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# SCHEDULE

## AGENDA

**CMS Winter Meeting 2022 | Réunion d'hiver de la SMC 2022**  
**Chelsea Hotel**  
**Toronto, Ontario**

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## AGENDA

- List of Abbreviations | Liste des abréviations
- Schedule | Horaire
- Talk List in Order of Speaker's Last Name | Liste de présentations par nom de famille du conférencier
- Public Mitacs Lecture | Conférence publique Mitacs
- Education Plenary | Conférence plénière sur l’éducation
- Plenary Lectures | Conférences plénières
- Prize Lectures | Conférence des lauréats
- Advances in Finite Elements & Application to Solid and Fluid Mechanics | Progrès des éléments finis et application à la mécanique des solides et des fluides
- Algebraic Combinatorics and Representation Theory | Combinatoire algébrique et théorie des représentations
- Algebraic and Spectral Graph Theory | Théorie algébrique et spectrale des graphes
- Algorithms and Complexity aspects of Optimization | Aspects algorithmiques et complexes de l'optimisation
- Analysis of PDEs | Analyse des EDP
- Approximation Theory, Function Spaces and Harmonic Analysis | Théorie de l'approximation, espaces de fonctions et analyse harmonique
- Calculus of Variations and its Applications | Calcul des variations et ses applications
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PRESIDENT'S WELCOME LETTER

On behalf of the Canadian Mathematical Society, it is my pleasure to welcome you to Toronto and the 2022 Winter CMS Meeting. This conference promises to provide many opportunities to gather together and engage in mathematical discussion. The scientific organising committee, led by directors Ada Chan (York University) and Gregory Smith (Queen’s University), have built a program of 32 sessions and 7 mini-courses on a diverse collection of topics spanning mathematics education, applied mathematics, pure mathematics, as well as probability and statistics.

The conference programme begins with a public lecture on Friday December 2nd by Suzanne Weekes (SIAM). Also featured are three plenary lectures by Fok-Shuen Leung (UBC), Peter Shor (MIT), and Gigliola Staffilani (MIT). Other special events during the conference include a student poster session on Saturday December 3rd, an EDI luncheon also on the 3rd, and several prize lectures.

At the banquet scheduled for Sunday evening we will celebrate and recognise John Mighton (Jump Math) as winner of the Adrien Pouliot Award, Jacques Hurtubise (McGill) as a winner of the David Borwein Award, Fabio Pusateri (Toronto) as a winner of the Coxeter-James Prize, David Oakden (retired) as winner of the Graham Wright Award, and Qin Deng (MIT) as a winner of the CMS Blair Spearman Doctoral Prize. Winners from the student poster session will also be honoured during the banquet.

A conference as large and diverse as this one is only possible thanks to a tremendous effort from people such as the scientific directors and their committee, the many session organisers and speakers, volunteers and CMS staff, to all of whom I extend our collective thanks. On behalf of the Society, I also wish to express our gratitude to the sponsors of the meeting: AARMS, CRM, Fields, PIMS, RBC, Edsfide, Maplesoft, York University, and Toronto Metropolitan University. RBC’s generosity in particular has provided registration subsidies to several students who belong to under-represented and equity-seeking groups.

To the conference participants, I hope that you have a positive and productive meeting, and that you enjoy coming together to discuss mathematics in person once again. Please take a moment to talk to the CMS staff at the registration desk, whose diligence during the disruptions of the past few years has been remarkable. They will appreciate your personal thanks, and if you are not currently a CMS member they will be pleased to tell you about the Society’s many activities above and beyond hosting conferences.

Welcome

David Pike
CMS President
LETTRE DE BIENVENUE DU PRÉSIDENT

Au nom de la Société mathématique du Canada, j'ai le plaisir de vous souhaiter la bienvenue à Toronto et à la réunion d'hiver 2022 de la SMC. Cette conférence promet d'offrir de nombreuses occasions de se réunir et de participer à des discussions mathématiques. Le comité d'organisation scientifique, dirigé par les directeurs Ada Chan (Université York) et Gregory Smith (Université Queen's), a construit un programme de 32 sessions et 7 mini-cours sur une collection variée de sujets couvrant l'enseignement des mathématiques, les mathématiques appliquées, les mathématiques pures, ainsi que les probabilités et les statistiques.

Le programme de la conférence commence par une conférence publique le vendredi 2 décembre par Suzanne Weekes (SIAM). Trois conférences plénières seront également données par Fok-Shuen Leung (UBC), Peter Shor (MIT) et Gigliola Staffilani (MIT). Parmi les autres événements spéciaux de la conférence, citons une session d'affiches pour les étudiants le samedi 3 décembre, un déjeuner de l'EDI également le 3, et plusieurs conférences de prix.


Une conférence aussi vaste et diversifiée que celle-ci n'est possible que grâce aux efforts considérables de personnes telles que les directeurs scientifiques et leur comité, les nombreux organisateurs de sessions et conférenciers, les bénévoles et le personnel de la SMC, à qui j'adresse tous mes remerciements. Au nom de la Société, je souhaite également exprimer notre gratitude aux commanditaires de la réunion : AARMS, CRM, Fields, PIMS, RBC, AMS, edufide, Maplesoft, MathMatize, York University et Toronto Metropolitan University. La générosité de RBC, en particulier, a permis de subventionner l'inscription de plusieurs étudiants appartenant à des groupes sous-représentés et en quête d'équité.

Aux participants à la conférence, j'espère que votre réunion sera positive et productive, et que vous serez heureux de vous retrouver une fois de plus pour discuter des mathématiques en personne. Veuillez prendre un moment pour parler au personnel de la SMC au bureau d'inscription, dont la diligence pendant les perturbations de ces dernières années a été remarquable. Ils apprécieront vos remerciements personnels, et si vous n'êtes pas actuellement membre de la SMC, ils seront heureux de vous parler des nombreuses activités de la Société au-delà de l'organisation de conférences.

Bienvenue

David Pike
Président de la SMC
A WORD FROM THE SCIENTIFIC DIRECTORS

Dear Participants,

Welcome to the 2022 Winter meeting of the Canadian Mathematical Society! Whether traveling from some far corner of the country or just making a short trip downtown, we hope that you find this conference to be enjoyable and invigorating.

As the second CMS meeting conducted in-person since the start of COVID pandemic, we see this event as an opportunity to renew and strengthen connections within our mathematical community. We hope that everyone, regardless of background or identity, feels welcome to participate fully. Your participation is key to the continuation of the long-standing CMS tradition of scientific diversity and excellence at these meetings.

We thank the Scientific Organization Committee, the organizers of the scientific sessions, the instructors of the mini-courses, the plenary lecturers, and all of the other speakers for their important contributions. We could not organize such a meeting without your efforts. We congratulate the award winners and new CMS fellows being recognized at this meeting. We also appreciate the CMS staff, especially Termeh Kousha, Sarah Watson, and Jessica Horobetz, for handling so many administrative details.

We acknowledge this conference takes place on the traditional land of many nations, including the Huron-Wendat, the Haudenosaunee, the Seneca, and the Mississaugas of the Credit. We are grateful to learn and play on these lands.

Ada Chan and Gregory G. Smith
2022 CMS Winter Meeting Scientific Directors

UN MOT DES DIRECTEURS SCIENTIFIQUES

Chers Participants,

Bienvenue à la Réunion d’hiver 2022 de la Société mathématique du Canada ! Que vous veniez d’un coin reculé du pays ou que vous fassiez simplement un court voyage en ville, nous espérons que vous trouverez cette conférence agréable et vivifiante.

Comme il s'agit de la deuxième réunion de la SMC tenue en personne depuis le début de la pandémie de COVID, nous voyons cet événement comme une occasion de renouveler et de renforcer les liens au sein de notre communauté mathématique. Nous espérons que chacun, quels que soient ses antécédents ou son identité, se sentira le bienvenu pour participer pleinement. Votre participation est essentielle à la poursuite de la longue tradition de la CMS en matière de diversité et d’excellence scientifiques lors de ces réunions.

Nous remercions le Comité d’organisation scientifique, les organisateurs des sessions scientifiques, les instructeurs des mini-cours, les conférenciers pléniers et tous les autres intervenants pour leurs importantes contributions. Nous ne pouvons pas organiser une telle réunion sans vos efforts. Nous félicitons les lauréats des prix et les nouveaux boursiers de la SMC qui sont reconnus lors de cette réunion. Nous apprécions également le personnel de la SMC, en particulier Termeh Kousha, Sarah Watson et Jessica Horobetz, pour avoir géré tant de détails administratifs.

Nous reconnaissons que cette conférence a lieu sur les terres traditionnelles de nombreuses nations, notamment les Hurons-Wendat, les Haudenosaunee, les Seneca et les Mississaugas du Crédit. Nous sommes reconnaissants d’apprendre et de jouer sur ces terres.

Ada Chan et Gregory G. Smith
Directeurs scientifiques de la Réunion d’hiver 2022 de la SMC
DAVID BORWEIN AWARD  
JACQUES HURTUBISE (MCGILL)

Dr. Jacques Hurtubise (McGill) has been named the recipient of the 2022 David Borwein Distinguished Career Award for his exceptional, continued, and broad contributions to mathematics. Dr. Hurtubise will receive his award and present a Prize Lecture at the CMS Winter meeting in Toronto, Ontario (December 2-5, 2022).

Awarded every four years, the David Borwein Distinguished Career Award is, by definition, reserved for those individuals who have made exceptional, broad, and continued contributions to Canadian mathematics.

Dr. Jacques Hurtubise is one of Canada’s most eminent research mathematicians. Since the start of his research career as a Rhodes Scholar at Oxford, Jacques has made contributions of outstanding caliber to the subjects in which he has worked. Dr. Hurtubise has thus gained worldwide recognition for his seminal work on the topology of the moduli spaces of instantons, as well as on integrable systems. His first-rate results have appeared in top mathematics journals, such as the Annals of Mathematics, Acta Mathematica, and the Duke Mathematical Journal, and have earned him several prestigious prizes and lectureships, including the CMS Coxeter-James Prize, a plenary talk at the annual meeting of the AMS, an AMS Centennial Fellowship—of which he was the first Canadian recipient—, election as a Fellow of the Royal Society of Canada, as an inaugural Fellow of the American Mathematical Society and, most recently, as an inaugural Fellow of the Canadian Mathematical Society.

Jacques Hurtubise is a member of the Department of Mathematics and Statistics at McGill University, of which he was Chair from 2009 to 2015 and from 2019 to 2022. After obtaining his Doctorate as a Rhodes Scholar in 1982 from Oxford University, he taught for five years at the Université du Québec à Montréal, before moving to McGill in 1988. From 1996 to 2003 he served as Deputy Director, then Director, of the Centre de Recherches Mathématiques. He has served the CMS in several roles over the years, notably as President from 2010 to 2012.

Jacques Hurtubise has taken on a leadership role both within and outside of the mathematical community. He has had a deep influence as a teacher and mentor of young mathematicians, having trained ten Ph.D. students, nineteen post-doctoral Fellows and nine Master’s students, most of whom have moved on to successful academic careers of their own. A five-day conference in honour of Jacques’ 60th birthday, which was hosted by the CRM in August of 2017, brought together a constellation of mathematicians from around the world whose research has been influenced and inspired by Jacques’ work.

One of the qualities that his colleagues most admire about Jacques is his unswerving, selfless devotion to the greater good. Jacques always places the interests of his academic unit, university, and professional community well before his own.

In summary, Jacques’ leadership is epitomized by his remarkable human qualities coupled with his charisma and scientific vision. They are the main reasons why he is unanimously admired by the colleagues whose lives and careers have been affected during his stewardship of the CRM, the McGill Department of Mathematics and Statistics, and the Canadian Mathematical Society.
PRIX DAVID BORWEIN

JACQUES HURTUBISE (MCGILL)

Professeur Jacques Hurtubise (McGill) a été nommé lauréat du 
Prix David Borwein de mathématicien émérite pour l’année 2022 en 
raison de sa contribution exceptionnelle, continue et étendue aux 
mathématiques. Prof. Hurtubise recevra son prix et présentera une 
conférence lors de la prochaine réunion d’hiver de la SMC à Toronto, Ontario (2-5 décembre 2022).

Décerné tous les quatre ans, le prix David-Borwein pour une carrière exceptionnelle est, par définition, réservé aux personnes qui ont apporté une contribution exceptionnelle, étendue et continue aux mathématiques canadiennes.


Jacques Hurtubise a assumé un rôle de leader à l’intérieur et à l’extérieur de la communauté mathématique. Il a exercé une profonde influence en tant que professeur et mentor de jeunes mathématiciens, ayant formé dix doctorants, dix-neuf boursiers post-doctoraux et neuf étudiants en master, dont la plupart ont poursuivi avec succès leur propre carrière universitaire. Une conférence de cinq jours en l’honneur du 60e anniversaire de Jacques, qui a été accueillie par le CRM en août 2017, a réuni une constellation de mathématiciens du monde entier dont la recherche a été influencée et inspirée par le travail de Jacques.

L’une des qualités que ses collègues admirent le plus chez Jacques est son dévouement inébranlable et désintéressé au bien commun. Jacques place toujours les intérêts de son unité académique, de son université, et de la communauté professionnelle bien avant les siens.

En résumé, le leadership de Jacques est incarné par ses remarquables qualités humaines associées à son charisme et à sa vision scientifique. Ce sont les principales raisons pour lesquelles il fait l’objet d’une admiration unanime de la part des collègues dont la vie et la carrière ont été affectées par sa gestion du CRM, du Département de mathématiques et statistiques de McGill et de la Société mathématique du Canada.
CMS BLAIR SPEARMAN
DOCTORAL PRIZE

QIN DENG (MIT)

Dr. Qin Deng (Massachusetts Institute of Technology) has been named the 2022 CMS Blair Spearman Doctoral Prize recipient. Dr. Deng will receive his award at the CMS Winter meeting in Toronto, Ontario.

Qin Deng is an outstanding researcher working in metric and Riemannian geometry as well as geometric analysis. Deng’s thesis contains a solution to a long-standing open problem in the theory of manifolds with lower Ricci curvature bounds and RCD spaces.

In the mid-1990s, Cheeger and Colding carried out a research program to understand the structure of spaces that arose as Gromov-Hausdorff limits of smooth Riemannian manifolds with Ricci curvature uniformly bounded from below, dimension uniformly bounded from above, and diameter uniformly bounded from above. These are natural objects of study when considering the basic rigidity theorems for manifolds of non-negative or positive Ricci curvature with the results of Cheeger and Colding quantitatively generalizing them.

A natural research direction has been to generalize the Cheeger-Colding results to the RCD setting. A combined community effort settled these problems in the affirmative, except for the Hölder continuity of tangent cones along geodesics. Deng's thesis settled this important case and developed new tools for computing the change in distance along the flow of a vector field in the non-smooth setting. Moreover, Deng proved the non-branching property for RCD spaces, which states that two geodesics that coincide for a small interval cannot come apart. This property is an important tool for obtaining some of the more desirable properties possessed by Riemannian manifolds in these new settings. Furthermore, an integral version of the second-order variation formula for regular Lagrangian flows in the RCD setting was obtained. The results in Deng's thesis may be viewed as a generalization of the breakthrough work of Colding and Naber on Hölder continuity of tangent cones, the latter appearing in the Annals of Mathematics in 2012. The thesis demonstrates Deng's ability to assimilate a wide variety of deep, technical results and originality in combining them to make substantial advances.

Deng received his PhD from the University of Toronto in 2021 under the supervision of Vitali Kapovitch. The recipient of several awards such as the Ida Bulat Teaching Award, Malcolm Slingsby Robertson Prize, George F.D. Duff Graduate Fellowship, and an NSERC Alexander Graham Bell Canada Graduate Scholarship, Deng is now a C.L.E. Moore Instructor at the Massachusetts Institute of Technology.
M. Qin Deng (Massachusetts Institute of Technology) a été nommé lauréat du Prix de doctorat Blair Spearman 2022 de la SMC. M. Deng recevra son prix à la réunion d’hiver de la SMC à Toronto, en Ontario.

Qin Deng est un chercheur exceptionnel travaillant en géométrie métrique et riemannienne ainsi qu’en analyse géométrique. La thèse de Deng contient une solution à un problème ouvert de longue date dans la théorie des variétés avec des limites inférieures de courbure de Ricci et des espaces RCD.

Au milieu des années 1990, Cheeger et Colding ont mené un programme de recherche pour comprendre la structure des espaces qui sont apparus comme des limites de Gromov-Hausdorff de variétés riemanniennes lisses avec une courbure de Ricci uniformément bornée par le bas, une dimension uniformément bornée par le haut et un diamètre uniformément borné par le haut. Ce sont des objets d’étude naturels lorsqu’on considère les théorèmes de rigidité de base pour les variétés à courbure de Ricci positives ou non négatives, avec les résultats de Cheeger et Colding qui les généralisent quantitativement.

