflicting vectors, we propose an efficient alternative: Conflict-Gated Gradient Scaling (CGGS). This method utilizes the cosine similarity between the data and physics gradients to dynamically modulate the penalty weight. Unlike standard annealing schemes that only normalize scales, CGGS acts as a geometric gate: it suppresses the physical constraint when directional conflict is high, allowing the optimizer to prioritize data fidelity, and restores the constraint when gradients align. We prove that this gating mechanism preserves the standard $O(1/T)$ convergence rate for smooth non-convex objectives, a guarantee that fails under fixed-weight or magnitude–balanced training when gradients are in conflict. We demonstrate that this mechanism autonomously induces a curriculum learning effect, improving parameter estimation in stiff epidemiological systems compared to magnitude-based baselines.

Jacques Bélair, Université de Montréal

[Tuesday, June 16; 10:00 am, ED 114]

Awareness and compliance in an infectious disease model

We consider a compartmental model of disease propagation in which information is the infection: knowledge of, and compliance with, measures limiting the propagation of an infectious disease (such as non-pharmaceutical interventions (NPIs)) are modeled as dynamic parameters. The population is divided in three classes: unaware individuals, aware but noncompliant and aware and compliant indivuduals. We analyse the dynamical consequences of different transition mechanisms between the compliants and noncompliants, leading to possible bistability of equilibria and existence of periodic solutions.

Matthew Betti, Mount Allison University

[Thursday, June 18; 10:30 am, CL 126 (virtual)]

Modeling barriers to freshwater turtle re-introduction in rebuilt marshlands

Turtle populations are unique among animals in their extreme life history strategy: they are long-lived, with adult mortality due largely to human intervention. In contrast, juveniles have extremely low survival rates, mainly due to predation. Practically, this has led to difficultly in re-introducing populations of turtles into historically viable ecosystems. We develop a model of freshwater turtle population dynamics in the context of generalist predation. The model explores the sensitivity of populations to adult mortality. We show that the model allows for a saddle-node bifurcation in adult mortality, elucidating that once a population is driven out of an area, it cannot easily be re-introduced. Furthermore, analysis of a Lyapunov function for the system highlights the structural issues of "headstarting" programs that aim to seed turtle populations with manual introduction of juvenile turtles.

Mandana Bidarvand, University of Saskatchewan

[Thursday, June 18; 11:30 am, CL 126]

Structure-Aware Reduction in Quantum Modeling: Insights from the Lanczos Framework

Mathematical modeling plays a central role in translating complex quantum systems into forms amenable to computation. In this talk, we explore how structure-aware techniques can significantly reduce the effective complexity of such models, drawing inspiration from the Lanczos algorithm. Rather than treating large-scale quantum operators as unstructured objects, we emphasize the importance of identifying latent geometric and algebraic patterns that govern their action.

Starting from the perspective of Krylov subspace methods, we examine how carefully chosen initial states and iterative projections reveal low-dimensional structures embedded within high-dimensional quantum systems. This viewpoint naturally leads to a framework in which model reduction is not merely an approximation, but a principled reorganization of the underlying space based on dynamical relevance.

We illustrate these ideas through examples motivated by interacting quantum systems, where defect-based or sector-based decompositions emerge from the dynamics induced by the Hamiltonian. The resulting reduced representations retain key spectral and structural properties while enabling more efficient computation, with potential implications for both classical simulation and quantum algorithm design.

The goal of this talk is to provide a mathematically grounded yet application-oriented perspective on how reduction techniques, inspired by Lanczos-type iterations, can serve as a bridge between abstract quantum models and practical computational workflows.

Rodolfo Brandao, University of British Columbia

[Monday, June 15; 4:00 pm, ED 114 (virtual)]

Coalescence of liquid droplets

We consider the dynamics of two equal, spherical liquid drops of Newtonian fluid, brought into contact at a negligible speed, and merging driven by surface tension. The effects of an outer fluid or that of gravity are disregarded, so that the entire motion is determined uniquely by a single dimensionless parameter, the Ohnersorge number Oh. Using methods of matched asymptotics, in the limit that the minimum radius r_0 of the bridge connecting the drops is much smaller than the initial drop radius, we compute the dynamics for $r_0(t)$, as well as the shape of the gap between the drops.

Roberto Budzinski, University of Lethbridge

[Monday, June 15; 10:00 am, ED 114]

Linking structure, dynamics, and computation in oscillator networks

Understanding how network structure gives rise to spatiotemporal dynamics and computation is a central challenge in computational neuroscience and artificial intelligence. Despite increasingly detailed connectomic data in neuroscience and vast datasets in machine learning, predicting dynamics and function in biological and artificial neural systems remains difficult. Here, we present a mathematical framework that directly links network architecture, emergent dynamics, and computation in analytically tractable models. We focus on networks of coupled oscillators, which have long served as models of neural systems and have more recently been explored as computational substrates in artificial neural networks. Our framework enables analytical predictions and stability analysis of emergent spatiotemporal patterns in terms of network structure, including connectivity and time delays. When applied to empirically derived brain networks, this approach provides a rigorous link between large-scale connectivity, distance-dependent delays, and wave dynamics observed across mesoscopic and whole-brain scales. Building on this theory, we introduce a new class of neural networks that exploit rich spatiotemporal dynamics as a substrate for computation while remaining exactly solvable. These networks support a range of computations, including memory, logic, sequence processing, and vision tasks, while preserving full interpretability. Together, these results demonstrate a general approach for connecting network structure, emergent dynamics, and computation, offering new tools for interpreting biological neural activity and for designing transparent dynamical models in artificial intelligence.

Kyung-Han Choi , University of Alberta

[Tuesday, June 16; 4:00 pm, ED 114]

The lingering phenomenon and pattern formation in a nonlocal population model with cognitive map

The rates at which individuals memorize and forget environmental information strongly influence their movement paths and long-term space use. To understand how these cognitive time scales shape population-level patterns, we propose and analyze a nonlocal population model with a cognitive map. The population density moves by a Fokker–Planck type diffusion driven by a cognitive map that stores habitat quality information nonlocally. The map is updated through local presence with learning and forgetting rates, and we consider both truncated and normalized perception kernels.

We first study the movement-only system without growth. We show that finite perceptual range generates spatial heterogeneity in the cognitive map even in nearly homogeneous habitats, and we prove a lingering phenomenon on unimodal landscapes: for the fixed high learning rate, the peak density near the best location is maximized at an intermediate forgetting rate.

We then couple cognitive diffusion to logistic growth. We establish local well-posedness and persistence by proving instability of the extinction equilibrium and the existence of a positive steady state, with uniqueness under an explicit condition on the motility function. Numerical simulations show that lingering persists under logistic growth and reveal a trade-off between the lingering and total population size, since near the strongest lingering regime, the total mass can fall below the total resource, in contrast to classical random diffusive-logistic models.

Muhammad Fiaz

[Monday, June 15; 11:00 am, ED 114]

Stakeholders' Behavioral Impact on Supply Chain Management: Bifurcation and Chaos Theory Analysis

Supply chain managers can adopt efficient and cost effective strategies to improve demand forecasting, inventory management, warehousing and over all supply chain optimization by better understanding the complex relationships between various stack holders. The resilience of supply chain networks depends heavily on how key stakeholders like retailers and distributors behave. This research investigates the impact of such behavioral patterns on the stability and effectiveness of an innovative three-dimensional Supply Chain Management (SCM) model. We employ bifurcation and chaos theory to analyze both integer- and fractional-order variants of the 3D-SCM model. Through averaging theory, we analytically determine the zero Hopf bifurcation. We also explore chaotic dynamics at specific fractional orders. Phase portraits, sensitivity dependence and chaotic time history for fractional version are provided. Our findings reveal that minor variations in retailer or distributor satisfaction can lead to substantial supply chain disruptions or, alternatively, significant performance enhancements. We provide numerical simulations to support our theoretical results. These findings contribute both theoretical understanding and practical recommendations for developing more robust SCM systems in complex, dynamic environments.