Une direction de recherche naturelle a été de généraliser les résultats de Cheeger et Colding au cadre RCD. Un effort combiné de la communauté a permis de résoudre ces problèmes par l’affirmative, sauf pour la continuité de Hölder des cônes tangents le long des géodésiques. La thèse de Deng a résolu ce cas important et a développé de nouveaux outils pour calculer le changement de distance le long du flux d’un champ de vecteurs dans le cadre non lisse. De plus, Deng a prouvé la propriété de non-ramification pour les espaces RCD, qui stipule que deux géodésiques qui coïncident pour un petit intervalle ne peuvent pas se séparer. Cette propriété est un outil important pour obtenir certaines des propriétés les plus souhaitables que possèdent les collecteurs riemanniens dans ces nouveaux contextes. De plus, une version intégrale de la formule de variation du second ordre pour les flux lagrangiens réguliers dans le cadre du RCD a été obtenue. Les résultats de la thèse de Deng peuvent être considérés comme une généralisation des travaux révolutionnaires de Colding et Naber sur la continuité de Hölder des cônes tangents, ces derniers ayant été publiés dans les Annales de mathématiques en 2012. La thèse démontre la capacité de Deng à assimiler une grande variété de résultats techniques profonds et son originalité à les combiner pour réaliser des avancées substantielles.

Deng a obtenu son doctorat à l’université de Toronto en 2021 sous la direction de Vitali Kapovitch. Lauréat de plusieurs prix tels que le Prix d’enseignement Ida Bulat, le Prix Malcolm Slingsby Robertson, la Bourse d’études supérieures George F.D. Duff et une Bourse d’études supérieures du Canada Alexander Graham Bell du CRSNG, Deng est maintenant instructeur C.L.E. Moore au Massachusetts Institute of Technology.
ADRIEN POULIOT AWARD

JOHN MIGHTON (JUMP MATH)

Dr. John Mighton (JUMP Math) is the recipient of the 2022 Adrien Pouliot Award in recognition of his outstanding contributions to mathematics education. He will be presented with his award at the 2022 CMS Winter Meeting.

Dr. John Mighton is an award-winning mathematician, playwright and best-selling author, who founded JUMP Math as a charity in 2002. He is internationally recognized for his ground-breaking work building children's confidence, skills, and success in math.

John began tutoring children in math as a financially struggling playwright, though he had abandoned the subject for years after having nearly failed first-year calculus in university. His success in helping students achieve levels of success that teachers and parents had thought impossible fueled his belief that everyone has great untapped potential. The experience of repeatedly witnessing the heart-breaking paradox of high potential and low achievement led him to conclude that the widely held assumption that mathematical talent is a rare genetic gift has created a self-fulfilling prophecy of low achievement.

John had to overcome his own "massive math anxiety" before making the decision to earn a PhD in Mathematics at the University of Toronto. He was later awarded a Natural Sciences and Engineering Research Council (NSERC) Fellowship for post-doctoral research in knot and graph theory. He is currently a Fellow of the Fields Institute for Research in Mathematical Sciences and has taught mathematics at the University of Toronto. He has also lectured in philosophy at McMaster University, where he received a master's degree in philosophy.

John developed JUMP (Junior Undiscovered Math Prodigies) Math to address academic and social inequities created by low expectations for students in math and to dispel the myth that only some people are naturally gifted at math while others are destined to struggle. What makes JUMP Math unique is the premise that anyone can learn mathematics, and anyone can teach it. His national best-seller, The Myth of Ability: Nurturing Mathematical Talent in Every Child, describes his approach and successes with the program. In 2007, John released a follow-up book, The End of Ignorance, as a further exploration of the JUMP Math philosophy and methods. In 2020, Alfred A. Knopf Canada published John’s third book on the subject, All Things Being Equal: Why Math is the Key to a Better World.

Through John’s leadership and innovation, JUMP Math has grown into an award-winning charitable organization dedicated to enhancing every child’s learning and life potential and addressing academic and social inequities through math education. Its evidence-based approach and comprehensive, curriculum-aligned Grades K-8 teaching resources empower educators in Canada, the US and other countries worldwide to build confidence, understanding and a love of mathematics in every student.

In recognition of his lifetime achievements, John has received numerous awards. He is a recipient of the Fields Institute for Research in Mathematical Sciences’ 2022 Margaret Sinclair Memorial Award. He has been awarded a prestigious Ashoka Fellowship for social entrepreneurship, a Schwab Foundation Social Entrepreneur of the Year award, an Ernst & Young Social Entrepreneur of the Year award for Canada, and six honorary doctorates. In 2010, he was named an Officer of the Order of Canada. John is also the recipient of the 10th Annual Egerton Ryerson Award for Dedication to Public Education and 2021 President’s Award from the Professional Engineers of Ontario. John is frequently consulted as a thought leader on math education. He has been featured in Scientific American Mind, The New York Times and The Globe & Mail, among other media. He has given hundreds of talks and training sessions, including a TEDx talk, the Nerenberg Lecture at the University of Western Ontario, the Hagey Lecture at the University of Waterloo, and a Public Lecture at the Perimeter Institute (broadcast by TVO). John was also invited by The New York Academy of Sciences to give a keynote at the Aspen Brain Forum and was invited as a contributor to the 2015 World Economic Forum in Davos.

As a mathematician and a playwright, John believes that there are more connections between the arts and sciences than people generally see, as mathematicians are often led by a sense of beauty or elegance in their work. His own plays have been performed across Canada, Europe, Japan, and the United States, and he has won several national awards including two Governor General’s Literary Awards for Drama, the Dora Award, the Chalmers Award, and the Siminovitch Prize. His play, Possible Worlds, was made into a full-length feature film of the same name by Robert Lepage. In a twist of fate, he played Matt Damon’s math tutor in the 1997 movie, Good Will Hunting.

Dr. John Mighton’s exceptional contributions to mathematics education make him a most deserving recipient of the 2022 Adrien Pouliot Award.
M. John Mighton (JUMP Math) est le lauréat du prix Adrien Pouliot 2022 en reconnaissance de sa contribution exceptionnelle à l'enseignement des mathématiques. Le prix lui sera remis lors de la réunion d'hiver 2022 de la SMC.

John Mighton est un mathématicien primé, un dramaturge et un auteur de best-sellers, qui a fondé JUMP Math en tant qu'organisation caritative en 2002. Il est internationalement reconnu pour son travail novateur visant à renforcer la confiance, les compétences et la réussite des enfants en mathématiques.

John a commencé à donner des cours de mathématiques à des enfants alors qu'il était un dramaturge en difficulté financière, même s'il avait abandonné cette matière pendant des années après avoir failli échouer en première année de calcul à l'université. Le fait qu'il ait réussi à aider des élèves à atteindre des niveaux de réussite que les enseignants et les parents pensaient impossibles à atteindre a renforcé sa conviction que chacun possède un grand potentiel inexploité. L'expérience de l'observation répétée du paradoxe déchirant du haut potentiel et de la faible réussite l'a amené à conclure que l'hypothèse largement répandue selon laquelle le talent mathématique est un don génétique rare a créé une prophétie autoréalisatrice de faible réussite.

John a dû surmonter sa propre "anxiété mathématique massive" avant de prendre la décision d'obtenir un doctorat en mathématiques à l'University of Toronto. Il a ensuite obtenu une bourse du Conseil de recherches en sciences naturelles et en génie (CRSNG) pour des recherches postdoctorales en théorie des graphes. Il est actuellement membre de Fields Institute pour la recherche en sciences mathématiques et a enseigné les mathématiques à l'University of Toronto. Il a également donné des cours de philosophie à McMaster University, où il a obtenu une maîtrise en philosophie.

John a développé JUMP (Junior Undiscovered Math Prodigies) Math pour s'attaquer aux inégalités scolaires et sociales créées par les faibles attentes des élèves en mathématiques et pour dissiper le mythe selon lequel seules certaines personnes sont naturellement douées en mathématiques, tandis que d'autres sont destinées à lutter. Ce qui rend JUMP Math unique, c'est le principe selon lequel tout le monde peut apprendre les mathématiques et tout le monde peut les enseigner. Son best-seller national, The Myth of Ability: Nurturing Mathematical Talent in Every Child, décrit son approche et ses succès avec le programme. En 2007, John a publié un livre complémentaire, The End of Ignorance, qui explore plus avant la philosophie et les méthodes de JUMP Math. En 2020, Alfred A. Knopf Canada a publié le troisième livre de John sur le sujet, All Things Being Equal: Why Math is the Key to a Better World.

Grâce au leadership et à l'innovation de John, JUMP Math est devenu une organisation caritative primée qui se consacre à l'amélioration du potentiel d'apprentissage et de vie de chaque enfant et à la lutte contre les inégalités scolaires et sociales par l'enseignement des mathématiques. Son approche fondée sur des preuves et ses ressources pédagogiques complètes et adaptées aux programmes scolaires de la maternelle à la 8e année permettent aux éducateurs du Canada, des États-Unis et d'autres pays du monde entier de renforcer la confiance, la compréhension et l'amour des mathématiques chez chaque élève.

En reconnaissance des réalisations de toute une vie, John a reçu de nombreux prix. Il a reçu le prix commémoratif Margaret Sinclair 2022 de l'Institut Fields pour la recherche en sciences mathématiques. Il a reçu la prestigieuse bourse Ashoka pour l'entrepreneuriat social, le prix de l'entrepreneur social de l'année de la Fondation Schwab, le prix de l'entrepreneur social de l'année d'Ernst & Young pour le Canada, ainsi que six doctorats honorifiques. En 2010, il a été nommé Officier de l'Ordre du Canada. John est également lauréat du 10e prix annuel Egerton Ryerson pour son dévouement à l'éducation publique et du 2021 President's Award de l'association Professional Engineers of Ontario.

John est fréquemment consulté en tant que leader d'opinion sur l'enseignement des mathématiques. Il a fait l'objet d'articles dans Scientific American Mind, le New York Times et le Globe & Mail, entre autres médias. Il a donné des centaines de conférences et de séances de formation, notamment une conférence TEDx, la conférence Nenberg à l'University of Western Ontario, la conférence Hagey à l'University of Waterloo et une conférence publique au Perimeter Institute (diffusée par TVO). John a également été invité par l'Académie des sciences de New York à prononcer une allocution au Aspen Brain Forum et a été invité en tant que contributeur au Forum économique mondial de 2015 à Davos.

En tant que mathématicien et dramaturge, John croit qu'il y a plus de liens entre les arts et les sciences que les gens ne le voient généralement, car les mathématiciens sont souvent guidés par un sens de la beauté ou de l'élegance dans leur travail. Ses propres pièces ont été jouées au Canada, en Europe, au Japon et aux États-Unis, et il a remporté plusieurs prix nationaux, dont deux Prix littéraires du Gouverneur général pour l'art dramatique, le Prix Dora, le Prix Chalmers et le Prix Siminovitch. Sa pièce, Possible Worlds, a été transformée en un long métrage du même nom par Robert Lepage. Par un coup du sort, il a joué le rôle du professeur de mathématiques de Matt Damon dans le film Good Will Hunting (1997).

Les contributions exceptionnelles de M. John Mighton à l'enseignement des mathématiques font de lui un lauréat méritant du prix Adrien Pouliot 2022.
GRAHAM WRIGHT AWARD
DAVID OAKDEN (RETIRED)

Dr. David Oakden (Retired) has been named the recipient of 2022 Graham Wright Award for Distinguished Service.

Dr. Oakden has made consistent and significant contributions to the Canadian mathematical community and to the Canadian Mathematical Society. He has served as CMS Treasurer since 2013 and as a member of the Board of Directors, Executive Committee, Finance Committee, and Invested Funds Committee.

David Oakden is a retired insurance and actuarial professional in Toronto. He is currently serving on the Board of the Property and Casualty Insurance Compensation Corporation and is Chairman of the Board of Commissioners for the Financial Services Commission of the Turks and Caicos Islands. His last full-time position was at the Office of the Superintendent of Financial Institutions (OSFI), where he served as Managing Director in the Actuarial Division and as Canada’s representative to the International Association of Insurance Supervisors.

Dr. Oakden has been active in the actuarial profession, and he has served as the President of the Canadian Institute of Actuaries, as a member of the Board of the Casualty Actuarial Society and as a member of the (Canadian) Actuarial Standards Board. He has spoken frequently at industry meetings on reserving, financial reporting, capital management and risk management.

Dr. Oakden has a Ph.D. in mathematics from the University of Toronto. He is a Fellow of the Canadian Institute of Actuaries and the Casualty Actuarial Society.

In addition to his contributions to the CMS, Dr. Oakden has been active in the actuarial community where he served as the President of the Canadian Institute of Actuaries.

PRIX GRAHAM WRIGHT
DAVID OAKDEN (RETRAITÉ)


M. Oakden a été actif au sein de la profession actuarielle, et il a été président de l’Institut canadien desactuaires, membre du conseil d’administration de la Casualty Actuarial Society et membre du Conseil des normes actuarielles (canadien). Il a souvent pris la parole lors de réunions de l’industrie sur le provisionnement, les rapports financiers, la gestion du capital et la gestion des risques.

M. Oakden est titulaire d’un doctorat en mathématiques de l’Université de Toronto. Il est membre de l’Institut canadien des actuaires et de la Casualty Actuarial Society.

En plus de ses contributions à la SMC, M. Oakden a été actif dans la communauté actuarielle où il a été président de l’Institut canadien des actuaires.
Dr. Fabio Pusateri (University of Toronto) is the recipient of the 2022 Coxeter-James Prize for his seminal work in Analysis and Partial Differential Equations. Dr. Pusateri will receive his award at the CMS Winter Meeting in December 2022, where he will give a prize lecture.

Fabio Pusateri obtained his BA and MSc from the Università Roma Tre in 2006. He then attended the Courant Institute of Mathematical Sciences where he obtained his PhD in 2011. After his PhD, he received a Simons Postdoctoral Fellowship from Princeton University. Fabio was an instructor at Princeton until 2014, then an Assistant Professor from 2014 to 2018. He joined the University of Toronto in 2018.

Fabio’s ideas and methods have direct applications to a large class of physical settings such as fluid dynamics, quantum mechanics, plasma turbulence and general relativity. He has carried out groundbreaking research on global existence and regularity of solutions of equations that describe water waves, for the first time incorporating physical effects such as gravity and surface tension. He also has important results on a variety of other problems, including the stability of spatially periodic waves, and the long-time asymptotics of special solutions, such as solitary waves and kinks, for various canonical evolution PDEs.

Dr. Pusateri is an Assistant Professor at the University of Toronto. He has published several articles on fluid dynamics and the motion of water waves. Fabio is also interested in the development of multilinear harmonic analysis using the Fourier transform adapted to Schrodinger operators, with applications to the stability of special solutions (such as soliton and kinks) for nonlinear PDEs, and has published work on the topic. Currently, Dr. Pusateri is working on the subject of periodic waves in the context of wave turbulence. Fabio continuously makes valuable contributions to mathematics, and the CMS is delighted to present him with the 2022 Coxeter-James Prize.
PRIX COXETER JAMES
FABIO PUSATERI (UNIVERSITY OF TORONTO)

Professeur Fabio Pusateri a été nommé lauréat du prix Coxeter-James 2022 grâce à son travail dans l’Analyse des équations différentielles et équations aux dérivées partielles. Professeur Pusateri recevra son prix et donnera une conférence à la Réunion d’hiver de la SMC en décembre 2022.


Les idées et méthodes de Fabio s’appliquent directement à une large classe de cadres physiques tels que : la dynamique des fluides, la mécanique quantique, la turbulence dans le plasma et la relativité générale. Tout en incorporant, pour la première fois, les effets physiques comme la gravité et la tension superficielle, Fabio a mené des recherches novatrices au sujet de l’existence globale et la régularité des solutions aux équations qui décrivent des ondes aquatiques. Il a, en plus, de résultats importants concernant divers problèmes comme la stabilisation des ondes spatialement périodiques, et l’asymptotique de longue durée des solutions spécifiques comme les ondes solitaires et les entortillements, pour diverses équations aux dérivées partielles canoniques de progression.

Fabio Pusateri est professeur adjoint à l’University of Toronto. Il a publié plusieurs articles à propos de la dynamique des fluides et le mouvement des ondes aquatiques. Fabio s’intéresse aussi au développement de l’analyse harmonique multilinéaire en employant la transformée de Fourier adaptée aux opérateurs Schrödinger avec les applications à la stabilité des solutions spécifiques pour les EDP non linéaires. Actuellement, il s’occupe de la question des ondes périodiques au contexte de la turbulence d’ondes. Fabio continue à faire des contributions valables aux mathématiques et la SMC est heureuse de lui présenter le Prix Coxeter-James 2022.
Dr. Chih-Whi Chen (National Central University) and Dr. Kevin Coulembier (University of Sydney) are the recipients of the 2022 G. de B. Robinson Award for papers published in the Canadian Journal of Mathematics.

Dr. Chen and Dr. Coulembier are receiving the award for their joint paper “The Primitive Spectrum and Category for the Periplectic Lie Superalgebra.” (Canadian Journal of Mathematics, 72(3), 625-655. doi:10.4153/S0008441X18000081)

This paper solves two problems in representation theory for the periplectic Lie superalgebra $\mathfrak{pe}(n)$, namely, the description of the primitive spectrum in terms of functorial realizations of the braid group and the decomposition of category into indecomposable blocks.