Yusra Hasan, University of Guelph

[Wednesday, June 17; 10:30 am, ED 114]

Spatio-temporal Variability of Meteorological Variables in Winter Months Using a High-Resolution WRF Model Over the City of Guelph

Urban microclimates create highly localized variations in temperature and precipitation, and winter road maintenance strategies aimed at saving lives and preventing infrastructure damage, requires high-resolution forecasts rather than uniform salt applications that can miss critical hotspots or accelerate road surface deterioration. High-resolution numerical weather prediction is essential for improving precipitation and winter weather forecasting in urban environments characterized by complex land atmosphere interactions. An evaluation of two widely used physics configurations of the Weather Research and Forecasting (WRF V4.7) model over the City of Guelph, Ontario, Canada, is conducted with one-way nesting down to a fine horizontal resolution of 200 m with 90 vertical layers. Daily simulations were conducted over a two-month period during the winter and analyzed against observations within a fully instrumented environmental monitoring station. Model performances were quantified using the bias, Root Mean Square Error (RMSE)

and Pearson correlation coefficient (r) as well as implementations of a confusion matrix specifically to assess hourly and daily precipitation accuracy. The results showcased that precipitation skill is strongly dependent on time scale for all cases. For predicting the hourly precipitation against the tipping bucket, the highest WRF performance was characterized by $r = 0.588$ and $RMSE = 0.51$ mm $hr - 1$, while the performance improved for predicting daily precipitation ($r = 0.921$, $RMSE = 3.31$ mm $day - 1$). Near-surface meteorological variables were reproduced with varying skill, but both WRF configuration versions encompassed reasonable output for Guelph. Confusion matrix analysis revealed that both configurations successfully detected snowfall and precipitation occurrence, with higher true positive rates considering daily events, as opposed to hourly events, supporting the WRF model applicability for operational forecasting and decision-making frameworks such as smart winter road maintenance and salt optimization strategies. This study represents the first city-scale, winter-focused WRF evaluation conducted for Guelph, Ontario, and demonstrates that convection-permitting and LES-scale configurations can reliably reproduce key mesoscale and precipitation processes in a humid continental urban climate.

Trisha Lawrence, University of Calgary

[Monday, June 15; 10:30 am, ED 114]

Statistical and Optimization Modelling Frameworks for Generating Electricity in Energy Markets

The global population with access to electricity is constantly increasing from 84 to 92 percent. However, as the world continues to advance towards sustainable energy targets, there still exist 900 million people living without access to electricity.

In this talk, we provide a modeling framework for analyzing mini-grid project performance and evaluating the economic impact of battery energy storage in competitive electricity markets. Using a dataset of 104 rural mini-grid installations, we estimate the probability of project success through both a Probit regression model and a Bayesian hierarchical model. Community ownership and the presence of storage systems emerge as statistically significant predictors, with Bayesian posterior estimates closely aligning with frequentist results while providing improved predictive stability.

Furthermore, we analyze the bidding behavior of the Alberta electricity market and construct a mixed-integer self-scheduling model that determines optimal charging and discharging strategies. Through numerical experiments we demonstrate how storage can enhance arbitrage profitability, influence market clearing prices, and support system reliability.

Our results highlight the value of combining statistical inference with optimization-based modeling to guide investment decisions.

Kenneth Lie, University of Regina

[Wednesday, June 17; 10:00 am, ED 114]

Numerical Solution of a Quadratic Matrix Equation

We consider the quadratic matrix equation (QME)

$$AX^2 - BX + C = 0,$$

where B is a nonsingular M-matrix, $B^{-1}A \geq 0$, $B^{-1}C \geq 0$, and $B - A - C$ is a regular M-matrix.

For the case where $B - A - C$ is a nonsingular M-matrix, we show that the QME can be reduced to a matrix equation studied in a paper by Chen, Li, and Ma. This reduction allows us to directly apply their convergence results for iterative methods, including the structure-preserving doubling algorithm, to the QME.

We then focus on the more challenging case where $B - A - C$ is a regular singular M-matrix with a simple zero eigenvalue. In this setting, we establish theoretical properties of the minimal nonnegative solution Φ and the solution Ψ of the associated dual equation. We further analyze the convergence of several iterative methods, showing (except in a critical case) linear convergence of the Bernoulli iteration and quadratic convergence of Newton's method and the structure-preserving doubling algorithm. This is joint work with Chun-Hua Guo.

Ahad Moosa, York University

[Tuesday, June 16; 3:30 pm, ED 114]

Analysing parameter identifiability for in–host compartmental models of mRNA vaccine immune responses

In–host mathematical models have become common place in mathematical epidemiology and immunology for the analysis of disease spread, treatment, and prevention. This theory has been extensively applied to modelling the immune responses of patients following vaccine administration by fitting data attained from clinical trials. Often such data is sparse and does not contain observations of all relevant compartments which can impact parameter identifiability. We consider an analysis of parameter identifiability of an in–host vaccine immune response model for LNP mRNA vaccines using simulated data. We employ the use of the software DAISY, for differential algebra analysis, and Monolix, for NMLE modelling that estimates model parameter values through fitting the simulated data. The results indicate the prior knowledge of T–cell and interleukin dynamics allowing for the fixing of parameters on a population level can yield accurate parameter estimates even when a limited number of compartments are observed.

Raziyeh Niknam, University of Regina

[Wednesday, June 17; 11:30 am, ED 114]

Sustainable Facility Location with Capacity and Emissions Constraints: A Capacitated Continuous Covering Model with Carbon Pricing

A sustainability-constrained facility location problem motivated by equitable access planning in healthcare logistics and urban service infrastructure is addressed. A capacitated continuous covering location model is formulated in which facilities are located in a continuous service region and demand zones are allocated to ensure coverage within a prescribed service radius while satisfying capacity limitations. Environmental performance is incorporated through operational and transportation-related emissions, together with carbon pricing and an aggregate emissions constraint. The resulting optimization problem integrates continuous location decisions with coverage, capacity, and emissions restrictions, yielding nontrivial trade-offs between total cost, feasibility, and equity-oriented penalties for uncovered demand.

To obtain high-quality solutions at practical instance sizes, two metaheuristic solvers implemented in MATLAB are developed: a Genetic Algorithm (GA) and a hybrid GA–Simulated Annealing (GA–SA) method equipped with constraint-handling and repair mechanisms. Benchmark instances with 25, 100, and 256 demand zones are used for evaluation. The computational results indicate that both approaches scale effectively across problem sizes; lower total system costs under binding capacity and emissions limits are more consistently achieved by GA–SA, while competitive solution quality with reduced runtime is provided by GA. A scalable formulation and computational study are thereby provided for sustainability-aware facility planning under coverage, capacity, and emissions constraints.

OLANREWAJU PHILIP OLADAPO , FEDERAL UNIVERSITY WUKARI

[Tuesday, June 16; 11:00 am, ED 114]

Mathematical modeling of unsteady radiative magnetohydromagnetic flow of Maxwell Nano-fluid in a porous medium with buoyancy and Arrhenius chemical kinetic