Dr. Chih-Whi Chen completed his PhD in 2016 at National Taiwan University. He was a postdoctoral fellow at the National Center for Theoretical Sciences (2016-2017), then Uppsala University (2017-2018). Dr. Chen worked as an Assistant Professor at Xiamen University from 2018 to 2019, before returning to Taiwan, where he is currently an Assistant Professor of Mathematics at National Central University. His research interests lie in the fields of the representation theory of Lie algebras and Lie superalgebras.

Prof. Chih-Whi Chen a terminé son doctorat en 2016 à National Taiwan University. Il a été stagiaire postdoctoral au National Centre for Theoretical Sciences (2016-2017), puis à Uppsala University (2017-2018). M. Chen a travaillé comme professeur adjoint à Xiamen University de 2018 à 2019, avant de retourner à Taiwan, où il est actuellement professeur adjoint de mathématiques à National Central University. Ses intérêts de recherche se situent dans les domaines de la théorie des représentations des algèbres de Lie et des superalgèbres de Lie.

Dr. Kevin Coulembier obtained his PhD in 2011 from Ghent University in Belgium. Dr. Coulembier’s work focuses on representation theory and category theory. In 2021, he won a Christopher Heyde Medal from the Australian Academy of Science. Dr. Coulembier is currently an Associate Professor at the University of Sydney, where he has been employed since 2015.

CALL FOR NOMINATIONS:
CMS BLAIR SPEARMAN DOCTORAL PRIZE

Nominations are currently welcomed for the 2023 CMS Blair Spearman Doctoral Prize.

**Deadline:** January 31
The prize is awarded to one recipient of a Ph.D. from a Canadian university whose overall performance in graduate school is judged to be the most outstanding. Although the dissertation will be the most important criterion (the impact of the results, the creativity of the work, the quality of exposition, etc.) it will not be the only one. Other publications, activities in support of students and other accomplishments will also be considered.

Nominations that were not successful in the first competition, will be kept active for a further year (with no possibility of updating the file) and will be considered by the Doctoral Prize Selection Committee in the following year’s competition.

**Nominations**
CMS aims to promote and celebrate diversity in the broadest sense. We strongly encourage department chairs and nominating committees to put forward nominations for outstanding candidates for research in the mathematical sciences regardless of race, gender, ethnicity or sexual orientation.

Candidates must be nominated by their university and the nominator is responsible for preparing the documentation described below, and submitting the nomination to the address below. The deadline for the receipt of nominations is indicated above.

**The documentation shall consist of:**
- A curriculum vitae prepared by the student.
- A resumé of the student’s work written by the student and which must not exceed ten pages. The resumé should include a brief description of the thesis and why it is important, as well as of any other contributions made by the student while a doctoral student.
- Three letters of recommendation of which one should be from the thesis advisor and one from an external reviewer. A copy of the external examiner’s report may be substituted for the latter. More than three letters of recommendation are not accepted.

All documentation, including letters of recommendation, should be submitted electronically, preferably in PDF format, by the deadline date above, to docprize@cms.math.ca.
APPEL DE MISES EN CANDIDATURE
PRIX DOCTORAL SMC BLAIR SPEARMAN

Nous acceptons actuellement les mises en candidature pour le Prix de doctorat SMC Blair Spearman 2023.

Date limite : 31 janvier

Le prix sera décerné à une personne qui aura reçu son diplôme de troisième cycle d’une université canadienne l’année précédant sa mise en candidature (entre le 1er janvier et le 31 décembre) et dont les résultats pour l’ensemble des études supérieures seront jugés les meilleurs. La dissertation constituera le principal critère de sélection (impact des résultats, créativité, qualité de l’exposition, etc.), mais ne sera pas le seul aspect évalué. On tiendra également compte des publications de l’étudiant, de son engagement dans la vie étudiante et de ses autres réalisations.

Les mises en candidature qui ne seront pas choisies dans leur première compétition seront considérées pour une deuxième année (sans possibilité de mise à jour du dossier), et seront révisées par le Comité de sélection du prix de doctorat l’an prochain.

Candidatures
La SMC a pour but de promouvoir et de célébrer la diversité au sens le plus large. Nous encourageons fortement les directrices et les directeurs de départements et les comités de mise en candidature à proposer des candidats exceptionnels sans distinction de race, de genre, d’appartenance ethnique ou d’orientation sexuelle.

Les candidats doivent être nommés par leur université; la personne qui propose un candidat doit se charger de regrouper les documents décrits dans les paragraphes suivants et de faire parvenir la candidature à l’adresse ci-dessous. La date limite pour recevoir la candidature est indiqué ci-dessus.

Le dossier sera constitué des documents suivants :
- Un curriculum vitae rédigé par l’étudiant.
- Trois lettres de recommandation, dont une du directeur de thèse et une d’un examinateur de l’extérieur (une copie de son rapport serait aussi acceptable). Le comité n’acceptera pas plus de trois lettres de recommandation.

Veuillez faire parvenir tous les documents par voie électronique, de préférence en format PDF, avant la date limite à prixdoc@smc.math.ca.
CALL FOR SESSIONS:
2023 CMS SUMMER MEETING

Call for Scientific Sessions

The Canadian Mathematical Society (CMS) welcomes and invites session proposals for the 2023 CMS Summer Meeting in Ottawa from June 2 to 5, 2023.

- Sessions are scheduled in 2.5-hour blocks and take place **June 3-5, 2023**. Typical scientific sessions have between 10 and 20 talks of 30 minutes each but 1-hour talks are possible.
- In accordance with the CMS mandate to *propose conferences which are accessible and welcoming to all groups*, diversity amongst organizers and speakers is strongly encouraged. To support organizers in their important work and in their efforts towards inclusivity and diversity, the CMS will host an **open call for abstracts** for all sessions, and asks organizers to consider all eligible abstract submissions for their session.
- Diversity includes topics of interest, career stages, geographic location, and demographics; designated underrepresented groups include, but are not limited to, women, Indigenous Peoples, persons with disabilities, members of visible minority/racialized groups, and members of LGBTQ2+ communities.
- Note that there will be a separate follow-up call for **Education Sessions**.

**Proposals should include:**

1. Names, affiliations, and contact information for all session co-organizers. Early career researchers are encouraged to propose sessions.
2. A title and brief description of the topic and purpose of the session. This can include a brief overview of the subject. Include a two to three sentence summary that will be posted on the website for potential speakers.
3. The number of 2.5 hour blocks expected, with a list of possible speakers.

Proposals will be selected by the Scientific Organizing Committee, limited by available classroom space, with priority for sessions that show intention to include a mix of senior and junior researchers, to make parts of their session accessible to graduate students, and to include speakers from designated underrepresented groups.

**Deadlines:**

There will be two rounds of submissions. Proposals submitted by **Wednesday, December 14, 2022** to the Scientific Directors with the CMS Office in cc will be considered in the first round, with responses early in January. The deadline for the second round will be February 28, 2023.

Monica Nevins: mnevins@uottawa.ca
Aaron Tikuisis: Aaron.Tikuisis@uottawa.ca
CMS Office: meetings@cms.math.ca
APPEL DE SESSIONS: RÉUNION D'ÉTÉ DE LA SMC 2023

Appel de Sessions scientifiques

La Société mathématique du Canada (SMC) lance un appel de propositions de sessions pour la Réunion d’été 2023 de la SMC qui se tiendra à Ottawa du 2 au 5 juin 2023.

- Les sessions sont programmées en blocs de 2,5 heures, et auront lieu du 3 au 5 juin 2023. Les sessions scientifiques comprennent généralement entre 10 et 20 exposés de 30 minutes chacun, mais des exposés d’une heure sont possibles.
- Conformément au mandat de la SMC de proposer des conférences accessibles et accueillantes pour tous les groupes, la diversité parmi les organisateurs et les conférenciers est fortement encouragée. Afin de soutenir les organisateurs dans leur important travail et dans leurs efforts en faveur de l’inclusion et de la diversité, la SMC organisera un appel à résumés ouvert pour toutes les sessions, et demande aux organisateurs de prendre en compte toutes les soumissions de résumés éligibles pour leur session.
- La diversité comprend les sujets d’intérêt, les étapes de la carrière, l’emplacement géographique et les données démographiques ; les groupes sous-représentés désignés comprennent, sans s’y limiter, les femmes, les peuples autochtones, les personnes handicapées, les membres des minorités visibles/groupes racialisés et les membres des communautés LGBTQ2+.
- Il y aura un appel à propositions distinct pour les sessions d’éducation.

Les propositions doivent comprendre :

1. Les noms, affiliations et coordonnées des co-organisateurs de la session. Les chercheurs en début de carrière sont encouragés à proposer des sessions.
3. Le nombre de blocs de 2,5 heures prévus, avec une liste de conférenciers possibles.

Les propositions seront sélectionnées par le comité d’organisation scientifique, dans la limite de l’espace disponible en salle de classe, avec une priorité pour les sessions qui montrent l’intention d’inclure un mélange de chercheurs seniors et juniors, de rendre certaines parties de leur session accessibles aux étudiants diplômés, et d’inclure des orateurs de groupes sous-représentés désignés.

Dates limites :
Il y aura deux tours de soumissions. Les propositions soumises avant le mercredi 14 décembre 2022 aux directeurs scientifiques avec le bureau de la SMC en copie conforme seront considérées dans le premier tour, avec des réponses début janvier. La date limite pour le deuxième tour sera le 28 février 2023.

Monica Nevins: mnevins@uottawa.ca
Aaron Tikuisis: Aaron.Tikuisis@uottawa.ca
CMS Office: meetings@cms.math.ca
CALL FOR EDUCATION SESSIONS:
2023 CMS SUMMER MEETING

The Canadian Mathematical Society (CMS) welcomes and invites education session proposals for the 2023 CMS Summer Meeting in Ottawa from June 2th to 5th, 2023.

This year, the education session proposals will be selected by the CMS Meeting Education Session Committee, which will also schedule the accepted sessions, in communication with their co-organizers.

Each proposal should follow the guidelines indicated in the call for Scientific Sessions. In addition, organizers are asked to specify the structure of their session (e.g., 20-minute talk followed by 5 minute Q&A and 5 minute transition; or a panel, or interactive session/workshop, etc.).

In parallel to the Scientific Session Proposals, there will be two rounds of submissions. Proposals submitted by Wednesday, December 14th, 2022 will be considered in the first round, with responses early in January. The deadline for the second round will be February 28th, 2023.

Email education sessions proposals (and any questions) to:

Andie Burazin a.burazin@utoronto.ca

With Monica Nevins mnevins@uottawa.ca, Aaron Tikuisis Aaron.Tikuisis@uottawa.ca, and the CMS Office meetings@cms.math.ca in cc.

APPEL À PROPOSITIONS DE SESSIONS EN MATIÈRE D'ÉDUCATION
RÉUNION D'ÉTÉ DE LA SMC 2023

The Canadian Mathematical Society (CMS) welcomes and invites education session proposals for the 2023 CMS Summer Meeting in Ottawa from June 2th to 5th, 2023.

This year, the education session proposals will be selected by the CMS Meeting Education Session Committee, which will also schedule the accepted sessions, in communication with their co-organizers.

Each proposal should follow the guidelines indicated in the call for Scientific Sessions. In addition, organizers are asked to specify the structure of their session (e.g., 20-minute talk followed by 5 minute Q&A and 5 minute transition; or a panel, or interactive session/workshop, etc.).

In parallel to the Scientific Session Proposals, there will be two rounds of submissions. Proposals submitted by Wednesday, December 14th, 2022 will be considered in the first round, with responses early in January. The deadline for the second round will be February 28th, 2023.

Email education sessions proposals (and any questions) to:

Andie Burazin a.burazin@utoronto.ca

With Monica Nevins mnevins@uottawa.ca, Aaron Tikuisis Aaron.Tikuisis@uottawa.ca, and the CMS Office meetings@cms.math.ca in cc.
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CMS WINTER MEETING
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MITACS LECTURE | CONFÉRENCE MITACS
Dr. Suzanne Weekes (SIAM)

PLENARY LECTURES | CONFÉRENCES PLENIÈRES
Dr. Gigliola Staffilani (Massachusetts Institute of Technology)
Dr. Peter Shor (Massachusetts Institute of Technology)
Dr. Fok-Shuen Leung (University of British Colombia)

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Dr. Ada Chan (York University)
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PRIZE LECTURES | CONFÉRENCES DE PRIX

ADRIEN POULIOT AWARD | PRIX ADRIEN POULIOT
Dr. John Mighton, OC (Jump Math)

COXETER-JAMES PRIZE | PRIX COXETER-JAMES
Dr. Fabio Pusateri (University of Toronto)

DAVID BORWEIN AWARD | PRIX DAVID BORWEIN
Dr. Jacques Hurtubise (McGill University)

BLAIR SPEARMAN DOCTORAL PRIZE | PRIX DE DOCTORAT BLAIR SPEARMAN
Dr. Qin Deng (University of Toronto)
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AdvFIEl</td>
<td>Advances in Finite Elements &amp; Application to Solid and Fluid Mechanics</td>
</tr>
<tr>
<td>AlComRe</td>
<td>Algebraic Combinatorics and Representation Theory</td>
</tr>
<tr>
<td>AlgOpti</td>
<td>Algorithms and Complexity aspects of Optimization</td>
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<tr>
<td>AlSpecG</td>
<td>Algebraic and Spectral Graph Theory</td>
</tr>
<tr>
<td>AnaPDE</td>
<td>Analysis of PDEs</td>
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<tr>
<td>AproxTh</td>
<td>Approximation Theory, Function Spaces and Harmonic Analysis</td>
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<tr>
<td>CalVarA</td>
<td>Calculus of Variations and its Applications</td>
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<tr>
<td>CDySys</td>
<td>Control of dynamical systems</td>
</tr>
<tr>
<td>ComGeM</td>
<td>Complex Geometry and Moduli Space</td>
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<td>CommBIT</td>
<td>Community building in instructor training</td>
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<tr>
<td>DioArit</td>
<td>Diophantine Arithmetic Geometry and Number Theory</td>
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<tr>
<td>EduHype</td>
<td>Where are we on the mathematics and statistics education hype curve?</td>
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<tr>
<td>EduPlen</td>
<td>Education Plenary</td>
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<td>EnvGeo</td>
<td>Environmental and Geophysical Fluid Mechanics</td>
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<td>FacOpAl</td>
<td>Facets of Operator Algebras</td>
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<td>IncPrac</td>
<td>Inclusive Practices in Large Classes</td>
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<td>LowDimT</td>
<td>Low-dimensional Topology</td>
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<td>MachLea</td>
<td>Machine learning in finance</td>
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<tr>
<td>MatAna</td>
<td>Matrix Analysis and Operator Theory (Bilingual Session)</td>
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<td>MathBio</td>
<td>Topics in Mathematical Biology: Theory, Applications and Future Perspectives</td>
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<tr>
<td>MathMod</td>
<td>Mathematical Modeling and Analysis in Spatial Ecology and Epidemiology</td>
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<tr>
<td>MMacLea</td>
<td>Mathematics of machine learning</td>
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<td>PlenLec</td>
<td>Plenary Lectures</td>
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<td>PopDyna</td>
<td>Transient Behaviors in Population Dynamics</td>
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<td>Poster</td>
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<td>PubLec</td>
<td>Public Mitacs Lecture</td>
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<td>PurEvaG</td>
<td>Pursuit-evasion games on graphs</td>
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<td>QualInf</td>
<td>Quantum Information Theory</td>
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<tr>
<td>RecAdv</td>
<td>Recent advances on nonlinear evolution equations</td>
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<td>RepreTh</td>
<td>Representation Theory of Algebras</td>
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<tr>
<td>SetThe</td>
<td>Set theory and its applications</td>
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<tr>
<td>StochSy</td>
<td>Stochastic Systems, Probability, and Other Mathematical Aspects of Data Science</td>
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<td>StuResT</td>
<td>Student Research Talks</td>
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<tr>
<td>TopMeth</td>
<td>Topological Methods in Model Theory</td>
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<tr>
<td>VarAna</td>
<td>Variational Analysis: Applications and Theory</td>
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<tr>
<td>Date</td>
<td>Time</td>
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<tr>
<td>Friday Dec 2</td>
<td>12:00 - 16:30</td>
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<tr>
<td>Saturday Dec 3</td>
<td>11:00 - 15:00</td>
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<tr>
<td>Sunday Dec 4</td>
<td>10:00 - 14:00</td>
</tr>
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<td></td>
<td>15:00 - 17:00</td>
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## Schedule for Related Activities
### Horaire pour Activités connexes

### Friday December 2  
vendredi 2 décembre

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<tr>
<th>Time</th>
<th>Activity</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>8:00 - 20:00</td>
<td>Registration / Inscription</td>
<td>Churchill Court</td>
</tr>
<tr>
<td>14:30 - 15:00</td>
<td>Break / Pause</td>
<td>Churchill Court</td>
</tr>
<tr>
<td>18:00 - 19:30</td>
<td>Welcome Reception / Réception de bienvenue</td>
<td>Churchill Court</td>
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</tbody>
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### Saturday December 3  
samedi 3 décembre