Parametric sensitivity of mathematical modeling of unsteady Maxwell magnetohydromagnetic nanofluid and second thermodynamic law analysis under Arrhenius kinetic with buoyancy is investigated in the presence of viscous heating and radiation. The porous flow channel is subjected to tension with material properties that vary with time without deformation. In the absence of fluid charge polarization, the conducting liquid is influenced by the sheet stretching velocity (see Olanrewaju et. Al, 2021). The flow coupled derivatives model is transformed to dimensionless form by relevant similarity variables. These are numerically solved by shooting numerical technique together with Fehlberg Runge-Kutta procedures (Tsokojo et. Al., 2024). The essential characteristics of the flow and thermodynamic irreversibility are determined. The results are quantitatively and qualitatively compared with other studies and are established to agree well. The graphical results revealed that Lewis number increases the molecular species concentration and the thermodynamic stability for reversibility can be enhanced by the augmentation of magnetic field, thermophoresis, and radiation. Therefore, for thermal and chemical reaction systems, increasing heat propagation should be managed to keep the system from blowing up. The buoyancy has a greater effects on the flow generally Keywords: Buoyancy, mathematical modeling, Arrhenius chemical kinetics, porous medium, internal heat generation

Yifan Qu, University of Toronto

[Monday, June 15; 3:30 pm, ED 114]

Numerical Approximation of Exercise Boundary of American Options

While there are several numerical methods that have been developed to compute the value of an American option, as well as studies on the accuracy of these methods, comparatively less attention has been devoted to accurately calculating the associated optimal exercise boundary. In practice, simple techniques often produce a piecewise or “stepwise” approximation of the free boundary, which may lead to non-monotonic behavior and oscillations or lack of smoothness over time. We investigate several techniques for approximating the exercise boundary based on different interpolation strategies applied to the option value or derivative values within the region of the partial differential equation. These interpolants are then extrapolated towards the exercise region,

and the free boundary is approximated by enforcing either continuity or continuity of derivative conditions. We seek a method that can attain a reasonably stable and reliable order of convergence and monotonicity with respect to time. Joint work with Christina Christara.

Marc R Roussel, University of Lethbridge

[Tuesday, June 16; 3:00 pm, ED 114]

Elaborate vs simple models for the control of the expression of Hmp by NsrR

In *Streptomyces coelicolor*, the expression of the nitric-oxide detoxification enzyme Hmp is repressed by NsrR, a dimeric, NO-sensitive iron-sulfur protein. The iron-sulfur cluster of each NsrR monomer can react up to eight times with NO, leading to a model with a large number of states. Recent experimental evidence indicates that NsrR binding to the *hmp* promoter is exquisitely sensitive to reaction with NO, with loss of binding occurring after a single reaction of NO with either iron-sulfur cluster of the dimer. Moreover, experiments suggest that reaction of NO with the two iron-sulfur clusters of NsrR is cooperative, i.e. that reaction at one iron-sulfur cluster accelerates reaction at the other. We can build a detailed model of this control system, but how much of the detail is necessary, and under what conditions do various details matter? This question is explored by comparing a detailed model to simpler variants. Some comments are offered on other systems whose modelling would raise similar issues.

Tim Rogalsky, Canadian Mennonite University

[Wednesday, June 17; 11:00 am, ED 114]

Detecting Natural Selection from Ancestral Recombination Graph Topology Using a Graph Isomorphism Network

Ancestral Recombination Graphs (ARGs) encode the full genealogical history of a sampled population and carry rich signatures of natural selection, but their complex topology has resisted standard statistical approaches. We present a Graph Isomorphism Network (GIN) framework for inferring selection parameters directly from local ARG tree topology, without positional information or full ARG context. Our work is motivated by the climatic stability hypothesis, which predicts that boreal bird populations — exposed to repeated glacial cycles — experienced more frequent and transient selective sweeps than their tropical counterparts. We simulate ARGs under four selection regimes (neutral, background, periodic, and continuous) using msprime and SLiM, with periodic sweeps serving as the primary learning target. Trained on 1,440 simulated ARGs, the GIN achieves seed-level onset Pearson $r = 0.949$ ($r^2 = 0.901$), demonstrating that local tree topology carries sufficient signal for accurate inference of selection timing. Sweep strength prediction remains an open challenge: we present a diagnosis of the underlying label-space difficulties and describe a Multiple Instance Learning reformulation in which the model learns tree-level relevance jointly with onset prediction.

Elizabeth Trofimenkoff, University of Lethbridge

[Tuesday, June 16; 4:30 pm, ED 114]

Mathematical modeling of FOXF2 pre-mRNA synthesis reveals the factors that favor co-transcriptional splicing

Splicing is a critical processing step in the gene expression pathway that utilizes an enzyme called the spliceosome to excise intervening sequences (introns) and ligate expressed sequences (exons) of an RNA transcript in order to assemble a continuous set of instructions for the synthesis of a protein. Errors in this process have been linked to diseases including cancers and dementias. Despite its importance, splicing has been sparsely studied using mathematical modeling methods, resulting in several gaps in the literature including incomplete understandings of discrepancies in reported splicing times, and of key parameters, kinetic steps, and mechanistic features involved in splicing. Our previous work, along with evidence from the literature, suggests that the spliceosomal activation step is rate limiting when splicing occurs post-transcriptionally (after RNA synthesis), and that the distribution of splicing times mostly depends on the rate constants that govern both this rate determining step and the final splicing step in the mechanism. However, approximately 75% of splicing events have been reported to occur co-transcriptionally, necessitating an extension of our model to embed splicing into the transcription process. Our results show that this inclusion is not sufficient to explain the preference for co-transcriptional splicing seen in the literature. We therefore must consider additional mechanistic features that may impact the frequency of co-transcriptional (CT) splicing. The literature shows that the polymerase (transcription enzyme) may pause when it transcribes the 3' splice site of the nascent RNA, and suggests a correlation between terminal exon length and CT splicing events. To analyze the factors that may contribute to CT splicing frequency, we constructed a CT splicing model of the FOXF2 pre-mRNA and performed stochastic simulations that show that the terminal exon length and 3' splice site pausing time are likely the main determinants of the CT splicing frequency, and that the average splicing and elongation rates make a lesser contribution.

Ray Wu, University of Toronto

[Monday, June 15; 3:00 pm, ED 114]

Quantization error under high-order convolution smoothing in parabolic PDE models for finance

Numerical solution of parabolic PDEs with nonsmooth initial conditions often exhibits reduced and/or unstable convergence orders due to the so-called quantization error. For a class of nonsmooth initial conditions, including representative payoffs of financial derivatives, we study how high-order convolution-based smoothings modify the quantization error. For each initial condition and smoothing operator, we derive closed-form expressions for the leading order terms of the quantization error. Examining the dependence of the quantization error leading coefficient on the relative location of the discontinuity with respect to the discretization grid, we identify the minimum smoothing order required to guarantee stable fourth-order convergence (with or without grid alignment), when using fourth-order discretizations in space and time. These results explain when extrapolation-based acceleration methods, including Richardson extrapolation and the sparse grid combination approach, succeed or fail.

Hongmei Zhu, York University

[Monday, June 15; 11:30 am, ED 114 (virtual)]

A Real Orthogonal Tensor Basis for $2^n - by - 2^n$ Matrices and Its Algebraic Properties

We introduce a real-valued representation for $2^n 2^n$ matrices based on tensor products of primitive 2×2 matrices, forming an orthogonal basis under the Frobenius inner product. This structure enables explicit matrix decompositions and efficient reconstruction, with connections to fast transform methods.

Building on this basis, we develop a non-commutative matrix algebra and examine its algebraic properties. In particular, we show that it admits a natural extension of the classical Euler formula in a matrix-valued setting. As an application, we demonstrate how this framework can be used to analyze differential equations, including reducing the three-dimensional Klein–Gordon equation to a system of four first-order partial differential equations, analogous to Dirac-type formulations.

This work provides a unified and computationally tractable framework linking linear algebra, non-commutative structures, and differential equations.