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<th>Time</th>
<th>Activity</th>
<th>Location</th>
</tr>
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<tbody>
<tr>
<td>7:30 - 18:00</td>
<td>Registration / Inscription</td>
<td>Churchill Court</td>
</tr>
<tr>
<td>10:00 - 16:30</td>
<td>Exhibits / Expositions</td>
<td>Churchill Court</td>
</tr>
<tr>
<td>10:30 - 11:00</td>
<td>Break / Pause</td>
<td>Churchill Court</td>
</tr>
<tr>
<td>11:00 - 12:00</td>
<td>AARMS-CMS Student Poster Session / Session de présentation par affiches pour étudiants AARMS-SMC</td>
<td>Churchill Court</td>
</tr>
<tr>
<td>12:00 - 13:00</td>
<td>Equity and Diversity in Mathematics Luncheon / Dîner-causerie: Égalité et diversité en mathématiques</td>
<td>Mountbatten Salon</td>
</tr>
<tr>
<td>15:30 - 16:00</td>
<td>Break / Pause</td>
<td>Churchill Court</td>
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<tr>
<td>19:00 - 21:00</td>
<td>Student Social / Soirée étudiante</td>
<td>Twilight Cafe</td>
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### Sunday December 4  
dimanche 4 décembre

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<tbody>
<tr>
<td>7:30 - 18:00</td>
<td>Registration / Inscription</td>
<td>Churchill Court</td>
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<tr>
<td>10:00 - 16:30</td>
<td>Exhibits / Expositions</td>
<td>Churchill Court</td>
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<tr>
<td>10:30 - 11:00</td>
<td>Break / Pause</td>
<td>Churchill Court</td>
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<tr>
<td>15:00 - 15:30</td>
<td>Break / Pause</td>
<td>Churchill Court</td>
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<tr>
<td>19:00 - 22:30</td>
<td>Awards Banquet / Banquet de prix</td>
<td>Mountbatten Salon</td>
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### Monday December 5  
lundi 5 décembre

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<tr>
<td>7:30 - 18:00</td>
<td>Registration / Inscription</td>
<td>Churchill Court</td>
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<tr>
<td>10:30 - 11:00</td>
<td>Break / Pause</td>
<td>Churchill Court</td>
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<tr>
<td>14:30 - 15:00</td>
<td>Break / Pause</td>
<td>Churchill Court</td>
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<tr>
<td>Time</td>
<td>Event</td>
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<tr>
<td>8:00 - 20:00</td>
<td>Registration / Inscription, RelActi, Churchill Court</td>
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<tr>
<td>11:00 - 11:30</td>
<td>Henry Wolkowicz (Waterloo), <em>Regularized Nonsmooth Newton Algorithms for Best Approximation, with Applications</em>, VarAna (p. 176), Austen</td>
<td></td>
</tr>
<tr>
<td>11:30 - 12:00</td>
<td>Andersen Ang (Waterloo), <em>Multigrid proximal gradient method for convex optimization</em>, VarAna (p. 174), Austen</td>
<td></td>
</tr>
<tr>
<td>13:00 - 13:30</td>
<td>Hristo Sendov (Western), <em>Polar convexity and a refinement of the Gauss-Lucas theorem</em>, VarAna (p. 176), Austen</td>
<td></td>
</tr>
<tr>
<td>13:30 - 14:00</td>
<td>Walaa Mousi (Waterloo), <em>How to project onto the intersection of a closed affine subspace and a hyperplane</em>, VarAna (p. 175), Austen</td>
<td></td>
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<tr>
<td>14:00 - 14:30</td>
<td>Kennedy Idu (Toronto), <em>On Approximating Zeros of Monotone Operators in Banach Spaces</em>, VarAna (p. 175), Austen</td>
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<tr>
<td>14:30 - 15:00</td>
<td>Break / Pause, RelActi, Churchill Court</td>
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<tr>
<td>14:30 - 15:00</td>
<td>Phillip Braun (Western), <em>On the Hadamard-Fischer’s Inequality, the Inclusion-Exclusion Formula, and Bipartite Graphs</em>, VarAna (p. 174), Austen</td>
<td></td>
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<tr>
<td>15:00 - 15:30</td>
<td>Haesol Im (Waterloo), <em>Revisiting Degeneracy, Strict Feasibility, Stability in Linear Programming</em>, VarAna (p. 175), Austen</td>
<td></td>
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<tr>
<td>15:30 - 16:00</td>
<td>Fei Wang (Waterloo), <em>Singularity degree for non-facially exposed faces</em>, VarAna (p. 176), Austen</td>
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<tr>
<td>17:00 - 18:00</td>
<td>Dr. Suzanne L. Weekes (Society for Industrial and Applied Mathematics), <em>On the SIAM Convening on Climate Science, Clean Energy, and Sustainability</em>, PubLec (p. 37), Churchill Ballroom</td>
<td></td>
</tr>
<tr>
<td>18:00 - 19:30</td>
<td>Welcome Reception / Réception de bienvenue, RelActi, Churchill Court</td>
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Saturday December 3

7:30 - 18:00 Registration / Inscription, RelActi, Churchill Court

8:00 - 8:30 Yeganeh Bahoo (Toronto Metropolitan University), Visibility: Theory and Application, AnaPDE (p. 61), Rosetti A

8:00 - 8:30 Jason Bell (University of Waterloo), Intersections of orbits of self-maps with subgroups in semiabelian varieties, DioArit (p. 88), Carlyle B

8:00 - 8:30 Robert Stephen Cantrell (University of Miami), A two-stage reaction-diffusion system, MathBio (p. 159), Churchill Ballroom

8:00 - 8:30 Kenneth Davidson (University of Waterloo), Positive Maps and Entanglement in Real Hilbert Spaces, FacOpAl (p. 99), Scott B

8:00 - 8:30 Franklin Tall (University of Toronto), An undecidable extension of Morley’s theorem on the number of countable models, SetThe (p. 150), Baker

8:00 - 8:30 Peter Taylor (Queen’s University), How are we doing?, EduHype (p. 178), Whistler

8:30 - 9:00 Jason Crann (Carleton), Gaussian quantum information over general kinematical systems, QualInf (p. 135), Rosetti B

8:30 - 9:00 Michel Delfour (Université de Montréal), Three-dimensional model of paclitaxel release from biodegradable polymer films, AnaPDE (p. 62), Rosetti A

8:30 - 9:00 Remus Floricel (University of Regina), C*-subproduct and product systems, FacOpAl (p. 100), Scott B

8:30 - 9:00 Manuela Girotti (Saint Mary’s University), The dynamics soliton gasses: Fredholm determinants, asymptotics, and kinetic equations, RecAdv (p. 139), Duchesse

8:30 - 9:00 Keping Huang (MSU), Greatest Common Divisors on the Complement of Numerically Parallel Divisors, DioArit (p. 89), Carlyle B

8:30 - 9:00 Christopher Musco (New York University), Robust Active Learning via Leverage Score Sampling, MMacLea (p. 125), Rosetti C

8:30 - 9:00 Aleksandr Nikolov (University of Toronto), Computing and Using Factorization Norms, AlgOpti (p. 58), Wren A

8:30 - 9:00 Vinicius Rodrigues (York University), Special sets of reals and weakenings of normality in Isbell-Mrówka spaces, SetThe (p. 150), Baker

8:30 - 9:00 Michael Roysdon (CRM-ISM, Concordia), Weighted Projection Bodies, AproxTh (p. 69), Scott A

8:30 - 9:00 Sabrina H. Streipert (University of Pittsburgh), Introduction and Application of the Augmented Phase Portrait, MathBio (p. 164), Churchill Ballroom

8:30 - 9:00 Amanda Harsy, Marie Meyer, Michael Smith, Cara Sulyok, Grading with a Growth Mindset, EduHype (p. 178), Whistler

8:30 - 9:00 Milen Yakimov (Northeastern University), Poisson geometry and representation theory of root of unity quantum cluster algebras, RepreTh (p. 147), Carlyle A

9:00 - 9:20 Steve Boyer (UQAM), The JSJ graph of knot exteriors and the L-space conjecture, LowDimT (p. 106), Austen

9:00 - 9:30 Julien Arino (University of Manitoba), Backward bifurcation in an SLIARS model with vaccination, MathBio (p. 158), Churchill Ballroom

9:00 - 9:30 Kelvin Chan (York University), Recent progress on super harmonics, AlComRe (p. 45), Wren B

9:00 - 9:30 Cesar Corral (York University), Strong Fréchet properties, squares and AD families, SetThe (p. 149), Baker

9:00 - 9:30 Joshua Flynn (CRM-ISM, McGill), Helgason-Fourier Analysis and Sharp Geometric Inequalities on the Rank One Symmetric Spaces, AproxTh (p. 67), Scott A

9:00 - 9:30 Marcelo Laca (University of Victoria), Equilibrium on C*-algebras of product systems, FacOpAl (p. 101), Scott B

9:00 - 9:30 Rongjie Lai (Rensselaer Polytechnic Institute), Learning Manifold-structured Data using Deep networks: Theory and Algorithms, MMacLea (p. 124), Rosetti C

9:00 - 9:30 Jeremy Levick (Guelph), Generalizing a result of Watrous on Mixed Unitarity, QualInf (p. 137), Rosetti B

9:00 - 9:30 Alessandro Malusà (Toronto), Quantisation on hyper-Kähler spaces, ComGeM (p. 82), Gerrard

9:00 - 9:30 Matt Olechnowicz (University of Toronto), Dynamically improper hypersurfaces for endomorphisms of projective space, DioArit (p. 91), Carlyle B
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<th>Speaker</th>
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<tr>
<td>9:00 - 9:30</td>
<td>Kostya Pashkovich (University of Waterloo)</td>
<td>Non-Adaptive Matroid Prophet Inequalities For Minor-Closed Matroid Classes</td>
<td>AlgOpti (p. 59), Wren A</td>
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<td>9:00 - 9:30</td>
<td>Scott Rodney (Cape Breton University)</td>
<td>Bounded Solutions and Counterexamples</td>
<td>AnaPDE (p. 64), Rosetti A</td>
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<tr>
<td>9:00 - 9:30</td>
<td>Dan Wolczuk (University of Waterloo)</td>
<td>Fact, Fiction, or Fad?</td>
<td>Whistler</td>
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<td>9:00 - 10:00</td>
<td>Slim Ibrahim (University of Victoria)</td>
<td>Fact, Fiction, or Fad?</td>
<td>RecAdv (p. 140), Duchesse</td>
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<tr>
<td>9:10 - 9:40</td>
<td>Charles Paquette (Royal Military College)</td>
<td>Bisperial algebras and bricks</td>
<td>RepreTh (p. 145), Carlyle A</td>
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<tr>
<td>9:30 - 10:00</td>
<td>Alberto Cavallo (UQAM)</td>
<td>Slice links and smooth 4-manifolds</td>
<td>LowDimT (p. 107), Austen</td>
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<tr>
<td>9:30 - 10:00</td>
<td>Daniel Calderon (University of Toronto)</td>
<td>Borel's conjecture and meager-additive sets</td>
<td>SetThe (p. 149), Baker</td>
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<td>9:30 - 10:00</td>
<td>Oscar Dominguez (Universidad Complutense Madrid)</td>
<td>Truncated smooth function spaces</td>
<td>AproxTh (p. 67), Scott A</td>
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<td>9:30 - 10:00</td>
<td>Julie Jenkins (McMaster University)</td>
<td>On the Proof Complexity of Integer Programming Solvers</td>
<td>EduHype (p. 178), Whistler</td>
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<tr>
<td>9:30 - 10:00</td>
<td>Masoud Khalkhali (Western University)</td>
<td>Double scaling limits of Dirac ensembles and Liouville quantum gravity</td>
<td>FacOpAl (p. 100), Scott B</td>
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<tr>
<td>9:30 - 10:00</td>
<td>Michael Kozdron (Regina)</td>
<td>A Quantum Martingale Convergence Theorem</td>
<td>QualInf (p. 136), Rosetti B</td>
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<td>9:30 - 10:00</td>
<td>Nguyen Lam (Memorial University)</td>
<td>Sharp quantitative stability for the Uncertainty Principle</td>
<td>AnaPDE (p. 62), Rosetti A</td>
</tr>
<tr>
<td>9:30 - 10:00</td>
<td>Anthony Lazzeroni (Hong Kong Baptist University)</td>
<td>Powersum Bases in Quasisymmetric Functions and Quasisymmetric Functions Functions in Non-commuting Variables</td>
<td>AlComRe (p. 46), Wren B</td>
</tr>
<tr>
<td>9:30 - 10:00</td>
<td>Maxence Mayrand (Sherbrooke)</td>
<td>Twistor constructions of hyperkähler and hypercomplex structures near complex submanifolds</td>
<td>ComGeM (p. 82), Gerrard</td>
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<tr>
<td>9:30 - 10:00</td>
<td>Robert Robere (University of McGill)</td>
<td>On the Proof Complexity of Integer Programming Solvers</td>
<td>AlgOpti (p. 59), Wren A</td>
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<tr>
<td>9:30 - 10:00</td>
<td>Shigui Ruan (University of Miami)</td>
<td>Imperfect and Bogdanov-Takens Bifurcations in Biological Models: From Harvesting of Species to Removal of Infectives</td>
<td>MathBio (p. 163), Churchill Ballroom</td>
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<tr>
<td>9:30 - 10:00</td>
<td>Esha Saha (University of Waterloo)</td>
<td>SPADE4: Sparsity and Delay Embedding based Forecasting</td>
<td>MMacLea (p. 126), Rosetti C</td>
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<tr>
<td>9:30 - 10:00</td>
<td>Xiao Zhong (University of Waterloo)</td>
<td>p-Adic interpolation of orbits under rational maps</td>
<td>DioArit (p. 92), Carlyle B</td>
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<tr>
<td>9:50 - 10:20</td>
<td>Shaping Liu (Université de Sherbrooke)</td>
<td>Module categories with a null forth power of the radical</td>
<td>RepreTh (p. 145), Carlyle A</td>
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10:00 - 10:30 Yuming Zhao (Waterloo), *An operator-algebraic formulation of self-testing*, QuaInf (p. 138), Rosetti B
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15:00 - 15:30 Nathan Bendetto-Proença (University of Waterloo), *An approximation algorithm for the weighted fractional cut-covering problem*, AlgOpti (p. 57), Wren A
15:00 - 15:30 Monica Cojocaru (University of Guelph), *Individual risk and discomfort perceptions, NPI policies and the evolution of the pandemic in Ontario 2020*, MathBio (p. 160), Churchill Ballroom
15:00 - 15:30 Manuela Girotti (Saint Mary’s University), *Neural Networks Efficiently Learn Low-Dimensional Representations with SGD*, MMacLea (p. 124), Rosetti C
15:00 - 15:30 Sumun Iyer (Cornell University), *Dynamics of the Knaster continuum homeomorphism group*, SetThe (p. 150), Baker
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<td>Evolution of dispersal in advective patchy environments, Math-</td>
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16:30 - 17:00 Theodore Kolokolnikov (Dalhousie University), *Modelling of disease spread through heterogeneous population*, MathMod (p. 116)

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16:30 - 17:00 Alex Tung (University of Waterloo), *Cheeger Inequalities for Vertex Expansion and Rewighted Eigenvalues*, AlgOpti (p. 59), Wren A

16:30 - 17:00 Nancy Wallace (York University), *String decomposition of Parking functions*, AlComRe (p. 47), Wren B

16:30 - 17:30 Catherine Sulem (University of Toronto), *A Hamiltonian approach to nonlinear modulation of surface water waves in the presence of linear shear currents*, RecAdv (p. 141), Duchesse

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17:00 - 17:30 Thomas Hillen (University of Alberta), *Pattern formation in non-local population models*, MathMod (p. 116)

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17:00 - 17:30 Sebastian Moraga (Simon Fraser University), *Deep neural Networks are effective at learning high-dimensional Banach-valued functions from limited data*, MMacLea (p. 124), Rosetti C

17:00 - 17:30 Sebastian Dominguez Rivera (Siemens), *Eigenvalues in linear elasticity: theory and approximation*, AdvFIEl (p. 44), Wren C

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17:20 - 17:50 Charles Senécal (Université de Montréal), *Centralizers of products of $LU_q(sl_2)$-modules at roots of unity*, RepreTh (p. 146), Carlyle A

17:30 - 17:50 Homayun Karimi (McMaster), *Concordance invariants of null-homologous knots in thickened surfaces*, LowDimT (p. 108), Austen

17:30 - 18:00 Stephanie Abo (University of Waterloo), *Can the clocks tick together despite the noise? Stochastic simulations and analysis*, MathBio (p. 158), Churchill Ballroom

17:30 - 18:00 Aaron Berk (McGill University), *Compressed sensing with generative models and Fourier measurements: provable guarantees under incoherence*, MMacLea (p. 122), Rosetti C

17:30 - 18:00 Nicolas Doyon (Université Laval), *Finite element implementation of Poisson Nernst Planck equations in models of neural structures*, AdvFIEl (p. 42), Wren C
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17:00 - 17:30 Jacques Belair (University of Montreal), *Modelling the use of Fangsang shelter hospitals in Wuhan*, PopDyna (p. 170), Duchesse
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8:00 - 8:30  |  Pingping Cong (University of Western Ontario), *Dynamics of a three-species food chain model with fear effect*, StuResT (p. 155), Carlyle B

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8:00 - 8:30  |  Hanna Jankowski (York University), *The isotonic single index model under fixed and random designs*, StochSy (p. 153), Rosetti C

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8:25 - 8:50  |  Greg Lewis (Ontario Tech University), *Numerical continuation of amplitude-modulated rotating waves in sheared annular electroconvection*, EnvGeo (p. 95), Wren B

8:30 - 9:00  |  Elena Braverman (University of Calgary), *The influence of the choice of a diffusion strategy on the harvesting outcome for spatially heterogeneous populations*, MathMod (p. 114), Gerrard

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Radzimski, Vanessa, *A Team Teaching Model for Graduate Students’ Development as Instructors*, CommBIT (p. 78), Sunday December 4, 15:30 - 16:00, Wren C

Ransford, Thomas, *Constructive polynomial approximation*, AproxTh (p. 68), Saturday December 3, 15:00 - 15:30, Scott A

Rivera, Sebastian Dominguez, *Eigenvalues in linear elasticity: theory and approximation*, AdvFIEI (p. 44), Saturday December 3, 17:00 - 17:30, Wren C
Robere, Robert, *On the Proof Complexity of Integer Programming Solvers*, AlgOpti (p. 59), Saturday December 3, 9:30 - 10:00, Wren A

Rodney, Scott, *Bounded Solutions and Counterexamples*, AnaPDE (p. 64), Saturday December 3, 9:00 - 9:30, Rosetti A

Rodney, Scott, *More Limits of Orlicz Norms*, AproxTh (p. 68), Saturday December 3, 17:30 - 18:00, Scott A

Rodrigues, Vinicius, *Special sets of reals and weakenings of normality in Isbell-Mrówka spaces*, SetThe (p. 150), Saturday December 3, 8:30 - 9:00, Baker

Rosenblum, Erica, *Observed and simulated surface salinity under transitioning ice cover in the Canada Basin*, EnvGeo (p. 96), Monday December 5, 15:50 - 16:15, Wren B

Roy, Dan, *Admissibility is Bayes optimality with infinitesimals*, StochSy (p. 153), Monday December 5, 15:00 - 15:30, Rosetti C

Roy, Subham, *Generalized Mahler measure of Laurent polynomials*, DioArit (p. 91), Saturday December 3, 17:30 - 18:00, Carlyle B

Roysdon, Michael, *Weighted Projection Bodies*, AproxTh (p. 69), Saturday December 3, 8:30 - 9:00, Scott A

Ruan, Shigui, *Improper and Bogdanov-Takens Bifurcations in Biological Models: From Harvesting of Species to Removal of Infectives*, MathBio (p. 163), Saturday December 3, 9:30 - 10:00, Churchill Ballroom

Ruan, Shigui, *On the Dynamics of a Diffusive Foot-and-Mouth Disease Model with Nonlocal Infections*, MathMod (p. 118), Sunday December 4, 16:00 - 16:30

Ruscitti, Kaleb D., *The Verlinde formula for flat SU(2) connections using a toric degeneration*, Poster (p. 181)

Sacka, Katarina, *Applications of Next-Iterate Operators to Discrete Planar Maps*, Poster (p. 182)

Saha, Esha, *SPADE4: Sparsity and Delay Embedding based Forecasting*, MMacLea (p. 126), Saturday December 3, 9:30 - 10:00, Rosetti C

Saint-Aubin, Yvan, *Spin chains as modules over the affine Temperley-Lieb algebra*, RepreTh (p. 145), Saturday December 3, 17:50 - 18:20, Carlyle A

Salgado, Ivan, *Approximate Solutions to the Superconducting Interface Model*, CalVarA (p. 74), Monday December 5, 15:30 - 16:00, Austen

Salmani, Yurij, *Modelling habitat loss with partial differential equations: the effects of habitat fragmentation on survival and abundance*, MathMod (p. 118), Sunday December 4, 18:00 - 18:30

Sanchez, Dayanna, *Analyzing the Impact of Alternative Assessments and Growth Mindset*, Poster (p. 182)

Santacruz-Hidalgo, Alejandro, *Down spaces over a measure space with an ordered core*, AproxTh (p. 69), Saturday December 3, 18:30 - 19:00, Scott A

Santos, Gustavo Cicchini, *Understanding Non-Equilibrium Steady States*, StuResT (p. 156)

Santos, Gustavo Cicchini, *UNDERSTANDING NON-EQUILIBRIUM STEADY STATES*, Poster (p. 182)

Sawyer, Eric, *Sums of squares of functions and matrices with application to hypoellipticity in the infinitely degenerate regime*, AnaPDE (p. 64), Sunday December 4, 8:30 - 9:00, Rosetti A

Sawyer, Eric, *Two weight T1 theorems for Sobolev and Lp spaces with doubling measures and Calderón-Zygmund operators*, AproxTh (p. 69), Sunday December 4, 9:30 - 10:00, Scott A

Scandolo, Carlo Maria, *The operational foundations of PT-symmetric and quasi-Hermitian quantum theory*, QualInf (p. 138), Sunday December 4, 16:00 - 16:30, Rosetti B

Scarpa, Carlo, *Special representatives of complexified Kähler classes*, ComGeM (p. 83), Sunday December 4, 16:00 - 16:30, Rosetti C

Schmah, Tanya, *Diffeomorphic image matching with a preference for “simple” transformations*, MMacLea (p. 126), Saturday December 3, 16:30 - 17:00, Rosetti C

Sehnem, Camila Fabre, *A uniqueness theorem for Toeplitz algebras of semigroups*, FacOpAl (p. 102), Saturday December 3, 16:00 - 16:30, Scott B

Sendov, Hristo, *Polar convexity and a refinement of the Gauss-Lucas theorem*, VarAna (p. 176), Friday December 2, 13:00 - 13:30, Austen

Senécal, Charles, *Centralizers of products of \(L_U(q\mathfrak{sl}_2)\)-modules at roots of unity*, RepreTh (p. 146), Saturday December 3, 17:20 - 17:50, Carlyle A

Serhiyenko, Khristyna, *Title: Leclerc’s conjecture on a cluster structure for type A Richardson varieties*, RepreTh (p. 146), Sunday December 4, 9:10 - 9:40, Carlyle A
Shan, Chunhua, *Transmission dynamics and periodic phenomena in a model of West Nile virus with maturation time*, MathBio (p. 164), Saturday December 3, 17:00 - 17:30, Churchill Ballroom

Shen, Chifeng, *Bayesian Online Changepoint Detection in Finance*, MachLea (p. 112), Monday December 5, 8:30 - 9:00, Carlyle A

Shen, Xi Sisi, *The Continuity Equation on Hopf and Inoue Surfaces*, ComGeM (p. 83), Sunday December 4, 16:30 - 17:00, Rosetti C

Shen, Zhongwei, *Population dynamics under climate change*, MathMod (p. 118), Saturday December 3, 17:30 - 18:00

Shen, Zhongwei, *Coexistence in random environments*, MathBio (p. 164), Monday December 5, 10:00 - 10:30, Churchill Ballroom

Shevyakov, Alexey, *Analytical Properties of Nonlinear Partial Differential Equations in Fluid Dynamics and Beyond*, AnaPDE (p. 64), Saturday December 3, 17:30 - 18:00, Rosetti A

Shi, Jia, *On the analyticity of the Muskat equation*, RecAdv (p. 141), Sunday December 4, 9:30 - 10:00, Duchesse

Shi, Junping, *Evolution of dispersal in advective patchy environments*, MathMod (p. 118), Saturday December 3, 15:00 - 15:30

Shi, Junping, *Turing type bifurcation in reaction-diffusion models with nonlocal dispersal*, MathBio (p. 164), Sunday December 4, 15:30 - 16:00, Churchill Ballroom

Shi, Yujia, *Achieving strong state transfer using a bounded potential*, AlSpecG (p. 53), Saturday December 3, 16:30 - 17:00

Shirazi, Mahsa, *Graphs with r-friendship property*, AlSpecG (p. 54), Sunday December 4, 17:30 - 18:00

Shlapentokh-Rothman, Yakov, *Self-Similarity for the Einstein Vacuum Equations and Applications*, RecAdv (p. 141), Saturday December 3, 10:00 - 10:30, Duchesse

Shor, Dr. Peter, *Quantum Money*, PlenLec (p. 39), Sunday December 4, 11:00 - 12:00, Churchill Ballroom

Siefken, Jason, *Active Learning and the Novice Instructor*, CommBIT (p. 78), Sunday December 4, 16:00 - 16:30, Wren C

Sigal, Michael, *Vacuum solutions of the theory of electroweak interactions*, RecAdv (p. 141), Saturday December 3, 14:30 - 15:30, Duchesse

Sinnamon, Gord, *The Fourier transform in rearrangement-invariant spaces*, AproxTh (p. 69), Saturday December 3, 17:00 - 17:30, Scott A

Skoufranis, Paul, *Joint Majorization in Continuous Matrix Algebras*, FacOpAl (p. 102), Sunday December 4, 16:30 - 17:00, Scott B

Skryzio, Diana, *Universal Design for Learning in Stats*, IncPrac (p. 105), Monday December 5, 8:30 - 9:00, Wren C

Skryzio, Diana, *Discussion and Next Steps*, EduHype (p. 178), Whistler

Smith, Chrystal, *Natural Language Processing in the field of Medical Translation*, MMacLea (p. 126), Saturday December 3, 16:00 - 16:30, Rosetti C

Sobchuk, Maria, *Quantum isomorphisms*, AlSpecG (p. 54), Monday December 5, 16:00 - 16:30

Soltani, Farhad, AlComRe (p. 47), Saturday December 3, 17:00 - 17:30, Wren B

Sorya, Patrick, *Pentes caractérisantes et nœuds satellites / Characterizing slopes for satellite knots*, LowDimT (p. 109), Sunday December 4, 9:30 - 9:50, Austen

Speyer, David, *Coxeter groups and torsion classes of quiver and preprojective algebras*, RepreTh (p. 146), Sunday December 4, 15:30 - 16:00, Carlyle A

Stadt, Melissa Maria, *Impact of feedforward and feedback controls on potassium homeostasis: Mathematical modelling and analysis*, Poster (p. 183)

Staffilani, Dr. Gigliola, *A small window on wave turbulence theory*, PlenLec (p. 39), Saturday December 3, 11:00 - 12:00, Churchill Ballroom

Stantejsky, Dominik, *A finite element approach for minimizing line and surface energies arising in the study of singularities in liquid crystals*, CalVarA (p. 75), Monday December 5, 8:00 - 8:30, Austen

Stastna, Marek, *Rotation effects in long-thin lakes*, EnvGeo (p. 96), Monday December 5, 10:05 - 10:30, Wren B

Stoffregen, Matt, *Concordance of cables of the figure eight knot*, LowDimT (p. 109), Saturday December 3, 18:00 - 18:20, Austen

Streipert, Sabrina H., *Introduction and Application of the Augmented Phase Portrait*, MathBio (p. 164), Saturday December 3, 8:30 - 9:00, Churchill Ballroom

Sudweeks, Jaye, Matthew Coles & Katie Faulkner, *Incorporating sustained community building in graduate TA experience*, CommBIT (p. 77), Sunday December 4, 9:30 - 10:00, Wren C

Sui, Yaode, MachLea (p. 112), Carlyle A

Sulem, Catherine, *A Hamiltonian approach to nonlinear modulation of surface water waves in the presence of linear shear currents*, RecAdv (p. 141), Saturday December 3, 16:30 - 17:30, Duchesse
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Sulyok, Amanda Harsy, Marie Meyer, Michael Smith, Cara, *Grading with a Growth Mindset*, EduHype (p. 178), Saturday December 3, 8:30 - 9:00, Whistler

Sun, Ruiran, *Isotriviality of algebraic fiber spaces and the distribution of entire curves*, DioArit (p. 92), Saturday December 3, 16:00 - 16:30, Carlyle B

Sun, Wanting, *Perfect Laplacian state transfer in graphs*, AlSpecG (p. 54), Monday December 5, 9:00 - 9:30, Whistler

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Tall, Franklin, *An undecidable extension of Morley’s theorem on the number of countable models*, SetThe (p. 150), Saturday December 3, 8:00 - 8:30, Baker

Tang, Yun-chi, *On Knots That Divide Ribbon Knotted Surfaces*, Poster (p. 183)

Taylor, Peter, *How are we doing?*, EduHype (p. 178), Saturday December 3, 8:00 - 8:30, Whistler

Tétreault, Étienne, *Plethystic decomposition of a power of homogeneous symmetric functions*, AlComRe (p. 47), Saturday December 3, 15:00 - 15:30, Wren B

Theurer, Thomas, *Resource theories of operations*, QualInf (p. 138), Sunday December 4, 16:30 - 17:00, Rosetti B

Thind, Jaimal, *IncPrac* (p. 105), Monday December 5, 9:00 - 9:30, Wren C

Uriarte-Tuero, Ignacio, *Groupoids with prescribed torsion homology*, FacOpAl (p. 103), Saturday December 3, 14:30 - 15:00, Scott B

Todorov, Gordana, *Nakayama Algebras which are Defect Invariant*, RepreTh (p. 146), Saturday December 3, 16:40 - 17:10, Carlyle A

Trichtchenko, Olga, *RecAdv* (p. 141), Saturday December 3, 16:00 - 16:30, Duchesse

Tung, Alex, *Cheeger Inequalities for Vertex Expansion and Reweighted Eigenvalues*, AlgOpti (p. 59), Saturday December 3, 16:30 - 17:00, Wren A

Turner, Graeme & Anton Mosunov, *Following Principles of UDL When Authoring Electronic Textbooks and Auto-Graded Assessments*, IncPrac (p. 105), Monday December 5, 9:30 - 10:00, Wren C

U

Uggenti, Chelsea, *Training graduate teaching assistants on active learning*, CommBIT (p. 78), Sunday December 4, 9:00 - 9:30, Wren C

Uriarte-Tuero, Ignacio, *Two weight norm inequalities for singular and fractional integral operators in \( \mathbb{R}^n \)*, AproxTh (p. 70), Saturday December 3, 14:30 - 15:00, Scott A

Uriarte-Tuero, Ignacio, *An operator theoretic application of two weight norm inequalities for SIOs in \( \mathbb{R}^n \)*, MatAna (p. 130), Monday December 5, 10:00 - 10:30, Scott

Usatine, Jeremy, *Motivic integration for Artin stacks*, ComGeM (p. 83), Saturday December 3, 17:30 - 18:00, Gerrard

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Vafadar, Reihaneh, *On divergence-free (form-bounded type) drifts*, AnaPDE (p. 65), Sunday December 4, 9:00 - 9:30, Rosetti A

van Bommel, Christopher, *Perfect State Transfer on Trees with Small Diameter*, AlSpecG (p. 54), Monday December 5, 8:30 - 9:00, Whistler

Vasilyeva, Olga, *Phase-plane analysis of steady states of a spruce budworm model with advection*, MathMod (p. 119), Sunday December 4, 17:00 - 17:30

Verbeke, Yvon, *Automorphisms of the fine curve graph*, LowDimT (p. 109), Saturday December 3, 17:00 - 17:20, Austen

Verreault, William, *Series expansion via unwinding*, Poster (p. 183)

Vinet, Luc, *Bivariate \( P \)-polynomial association schemes*, AlSpecG (p. 55), Saturday December 3, 14:30 - 15:00

Vriend, Silas, *Infinite bubbles: a planar isoperimetric problem with two unbounded chambers*, StuResT (p. 156), Monday December 5, 10:00 - 10:30, Carlyle B

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Waite, Michael, *Viscous generation of potential enstrophy in breaking gravity waves*, EnvGeo (p. 97), Monday December 5, 16:40 - 17:05, Wren B

Wallace, Nancy, *String decomposition of Parking functions*, AlComRe (p. 47), Saturday December 3, 16:30 - 17:00, Wren B

Wang, Fei, *Singularity degree for non-facially exposed faces*, VarAna (p. 176), Friday December 2, 15:30 - 16:00, Austen

Wang, Hao, *Cognitive Animal Movement Modelling*, MathBio (p. 165), Monday December 5, 8:30 - 9:00, Churchill Ballroom
Wang, Hao, *Multi-scale and qualitative analysis of a stoichiometric algae model*, PopDyna (p. 171), Monday December 5, 15:00 - 15:30, Duchesse

Wang, Lin, *PopDyna* (p. 172), Duchesse

Wang, Weiqi, *Compressive Fourier collocation methods for high-dimensional diffusion equations with periodic boundary conditions*, MMacLea (p. 126), Sunday December 4, 10:00 - 10:30, Rosetti C

Wang, Zhichao, *Min-max minimal hypersurfaces with higher multiplicity*, CalVarA (p. 75), Monday December 5, 15:00 - 15:30, Austen

Watmough, James, *MathMod* (p. 119), Monday December 5, 15:30 - 16:00

Weekes, Dr. Suzanne L., *On the SIAM Convening on Climate Science, Clean Energy, and Sustainability*, PubLec (p. 37), Friday December 2, 17:00 - 18:00, Churchill Ballroom

Williams, Nicholas, *Cyclic polytopes and representation theory*, RepreTh (p. 147), Sunday December 4, 8:30 - 9:00, Carlyle A

Wilson, Alex, *A Diagram-Like Basis for the Multiset Partition Algebra*, AlComRe (p. 47), Saturday December 3, 14:30 - 15:00, Wren B

Wilson, Michael, *Smooth approximations to the d-dimensional Haar system*, AproxTh (p. 70), Sunday December 4, 9:00 - 9:30, Scott A

Wolczuk, Dan, *Fact, Fiction, or Fad?*, EduHype (p. 178), Saturday December 3, 9:00 - 9:30, Whistler

Wolf, Thomas, *Exact solitary wave solutions for a coupled gKdV-NLS system*, RecAdv (p. 141), Saturday December 3, 18:00 - 18:30, Duchesse

Wolkowicz, Gail, *Transient oscillations induced by delayed growth response in the chemostat*, PopDyna (p. 172), Sunday December 4, 9:00 - 9:30, Gerrard

Wolkowicz, Henry, *Regularized Nonsmooth Newton Algorithms for Best Approximation, with Applications*, VarAna (p. 176), Friday December 2, 11:00 - 11:30, Austen

Wong, Mike, *Ribbon homology cobordism*, LowDimT (p. 109), Saturday December 3, 18:30 - 18:50, Austen

Ye, Deping, *The Minkowski type problems for unbounded convex hypersurfaces*, AnaPDE (p. 65), Sunday December 4, 9:30 - 10:00, Rosetti A

Ye, Pei, *Complex Bifurcations of a Predator-Prey System with Allee Effect*, PopDyna (p. 172), Sunday December 4, 15:30 - 16:00, Duchesse

Zabanfahm, Sina, *Cluster pictures for Hitchin fibers of rank two Higgs bundles*, DioArit (p. 92), Saturday December 3, 17:00 - 17:30, Carlyle B

Zhan, Harmony, *The second largest eigenvalue of a tree*, AlSpecG (p. 55), Sunday December 4, 9:30 - 10:00, Whistler

Zhang, Jing, *SetThe* (p. 150), Saturday December 3, 16:00 - 16:30, Baker

Zhang, Xiaohong, *Constructing cospectral graphs*, AlSpecG (p. 55), Monday December 5, 16:30 - 17:00, Whistler
Talk List

Zhao, Xiaqiang, *Spatial Dynamics of Species with Annually Synchronized Emergence of Adults*, MathBio (p. 165), Sunday December 4, 10:00 - 10:30, Churchill Ballroom

Zhao, Yibin, *A Simple and Efficient Parallel Laplacian Solver*, AlgOpti (p. 59), Saturday December 3, 17:00 - 17:30, Wren A

Zhao, Yuming, *An operator-algebraic formulation of self-testing*, QualInf (p. 138), Saturday December 3, 10:00 - 10:30, Rosetti B

Zhao, Yuming, *There is no sum-of-squares certificate for positivity in tensor product of free algebras*, Poster (p. 183)

Zhong, Xiao, *p-Adic interpolation of orbits under rational maps*, DioArit (p. 92), Saturday December 3, 9:30 - 10:00, Carlyle B

Zhu, Huaiping, *MathBio* (p. 165), Monday December 5, 8:00 - 8:30, Churchill Ballroom

Zhu, Huaiping, *Dynamics of the asymptomatic infection in the spread of SARS-CoV-2*, PopDyna (p. 172), Monday December 5, 16:00 - 16:30, Duchesse

Zivkov, Eugene, *Thin liquid film stability in the presence of bottom topography and surfactant*, Poster (p. 183)

Zou, Xingfu, *Evolution of anti-predation response of prey in a general patchy environment*, MathMod (p. 119), Monday December 5, 15:00 - 15:30
Abstract/Résumé

DR. SUZANNE L. WEEKES, Society for Industrial and Applied Mathematics
[Friday December 2 / vendredi 2 décembre, 17:00 – Churchill Ballroom]
On the SIAM Convening on Climate Science, Clean Energy, and Sustainability

The Society for Industrial and Applied Mathematics (SIAM) hosted a 3-day workshop with a broad group of researchers and practitioners from various disciplines and from a variety of institutions and companies around the general theme of climate science, sustainability, and clean energy. The SIAM Convening on Climate Science, Sustainability, and Clean Energy engaged the scientific community in the identification and articulation of research needs related to these areas in order to explore what foundational long-term research and plans are needed over the next decade, and to give focused input to federal research and development agencies. In this talk, we highlight the recommendations that emerged.
Abstract/Résumé

DR. FOK-SHUEN LEUNG, University of British Columbia
[Monday December 5 / lundi 5 décembre, 11:00 – Churchill Ballroom]
Teaching Assistance

The MATH 10X Project at the University of British Columbia is an attempt to teach a very large number of students in an effective, authentic way. It uses the small class model, which has, at its core, groups of 3-5 students talking and writing mathematics. In this talk, we will describe how the model was developed and expanded, take a closer look at how individual students, TAs and instructors spoke up at crucial moments, and ask: "How can we make it easier for this to happen?"
Plenary Lectures  
Conférences plénières

Schedule/Horaire

Saturday December 3  
samedi 3 décembre
11:00 - 12:00  
Dr. GIGLIOLA STAFFILANI (Massachusetts Institute of Technology),  
*A small window on wave turbulence theory* (p. 39)

Sunday December 4  
dimanche 4 décembre
11:00 - 12:00  
Dr. PETER SHOR (Massachusetts Institute of Technology),  
*Quantum Money* (p. 39)

Abstracts/Résumés

**DR. PETER SHOR, MIT**  
[Sunday December 4 / dimanche 4 décembre, 11:00 – Churchill Ballroom]

*Quantum Money*

Quantum money is a quantum cryptograph protocol with several players, one of whom we call the mint. We assume all participants have quantum computers. For a quantum money protocol, we need

1. The mint must be able to create a quantum money state (with an associated serial number)
2. A merchant holding the quantum money state and knowing the serial number must be able to verify that it is a valid quantum money state.
3. An aspiring counterfeiter having both the quantum money and the serial number cannot create two states which both pass the verification test.

Quantum money was first proposed in 2009. Since then, a number of quantum money schemes have been proposed, several of which have been broken. We will discuss the history of quantum money and sketch how some of the schemes work.

**DR. GIGLIOLA STAFFILANI, Massachusetts Institute of Technology**  
[Saturday December 3 / samedi 3 décembre, 11:00 – Churchill Ballroom]

*A small window on wave turbulence theory*

Wave turbulence theory is a vast subject and its goal is to formulate for us a global picture of wave interactions. Phenomena involving interactions of waves happen at different scales and in different media: from gravitational waves to the waves on the surface of the ocean, from our milk and coffee in the morning to infinitesimal particles that behave like wave packets in quantum physics. These phenomena are difficult to study in a rigorous mathematical manner, but maybe because of this challenge mathematicians have developed interdisciplinary approaches that are powerful and beautiful. I will describe some of these approaches and show for example how the need to understand certain multilinear and periodic interactions gave also the tools to prove a famous conjecture in number theory, or how classical tools in probability gave the right framework to still have viable theories behind certain deterministic counterexamples.
Prize Lectures
Conférence des lauréats

Prize Lectures will be given by the laureates of the following awards:
Adrian Pouliot Award  David Borwein Award  Coxeter-James Prize  CMS Blair Spearman Doctoral Prize

Les conférences de prix seront donnés par les lauréats des prix suivants :
Prix Adrian Pouliot  Prix David Borwein  Prix Coxeter-James  Prix Doctoral SMC Blair Spearman

Schedule/Horaire

Room/Salle: Churchill Ballroom

Saturday December 3
13:30 - 14:30  Dr. John Mighton (JUMP Math), Solving the problem of equality with math (p. 40)

Sunday December 4
13:00 - 14:00  Dr. Fabio Pusateri (University of Toronto), Nonlinear PDEs with potentials and the stability of Solitons and Kinks (p. 41)
14:00 - 15:00  Dr. Jacques Hurtubise (McGill), Gauge theory, looking back. (p. 40)

Monday December 5
13:30 - 14:30  Dr. Qin Deng (Massachusetts Institute of Technology), Non-branching on metric measure spaces with Ricci curvature bounded below (p. 40)

Abstracts/Résumés

Prize Lectures

DR. QIN DENG, Massachusetts Institute of Technology
[Monday December 5 / lundi 5 décembre, 13:30 – Churchill Ballroom]

Non-branching on metric measure spaces with Ricci curvature bounded below

On a smooth Riemannian manifold, the uniqueness of a geodesic given initial conditions follows from standard ODE theory. In this talk, I will extend a version of this result to the setting of RCD(K,N) spaces, which are metric measure spaces satisfying a synthetic notion of Ricci curvature bounded below first introduced by Sturm-Lott-Villani. To do so, I will also generalize a well-known result of Colding-Naber concerning the Hölder continuity of the geometry of small balls along geodesics to this setting.

DR. JACQUES HURTUBISE, McGill
[Sunday December 4 / dimanche 4 décembre, 14:00 – Churchill Ballroom]

Gauge theory, looking back.

(or the Uses of instantons, with apologies to Sidney Coleman) When giving a talk linked to a career award, the obvious option is to review one’s own work. This can unfortunately be quite dull. Instead, I will try to review the evolution of a subject whose rise to prominence coincides roughly with the start of my career and which has insinuated itself into a surprising number of subjects of mathematics.
Dr. John Mighton, Jump Math

[Saturday December 3 / samedi 3 décembre, 13:30 – Churchill Ballroom]

Solving the problem of equality with math

New research in cognitive science suggests that math may be the most universally accessible and the most important subject for young brains. But a decade of significant investments in new technologies and curricula hasn’t significantly improved outcomes in math. We will discuss potential solutions to this problem including some key findings from the science of learning that could help us nurture the full intellectual potential of every student and create a more equitable and productive society.

Dr. Fabio Pusateri, University of Toronto

[Sunday December 4 / dimanche 4 décembre, 13:00 – Churchill Ballroom]

Nonlinear PDEs with potentials and the stability of Solitons and Kinks

Solitons are coherent structure that emerge from the balance of linear restoring forces and nonlinear focusing interactions in many physical models. They play a key role in our understanding of complex nonlinear systems and their time evolution. While the literature on classical (spatially localized) Solitons is very extensive, much less is known about Topological Solitons, which are typically non-localized structures. The simplest example of a Topological Soliton is a 1 dimensional ‘Kink’, a stationary solution which connects two different trivial states at plus and minus infinity.

The starting point for the analysis of all these coherent structures is the linearization of the equations in their vicinity. This naturally leads to study nonlinear evolution equations of wave/dispersive-type with large potentials. In this talk we will give an introduction to this class of problems, and present some recent results with applications to the stability of kinks and Solitons, and to the phenomenon of “Radiation Damping”. Our general approach is based on the use of the distorted Fourier transform, that is, the Fourier transform adapted to a Schrödinger operator, and the development of multilinear Harmonic Analysis in this setting.

This talk is based on joint works with P. Germain (Imperial), F. Rousset (Paris-Saclay Orsay), A. Soffer (Rutgers), G. Chen (Georgia Tech), T. Léger (Princeton), Z. Zhang (NYU), A. Kairzhan (U of Toronto).
Advances in Finite Elements & Application to Solid and Fluid Mechanics
Progrès des éléments finis et application à la mécanique des solides et des fluides

Org: Javier Almonacid and Nilima Nigam (SFU)

"The finite element method continues to be of great importance in the numerical solution of partial differential equations. Increasingly complex applications in areas such as cardiac and muscle mechanics, viscoelastic materials, fluid-structure interaction, and magnetohydrodynamics (to name a few) have led to new and important results in the study of this numerical method. In this session, we will invite researchers from diverse areas to present their latest advances on finite elements and applications to problems in continuum mechanics. Talks can range from theoretical aspects of the finite element method to applications of already-known finite elements in fluid and solid mechanics."

"La méthode des éléments finis continue de revêtir une grande importance dans la résolution numérique des équations différentielles partielles. Des applications de plus en plus complexes dans des domaines tels que la mécanique cardiaque et musculaire, les matériaux viscoélastiques, l’interaction fluide-structure et la magnétohydrodynamique (pour n’en citer que quelques-uns) ont conduit à des résultats nouveaux et importants dans l’étude de cette méthode numérique. Au cours de cette session, nous inviterons des chercheurs de divers domaines à présenter leurs dernières avancées sur les éléments finis et leurs applications à des problèmes de mécanique des milieux continus. Les présentations peuvent aller des aspects théoriques de la méthode des éléments finis aux applications d’éléments finis déjà connus en mécanique des fluides et des solides."

Schedule/Horaire

Saturday December 3 / samedi 3 décembre

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Lilia Krivodonova (University of Waterloo), Stabilization techniques for solution of hyperbolic conservation laws on unstructured nonconforming meshes (p. 43)

15:00 - 15:30
Jose Pablo Lucero Lorca (University of Colorado Boulder), Nonoverlapping Schwarz Preconditioners in linear and nonlinear settings applied to radiation transport problems. (p. 43)

16:00 - 16:30
Keegan Kirk (Rice University), Convergence analysis of a pressure-robust space-time HDG method for incompressible flows (p. 43)

16:30 - 17:00
Conor McCoid (Université Laval), Robust algorithm for the intersection of simplices (p. 44)

17:00 - 17:30
Sebastian Dominguez Rivera (Siemens), Eigenvalues in linear elasticity: theory and approximation (p. 44)

17:30 - 18:00
Nicolas Doyon (Université Laval), Finite element implementation of Poisson Nernst Planck equations in models of neural structures (p. 42)

18:00 - 18:30
Javier Almonacid (Simon Fraser University), Finite-element discretization of a 3D hyperelastic model of skeletal muscle (p. 42)

Abstracts/Résumés

JAVIER ALMONACID, Simon Fraser University

[Saturday December 3 / samedi 3 décembre, 18:00 – Wren C]

Finite-element discretization of a 3D hyperelastic model of skeletal muscle

Recent studies on whole-muscle biomechanics have shown the importance of mass and inertial effects on muscle function. Because traditional models based on massless springs cannot capture these features, we must turn our attention to continuum-based three-dimensional models. In this talk, we will discuss the discretization process of a dynamical model that views skeletal muscle as a hyperelastic (nonlinear) deformable solid. From a mechanical perspective, this material is quasi-incompressible, transversely isotropic, and can be deformed by the action of active and passive forces. We will go over the different types of approximations (physiological and numerical) that must be considered to make the equations more tractable. The three-field formulation is discretized in space using a standard second-order finite element. In addition, we will discuss the Newton-Krylov strategy used to solve the set of nonlinear equations.
NICOLAS DOYON, Laval University
[Saturday December 3 / samedi 3 décembre, 17:30 – Wren C]

Finite element implementation of Poisson Nernst Planck equations in models of neural structures

Signaling in neural structures is determined by the movement of ions subjected to an electrical field which is best described by the Nernst Planck partial differential equations. The distribution of ionic concentrations in turns determines the electric field through the Poisson equation. The coupling of these equations gives rise to the Poisson Nernst-Planck (PNP) system of partial differential equations. To complete the picture, the opening of transmembrane channels describing the boundary conditions are often given by systems of ordinary differential equations involving the electrical field. In this talk, we present a model describing the evolution of ionic concentrations in a node of Ranvier using PNP equations together with Hodgkin-Huxley equations describing dynamics of transmembrane voltage-gated channels. Solving this model gives rise to many numerical difficulties. For one, small imbalances in ionic concentrations can have a huge impact on the electrical field making it difficult to treat the problem as a fully coupled one. Second, the elongated geometries of structures such as axons or nodes of Ranvier makes difficult the construction of an efficient spatial mesh. Finally, the presence of a mostly impermeable membrane leads to solutions being non differentiable and exhibiting steep variations near the membrane cytosol interface. We will see how to tackle some of these difficulties in particular by using automatic mesh adaptation. We will also discuss the relevance of related models and how they can be used in other contexts such as the description of cardiac cells and presynaptic vesicles.

KEEGAN KIRK, Rice University
[Saturday December 3 / samedi 3 décembre, 16:00 – Wren C]

Convergence analysis of a pressure-robust space-time HDG method for incompressible flows

Much of the recent progress in the numerical solution of incompressible flow problems has concentrated on pressure-robust finite element methods, a class of mimetic methods that preserve a fundamental invariance property of the incompressible Navier–Stokes equations. Two essential ingredients are required for pressure-robustness: exact enforcement of the incompressibility constraint, and H(div)-conformity of the finite element solution.

In this talk, I will introduce a space-time hybridized discontinuous Galerkin finite element method for the evolutionary incompressible Navier–Stokes equations. The numerical scheme has a number of desirable properties, including pointwise mass conservation, energy stability, and higher-order accuracy in both space and time. Through the introduction of a pressure facet variable, $H(div)$-conformity of the discrete velocity solution is enforced, ensuring the numerical scheme is pressure-robust. Well-posedness of the resulting nonlinear algebraic system will be considered, and uniqueness of the discrete solution will be shown in two spatial dimensions under a small data assumption. A priori error estimates for smooth solutions will be presented, as well as convergence to weak solutions in the sense of Leray and Hopf using compactness results for discontinuous Galerkin methods.

LILIA KRIVODONOVA, University of Waterloo
[Saturday December 3 / samedi 3 décembre, 14:30 – Wren C]

Stabilization techniques for solution of hyperbolic conservation laws on unstructured nonconforming meshes

In order to resolve fine features of a numerical solution, run-time mesh refinement might be required. Commonly used refinement strategies aimed at preserving mesh quality result in nonconforming meshes, i.e. meshes where a larger element might share an edge with several smaller elements. In this talk we will address solution stabilization techniques on such meshes using limiters. Limiting is a technique aimed at suppressing nonphysical oscillations in a numerical solution in the presence of shocks and steep solution gradients. Limiting on nonconforming meshes is difficult due to lack of structure in the mesh and because most limiting algorithms were developed for conforming meshes. The proposed limiter modifies solution coefficients (or moments) by reconstructing the slopes along a set of directions in which the moments decouple. The resulting solutions satisfy the local maximum principle (LMP) for scalar problems, i.e. are stable in the maximum norm. We show that our algorithm is efficient for solution of nonlinear hyperbolic systems such as Euler equations and scales well when implemented on GPUs.
JOSE PABLO LUCERO LORCA, University of Colorado at Boulder
[Saturday December 3 / samedi 3 décembre, 15:00 – Wren C]
Nonoverlapping Schwarz Preconditioners in linear and nonlinear settings applied to radiation transport problems.

We explore the application of multilevel, nonoverlapping domain decomposition to solve integro-differential problems of radiation transport colliding in media with the inclusion of a local thermodynamic equilibrium (LTE) nonlinearity. We discretize using discontinuous Galerkin finite elements, making the local problems small versions of the global problem.

By including a coarse space and minimizing the size of the local domains but ordering the application of the local solvers, we robustly achieve a constant amount of iterations for a fixed residual reduction in all regimes. We sequentially sweep local solves when collisions are low, and solve in parallel when they are high.

Our implementation takes advantage of the achievable parallelization while sweeping and complete parallelization while in the high-collision regime. With this preconditioner architecture, we apply the same philosophy for local non-linear solves, which are shown to be very effective for a local nonlinearity such as LTE and are promising for problems where the nonlinearity effect has a dominant direction.

CONOR MCCOID, Université Laval
[Saturday December 3 / samedi 3 décembre, 16:30 – Wren C]
Robust algorithm for the intersection of simplices

For some applications it is commonplace to use multiple grids in a single finite element solver. For example, in fluid-structure coupling a grid for the structure can be used separate from the grid for the fluid. This may occur as a 2D interface or, in the case of 3D mortar methods, the intersection of tetrahedral meshes. It is then essential to be able to project between simplicial meshes as robustly as possible. This talk presents an intersection algorithm designed to do just that between two simplicial grids in general dimension, making use of the principle of parsimony, with a focus on 2D and 3D grids.

SEBASTIAN DOMINGUEZ RIVERA, Siemens
[Saturday December 3 / samedi 3 décembre, 17:00 – Wren C]
Eigenvalues in linear elasticity: theory and approximation

In this talk we will discuss some eigenproblems regarding the Lamé operator for linear elasticity. Based on recent work, we consider different types of eigenvalue problems, including Steklov eigenvalues in elasticity, normal-tangential (where the normal component of the traction and the tangential component of the displacement are set to zero on the boundary) and tangential-normal (where the tangential component of the traction and the normal component of the displacement are set to zero on the boundary). We will cover theory, including some new types of Korn’s inequality, and the approximation of these eigenpairs with the use of the finite element method.
Algebraic Combinatorics and Representation Theory
Combinatoire algébrique et théorie des représentations

Org: Nantel Bergeron and/et Mike Zabrocki (York)

This session will focus on applications of combinatorics to algebraic structures and representation theory. Algebra is discrete by nature and describing structures such as bases and linear operations using combinatorial objects (e.g. sets, partitions, paths, etc.) is important for understanding basic properties.

Cette session se concentrera sur les applications de la combinatoire aux structures algébriques et à la théorie des représentations. L’algèbre est discrète par nature et la description de structures telles que les bases et les opérations linéaires à l’aide d’objets combinatoires (par exemple, les ensembles, les partitions, les chemins, etc.) est importante pour comprendre les propriétés de base.

Schedule/Horaire

Saturday December 3 samedi 3 décembre

9:00 - 9:30 Kelvin Chan (York University), Recent progress on super harmonics (p. 45)
9:30 - 10:00 Anthony Lazzeroni (Hong Kong Baptist University), Powersum Bases in Quasisymmetric Functions and Quasisymmetric Functions in Non-commuting Variables (p. 46)
10:00 - 10:30 Kevin Purbhoo (University of Waterloo), The MTV machine (p. 46)
14:30 - 15:00 Alex Wilson (Dartmouth College), A Diagram-Like Basis for the Multiset Partition Algebra (p. 47)
15:00 - 15:30 Étienne Tétreault (Université du Québec à Montréal), Plethystic decomposition of a power of homogeneous symmetric functions (p. 47)
16:00 - 16:30 Lucas Gagnon (York University), Unipotent symmetric functions (p. 46)
16:30 - 17:00 Nancy Wallace (York University), String decomposition of Parking functions (p. 47)
17:00 - 17:30 Farhad Soltani (York University) (p. 47)
17:30 - 18:00 GaYee Park (Université du Québec à Montréal), Minimal skew semistandard Young tableaux and the Hillman–Grassl correspondence (p. 46)
18:00 - 18:30 Baptiste Louf (Université du Québec à Montréal) (p. 46)
18:30 - 19:00 François Bergeron (Université du Québec à Montréal), The Super $\nabla$-Operator (p. 45)

Abstracts/Résumés

FRANÇOIS BERGERON, UQAM

[Saturday December 3 / samedi 3 décembre, 18:30 – Wren B]

The Super $\nabla$-Operator

I will describe a super version of the $\nabla$ operator on the combinatorial Macdonald polynomials: $\tilde{H}_\mu(x)$. For an extra set of variables $y$, it is obtained by considering $\tilde{H}_\mu(y)$ as an “eigenvalue” for $\tilde{H}_\mu(x)$. After explaining why this new operator naturally contains and generalizes all instances of the operators involved in the $\Delta$-conjecture, we will establish some of its properties. If time allows, we will discuss how to “lift” it to more parameters than just $q$ and $t$, and associated implications regarding a bosonic-fermionic duality. This is joint work with J. Haglund, A. Iraci, and M. Romero.

KELVIN CHAN, York University

[Saturday December 3 / samedi 3 décembre, 9:00 – Wren B]

Recent progress on super harmonics
Super harmonics $\text{SH}_n$ are anti-commuting variants of diagonal harmonics. The space $\text{SH}_n$ is a symmetric group module whose dimension is conjectured to be counted by ordered set partitions. It is also conjectured by Zabrocki (arXiv:1902.08966) to yield a representation theoretic interpretation in superspace of the Delta Theorem at $t = 0$. In this talk, we introduce a conjectured basis informed by a bijection on packed words and discuss some recent progress.

**LUCAS GAGNON**, York University

[Saturday December 3 / samedi 3 décembre, 16:00 – Wren B]

*Unipotent symmetric functions*

Symmetric functions are often thought of in relation to the representation theory of the symmetric groups, but they also have a representation theoretic connection to unipotent objects for the general linear groups over a finite field, $\text{GL}_n(\mathbb{F}_q)$. In this talk I will describe how this connection can be used to realize two well known symmetric functions, the chromatic quasisymmetric function of an indifference graph and the unicellular LLT polynomial, via certain $\text{GL}_n(\mathbb{F}_q)$ representations. The representations in question arise naturally from an investigation of the subgroup $\text{UT}_n(\mathbb{F}_q)$ of unipotent upper triangular matrices, and this process suggests a more general method of constructing families of symmetric functions. As an added bonus, this construction also gives a new perspective on the relationship between chromatic quasisymmetric functions and unicellular LLT polynomials.

**ANTHONY LAZZERONI**, Hong Kong Baptist University

[Saturday December 3 / samedi 3 décembre, 9:30 – Wren B]

*Powersum Bases in Quasisymmetric Functions and Quasisymmetric Functions in Non-commuting Variables*

We introduce a new $P$ basis for the Hopf algebra of quasisymmetric functions that refine the symmetric powersum basis. Unlike the quasisymmetric power sums of types 1 and 2, our basis is defined combinatorially: its expansion in quasisymmetric monomial functions is given by fillings of matrices. This basis has a shuffle product, a deconcatenate coproduct, and has a change of basis rule to the quasisymmetric fundamental basis by using tuples of ribbons. We lift our quasisymmetric powersum $P$ basis to the Hopf algebra of quasisymmetric functions in non-commuting variables by introducing fillings with disjoint sets. This new basis has a shifted shuffle product and a standard deconcatenate coproduct, and certain basis elements agree with the fundamental basis of the Malvenuto-Reutenauer Hopf algebra of permutations.

**BAPTISTE LOUF**, Université du Québec à Montréal

[Saturday December 3 / samedi 3 décembre, 18:00 – Wren B]

**GAYEE PARK**, UQAM

[Saturday December 3 / samedi 3 décembre, 17:30 – Wren B]

*Minimal skew semistandard Young tableaux and the Hillman–Grassl correspondence*

Standard tableaux of skew shape are fundamental objects in enumerative and algebraic combinatorics and no product formula for the number is known. In 2014, Naruse gave a formula as a positive sum over excited diagrams of products of hook-lengths. In 2018, Morales, Pak, and Panova gave a $q$-analogue of Naruse's formula for semi-standard tableaux of skew shapes. They also showed, partly algebraically, that the Hillman-Grassl map restricted to skew shapes gave their $q$-analogue. We study the problem of making this argument completely bijective. For a skew shape, we define a new set of semi-standard Young tableaux, called the *minimal SSYT*, that are equinumerous with excited diagrams via a new description of the Hillman–Grassl bijection and have a version of excited moves. Lastly, we relate the minimal skew SSYT with the terms of the Okounkov-Olshanski formula for counting SYT of skew shape. This is joint work with Alejandro Morales and Greta Panova.
**KEVIN PURBHOO, University of Waterloo**  
*Saturday December 3 / samedi 3 décembre, 10:00 – Wren B*

**The MTV machine**

Mukhin, Tarasov and Varchenko developed a "machine" for solving certain algebraic systems of equations, which arise in several places, including: Schubert calculus, algebraic curves, linear series, Wronskians of polynomials, mathematical physics, differential equations, and control theory. The machine is quite remarkable. Essentially, it transforms a hard system of algebraic equations into an easy system of differential equations. In this talk, I will attempt to explain how the machine works, and offer a new explanation for why it works.

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**FARHAD SOLTANI, York University**  
*Saturday December 3 / samedi 3 décembre, 17:00 – Wren B*

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**ETIENNE TÉTREAULT, Université du Québec à Montréal**  
*Saturday December 3 / samedi 3 décembre, 15:00 – Wren B*

**Plethystic decomposition of a power of homogeneous symmetric functions**

The composition of (polynomial) representations of $\text{GL}_n$ defines an operation, called plethysm, on associated characters. It is well-known that the decomposition of such a plethysm in irreducible characters is a hard problem, and we have no nice combinatorial description in general.

All this may be formulated in terms of symmetric functions, with Schur functions corresponding to irreducible characters. We consider the problem of decomposing, in the Schur basis, the plethysm $s_\mu[h_\lambda]$, where $s_\mu$ is a Schur function and $h_\lambda$ a complete homogeneous symmetric function.

We approach this in the following way. Let $m$ be an integer. We can write $h_\lambda^m$ as a sum of plethysms $s_\mu[h_\lambda]$, one for each standard tableau of shape $\mu$, for all partitions $\mu$ of $m$. Also, we know that the decomposition of $h_\lambda^m$ is given by tableaux of content $\lambda^m$. Our conjecture is that the we can assign to thoses tableaux a type, which tells us in which plethysm the Schur function associated to this tableau appears. We show that to do so, we only need to consider $h_\mu^m$, and to construct what we call a Kronecker map, which involve a knowledge of the Kronecker coefficients.

In this talk, we quickly describe the problematic, and describe some exciting new advances toward the resolution of the conjecture. We also expose setbacks and limits which restrict us in our research.

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**NANCY WALLACE, York University**  
*Saturday December 3 / samedi 3 décembre, 16:30 – Wren B*

**String decomposition of Parking functions**

The search for the irreducible bicharacters for the space of diagonal harmonics, the search for a bijection that inverts the statistics area and bounce (or dinv) in the $(q,t)$-Catalan formula of Garsia and Haiman or the $(q,t)$-Schröder formula of Haglund, and the more recent search for a basis for the diagonal harmonic alternants of Garsia and Zabrocki, all relate to the decomposition of these into strings that preserve the bidegree. In this talk we will give partial results on such a decomposition.

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**ALEX WILSON, Dartmouth College**  
*Saturday December 3 / samedi 3 décembre, 14:30 – Wren B*

**A Diagram-Like Basis for the Multiset Partition Algebra**

There’s a classical connection between the representation theory of the symmetric group and the general linear group called Schur-Weyl Duality. Variations on this principle yield analogous connections between the symmetric group and other objects...
such as the partition algebra and more recently the multiset partition algebra. The partition algebra has a well-known basis indexed by graph-theoretic diagrams which allows the multiplication in the algebra to be understood visually as combinations of these diagrams. I will present an analogous basis for the multiset partition algebra and show how this basis can be used to describe generators and construct representations for the algebra.
Algebraic and Spectral Graph Theory
Théorie algébrique et spectrale des graphes

Org: Jane Breen (Ontario Tech), Sooyeong Kim (York), Hermie Monterde (Manitoba) and/or Xiaohong Zhang (Waterloo)

"The interplay of graphs and matrices is long-established in the fields of algebraic graph theory, spectral graph theory, and combinatorial matrix theory. In algebraic graph theory, properties of a graph are determined by studying features of an associated algebraic structure; in spectral graph theory, a graph is represented by a matrix and studied via its eigenvalues; in contrast, in combinatorial matrix theory, properties of a matrix are determined from its combinatorial structure - that is, by studying properties of an associated graph. Techniques from all three fields have a wide range of applications, from quantum computing, to network science, to dynamical systems. Furthermore, research in these fields has long been prevalent in Canada, with strong collaborations among mathematicians across the country, and between these fields too. "

"L’interaction entre les graphes et les matrices est établie depuis longtemps dans les domaines de la théorie algébrique des graphes, de la théorie spectrale des graphes et de la théorie combinatoire des matrices. Dans la théorie algébrique des graphes, les propriétés d’un graphe sont déterminées par l’étude des caractéristiques d’une structure algébrique associée ; dans la théorie spectrale des graphes, un graphe est représenté par une matrice et étudié par ses valeurs propres ; en revanche, dans la théorie combinatoire des matrices, les propriétés d’une matrice sont déterminées à partir de sa structure combinatoire, c’est-à-dire par l’étude des propriétés d’un graphe associé. Les techniques de ces trois domaines ont un large éventail d’applications, de l’informatique quantique à la science des réseaux, en passant par les systèmes dynamiques. De plus, la recherche dans ces domaines est depuis longtemps répandue au Canada, avec de fortes collaborations entre les mathématiciens de tout le pays, et entre ces domaines également. "

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### Algebraic and Spectral Graph Theory

**Monday December 5**

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### Abstracts/Résumés

**ROBERT F. BAILEY**, Grenfell Campus, Memorial University  
[Monday December 5 / lundi 5 décembre, 15:00]

*Cataloguing strongly regular graphs with primitive automorphism groups*

A graph is **strongly regular** with parameters \((n, k, \lambda, \mu)\) if it has \(n\) vertices, is \(k\)-regular, and two vertices have either \(\lambda\) or \(\mu\) common neighbours depending on whether or not they are adjacent. This is equivalent to a \(k\)-regular graph having exactly three eigenvalues, namely \(k\) and two others which can be calculated explicitly from the parameters, as can their multiplicities.

Many well-known examples of strongly regular graphs arise from group actions. The GAP computer algebra system contains libraries of primitive groups (i.e. those which preserve no interesting equivalence relations) on up to 4095 points. We discuss a detailed analysis of these libraries to catalogue the strongly regular graphs (and the more general class of distance-regular graphs) which arise from these groups: while most of the graphs were already known, a few surprises which came up along the way, and some interesting questions (both theoretical and computational) remain open.

This is joint work with my NSERC USRA students Alaina Pardy and Abigail Rowsell.

**STEVE BUTLER**, Iowa State University  
[Sunday December 4 / dimanche 4 décembre, 9:00]

*Complements of coalescing sets*

Given graphs \(H_1, H_2\) with \(B_1 \subseteq V(H_1), B_2 \subseteq V(H_1)\) we say that \((H_1, B_1)\) and \((H_2, B_2)\) are coalescing cospectral if attaching any rooted graph \(G\) onto the vertices of \(B_1\) in \(H_1\) and onto the vertices of \(B_2\) in \(H_2\) always results in cospectral graphs (with respect to some designated matrix associated with the graphs, e.g. adjacency, Laplacian, ...); we denote this by \((H_1, B_1) \sim (H_2, B_2)\). Our main result is to show that for many standard matrices (adjacency, Laplacian, signless Laplacian) that \((H_1, B_1) \sim (H_2, B_2)\) if and only if \((H_1, \overline{B_1}) \sim (H_2, \overline{B_2})\). As an application we will look at cospectral trees and non-trees for the signless Laplacian matrix.

**MICHAEL CAVERS**, University of Toronto Scarborough  
[Sunday December 4 / dimanche 4 décembre, 16:00]

*Spectra of sign patterns*
A sign pattern is a matrix with entries in \{+, -, 0\}. To every square sign pattern there is a corresponding signed directed graph. We discuss different spectral properties a square sign pattern can have along with the restrictions these properties imply on the structure of the corresponding signed digraph. Techniques employed in this area are outlined.

**QIUTING CHEN**, University of Waterloo

[Monday December 5 / lundi 5 décembre, 10:00]

*Bipartite walks are better than Grover’s walk*

We introduce a new discrete quantum walk model, known as bipartite walks. We show that Grover’s walk is a special case of bipartite walks. Using the connections between the spectrum of a graph \(G\) and the spectrum of the subdivision graph of \(G\), we show that when \(G\) is a regular bipartite graph, one step of bipartite walk defined over \(G\) is two steps of Grover’s walk defined over \(G\).

**SHAUN FALLAT**, University of Regina

[Sunday December 4 / dimanche 4 décembre, 8:00]

*Revisiting the Parter-Wiener Theorem*

The celebrated Parter-Wiener theorem is an important result concerning the multiplicities of eigenvalues associated with trees. The theorem essentially verifies the existence of a vertex in a tree whose deletion increases the multiplicity of a given eigenvalue under certain conditions. In this presentation, we revisit the proof of this result and establish both the classical theorem and a known extension using the notion of the Schur-complement. We will also explore some related implications using both the Schur-complement and other basic matrix theory. This work represents joint work with an NSERC-USRA, Johnna Parenteau.

**CHRIS GODSIL**, University of Waterloo

[Monday December 5 / lundi 5 décembre, 8:00]

*State transfer on big graphs*

Childs and colleagues have made use of continuous quantum walk on infinite graphs, obtained by merging infinite paths onto some vertices of a finite graph. This works raises questions about state transfer on such graphs. I have proved that perfect state transfer cannot occur on a connected infinite graph with bounded valency. I will discuss some of the components of this proof, and of some related results.

**LORD KAVI**, University of Ottawa

[Sunday December 4 / dimanche 4 décembre, 17:00]

*3-independence number of graphs*

We present a spectral bound on the 3-independence number of graphs and apply this bound to well-known families of graphs. We investigate tightness of this bound on the Hamming graph \(H(d,q)\). In particular, we give a construction of 3-independent sets in \(H(d,2)\) and show tightness of the bound for \(d = 2^r\) and \(d = 2^r - 1\) with \(r \in \mathbb{Z}^+\).

**MARK KEMPTON**, Brigham Young University

[Sunday December 4 / dimanche 4 décembre, 10:00]

*Isospectral Reductions and Quantum Walks*

The isospectral reduction of a graph to a subset of its vertex set is a way to produce a smaller, function-weighted graph preserving spectral properties. Recently, cospectral vertices were characterized by isospectral reductions. In this talk, we will discuss this result and follow-up work that shows even stronger connections to the quantum walk matrix.
PAULA KIMMERLING, Washington State University

[Saturday December 3 / samedi 3 décembre, 17:30]

**Rank of Average Mixing Matrix in Dutch Windmill Graphs**

Let $X$ be a graph. We associate this graph with a continuous-time quantum walk by using a transition matrix $U(t) = \exp(itA)$, where $A$ is the adjacency matrix. This allows us to create the average mixing matrix $M$ which is time-independent and gives some sense of average probability values and long-term behavior. $M$ has previously been studied on trees and graphs with distinct eigenvalues. Our focus is on Dutch Windmill graphs which all have repeated eigenvalues. In this talk we will show that $M$ has "half-rank" and why, including the relationships between the spectra of Dutch Windmill graphs and path/star graphs.

STEVE KIRKLAND, University of Manitoba

[Sunday December 4 / dimanche 4 décembre, 15:30]

**Kemeny's constant for an undirected graph: how much can adding one edge change things?**

Given a connected graph $G$, we consider the corresponding random walk, described as follows. Our random walker moves from one vertex to another in discrete time; when the walker is on vertex $v$ at time $t$, one of the neighbours of $v$, say $v'$, is chosen at random, and the walker moves to vertex $v'$ at time $t+1$. The expected time it takes for the random walker to move from a randomly chosen initial vertex to a randomly chosen destination vertex is known as Kemeny’s constant, and it can be thought of as measuring the random walker’s ease of movement through the graph.

What happens to Kemeny’s constant when a new edge is added to $G$? It turns out that, depending on the structure of the graph and the placement of the new edge, Kemeny’s constant might increase, or decrease, or stay the same. In this talk we take a step towards quantifying this behaviour. For each natural number $n$, we consider the family of trees on $n$ vertices. We identify the tree in that family, as well as the new edge to be added, so that the increase in Kemeny’s constant is maximized. We also solve the corresponding problem for maximizing the decrease in Kemeny’s constant. The techniques rely on a detailed analysis of distance matrices for trees.

PRATEEK VISHWAKARMA KUMAR, University of Regina

[Sunday December 4 / dimanche 4 décembre, 8:30]

**The Gantmacher–Krein determinantal inequalities via planar networks**

Gantmacher and Krein discovered a relation between the determinant of a totally nonnegative matrix and its partial Laplace expansions along the first row using Sylvester’s determinant identity. We shall present an alternate proof of the same using the re-parameterization of totally nonnegative matrices in terms of weighted acyclic directed planar networks, which is popularly known as the converse of Lindström’s lemma. To conclude, we shall articulate some of the outcomes of employing this method in related and ongoing work with Shaun Fallat.

SABRINA LATO, University of Waterloo

[Saturday December 3 / samedi 3 décembre, 15:00]

**Characterizations of Distance-Biregular Graphs and Related Problems**

Fiol, Garriga, and Yebra developed a couple of characterizations of distance-regular graphs based on the existence of a polynomial with specific properties. We extend their characterizations to distance-biregular graphs and show how these characterizations can be used to study bipartite graphs with distance-regular halved graphs and graphs with the spectrum of a distance-biregular graph.
MAXWELL LEVIT, University of Waterloo
[Monday December 5 / lundi 5 décembre, 15:30]
Covers of Graphs from Extensions of Groups

For each \( n \)-cube, there is a graph on twice as many vertices which covers (in a mildly technical sense which we will discuss) the \( n \)-cube but contains no 4-cycles. There is a lot to say about these graphs: They originated in a uniqueness proof for certain generalized hexagons. They appear implicitly in Haung’s resolution of the Sensitivity Conjecture. And they demonstrate a nice correspondence between covers of Cayley graphs and extensions of groups which I have had some success in exploring. I will discuss these graphs and these contexts.

GABOR LIPPNER, Northeastern University
[Saturday December 3 / samedi 3 décembre, 16:00]
Pretty Good Fractional Revival via diagonal perturbation

Continuing our study of the effect of magnetic fields on state transfer, in this talk we focus on Pretty Good Fractional Revival (PGFR) in the setting of continuous time quantum walks on graphs. Fractional Revival is a generalization of Perfect State Transfer, in which the walk, at a specific time, is required to return to a fixed “starting subset” of nodes with probability 1. PGFR is then the usual asymptotic relaxation where only the supremum of this probability (as time goes to infinity) needs to be 1.

We develop the requisite spectral and number-theoretic tools to prove PGFR under a generic diagonal perturbation (aka magnetic field) and show how to construct examples of PGFR based on this theory. A key point is that we are able to generalize everything to subsets of more than 2 nodes, which would be the standard setting for state transfer.

Joint work with Mark Kempton.

SEYED AHMAD MOJALLAL, University of Regina
[Sunday December 4 / dimanche 4 décembre, 16:30]
Distribution of Laplacian eigenvalues of graphs

Let \( G \) be a graph of order \( n \) with \( m \) edges. Also let \( \mu_1 \geq \mu_2 \geq \cdots \geq \mu_n = 0 \) be the Laplacian eigenvalues of graph \( G \) and let \( \sigma = \sigma(G) \) (\( 1 \leq \sigma \leq n \)) be the largest positive integer such that \( \mu_\sigma \geq \frac{2m}{n} \). In this talk, we show that \( \mu_\sigma(G) \geq \frac{2m}{n} \) for almost all graphs. Moreover, we characterize the extremal graphs for any graphs. We also provide the answer to Problem 3 in [Distribution of Laplacian eigenvalues of graphs, Linear Algebra Appl. 508 (2016), 48–61], that is, the characterization of all graphs with \( \sigma = 1 \). Moreover, we present a few relations between \( \sigma \) and other graph invariants, in particular, we give a Nordhaus–Gaddum-type result for \( \sigma \).

HERMIE MONTERDE, University of Manitoba
[Monday December 5 / lundi 5 décembre, 9:30]
Fractional revival between twin vertices

Fractional revival is a generalization of perfect state transfer. But unlike perfect state transfer, fractional revival is a relatively unexplored quantum phenomenon. In this talk, we will discuss the existence of fractional revival between twin vertices.

YUJIA SHI, Northeastern University
[Saturday December 3 / samedi 3 décembre, 16:30]
Achieving strong state transfer using a bounded potential
Considering each particle of an n-qubit system as a vertex, we can describe quantum transport phenomena using graphs. The probability of transferring the state of node $u$ to node $v$ at time $t$ is given by $p(t) = \langle u | e^{itH} | v \rangle^2$. Here the Hamiltonian, $H$, of this system corresponds to the adjacency matrix and energy potential.

Assume the graph has an involution $T$ and the potential takes value $Q$ on nodes $u$ and $v = Tu$ and 0 elsewhere. In this setting Lin, Lippner, and Yau have shown that there is asymptotic state transfer, that is, $\sup_t p(t) \to 1$ as $Q$ goes to infinity. Kirkland and van Bommel recently proved a strong quantitative version of this result when the graph is a path with endpoints $u$ and $v$.

In this talk, I will discuss a generalization of the Kirkland - van Bommel bound to arbitrary graphs with an involution. By studying approximate eigenvectors of the Hamiltonian, we get quantitative bounds on the potential that guarantees asymptotic state transfer. Remarkably, these bounds depend only on the maximum degree of the graph and not its size.

Joint work with Gabor Lippner.

MAHSA SHIRAZI, University of Manitoba
[Sunday December 4 / dimanche 4 décembre, 17:30]
Graphs with $r$-friendship property

For $r \geq 1$, a graph has $r$-friendship property if every pair of vertices has exactly $r$ common neighbours. The motivation for this definition is from the Friendship theorem, which is on the graphs with $1$-friendship property. The Friendship theorem, first proved by Erdős, Rényi, and Sós in 1966, states that if $G$ is a graph in which every pair of vertices has exactly one common neighbour, then $G$ has a universal vertex $v$ adjacent to all others, and the graph induced by $V(G) \setminus \{v\}$ is a matching. In this presentation, we study graphs with $r$-friendship property, where $r \geq 2$. We show all such graphs are strongly regular. Furthermore, we prove that for any $r \geq 2$, there are only finitely many graphs with $r$-friendship property. This is an ongoing joint work with Karen Gunderson.

MARIIA SOBCHUK, University of Waterloo
[Monday December 5 / lundi 5 décembre, 16:00]
Quantum isomorphisms

You will learn about quantum isomorphism and recent developments in this area.

WANTING SUN, University of Waterloo
[Monday December 5 / lundi 5 décembre, 9:00]
Perfect Laplacian state transfer in graphs

Let $X$ be a graph with Laplacian matrix $L$. We study continuous quantum walks on $X$ defined by the transition matrix $U(t) = \exp(itL)$. Assume that $Y$ is a graph whose vertex set is equal to $V(X)$. The Laplacian state associated with $Y$ is defined as $\frac{1}{2^{E(Y)}} L(Y)$. Particularly, when $K_2$ (resp. $K_3$) is the unique non-trivial component of $Y$, we denote the Laplacian state associated with $Y$ by pair state (resp. triangle state) of $Y$. In this talk, we investigate the existence of perfect Laplacian state transfer in threshold graphs and strongly regular graphs. Firstly, we characterize all connected threshold graphs having perfect pair state transfer. Then we prove that a strongly regular graph $X$ on $n$ vertices admits perfect pair state transfer (resp. perfect triangle state transfer) if and only if $X$ is isomorphic to $\frac{n}{2}K_2$ or $\frac{n}{2}K_3$. This is a joint work with Ada Chan, Qiuting Chen, Chris Godsil and Xiaohong Zhang.

CHRISTOPHER VAN BOMMEL, University of Manitoba
[Monday December 5 / lundi 5 décembre, 8:30]
Perfect State Transfer on Trees with Small Diameter

Quantum computing is believed to provide many advantages over traditional computing, particularly considering the speed at which computations can be performed. One of the challenges that needs to be resolved in order to construct a quantum
computer is the transmission of information from one part of the computer to another. This transmission can be implemented by spin chains, which can be modeled as a graph, and analyzed using algebraic graph theory. We investigate the possibility of perfect state transfer on trees with small diameter, showing it is impossible for trees of diameter 4, and discussing progress for trees of diameter 5. Joint work with Steve Kirkland.

LUC VINET, IVADO/CRM

[Bivariate $P$-polynomial association schemes]
We offer a generalization of $P$-polynomial association schemes to situations where the underlying univariate polynomial families are replaced by bivariate polynomials. Examples of association schemes that fit the proposed framework are presented.

Based on work done in collaboration with Pierre-Antoine Bernard, Nicolas Crampé, Loïc Poulain D’Andecy and Meri Zaimi.

WEICHEN XIE, Clarkson University

[Breaking the Perfect State Transfer Speed Limit]
We describe a protocol for breaking the speed limit of perfect state transfer on quantum spin chains. The simple protocol relies on a fundamental application of fractional revival and dual-rail encoding. It offers a rare glimpse of the anti-Zeno effect at work in quantum state transfer. This is joint work with Alastair Kay and Christino Tamon.

HARMONY ZHAN, Simon Fraser University

[The second largest eigenvalue of a tree]
I will talk about the second largest eigenvalue of a tree with prescribed number of vertices and diameter. In particular, any tree that maximizes the second largest eigenvalue in this family must be a caterpillar with at most two bouquets. This is joint work in progress with Kumar, Mohar and Pragada.

XIAOHONG ZHANG, Université de Montréal

[Constructing cospectral graphs]
In this talk, we present a way to construct families of graphs that are pairwise cospectral with respect to the adjacency, Laplacian, unsigned Laplacian, and normalized Laplacian matrices. For example, with this construction, we obtain a family of 373 graphs on 25 vertices, all cospectral with respect to the above four matrices.
"Optimization is the study of problems wherein one maximizes an objective subject to constraints. Such tasks are ubiquitous across various branches of science, both in theory and in practice. This is a vast field of research, and studying the existence/inexistence of efficient algorithms computing/approximating a given optimization problem has spawned several distinct subfields with well developed theories. An immensely useful algorithmic approach to optimization has been to pass from the original optimization problem to a related convex optimization problem (i.e. minimize a convex function over a convex set) which can then be solved efficiently. A particular focus of this session will be on various cutting edge aspects of convex optimization such as,
- Broadening the set of tasks known to be amenable to convex optimization - Speeding up the runtime of convex optimization for optimization problems with sufficient structure - Limitations of convex optimization (and related hierarchies) for certain optimization tasks

The above pursuits often draw upon tools from various established areas of mathematics such as spectral graph theory, high dimensional geometry, Fourier analysis, coding theory, etc. The session will also feature results from these areas that closely inform techniques and intuition in optimization."

Schedule/Horaire

**Saturday December 3**

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Abstracts/Résumés
An approximation algorithm for the weighted fractional cut-covering problem

A cut in a graph $G = (V, E)$ is a set of edges which has precisely one endpoint in $S$, for a given subset $S$ of $V$. The fractional cut-covering number is the optimal value of a linear programming relaxation for the problem of covering each edge by a set of cuts. We define a semidefinite programming relaxation of fractional cut covering whose approximate optimal solutions may be rounded into a fractional cut cover via a randomized algorithm. These results arise from the tight connection between fractional cut covering and the maximum cut problem. By pinpointing the fundamental aspects of this relationship via antiblocker and gauge duality, we are not only able to obtain dual results to the celebrated work of Goemans and Williamson, but also to tie both approximation constants, to obtain new optimality certificates, and to relate both problems to geometric representation of graphs.

This is joint work with Marcel K. de Carli Silva, Cristiane Maria Sato, and Levent Tunçel.

Bit Complexity of Efficient Optimization

Optimization is a fundamental area in applied math, with applications ranging from economics to machine learning. There has been abundant interest in recent years in improving the asymptotic running times of algorithms for fundamental convex optimization problems. However, most of these works assume infinite precision for arithmetic operations. In this talk, we discuss the bit complexity of fundamental convex optimization problems under fixed-point arithmetic, including linear programming and $p$-norm regression. This requires analyzing the stability of the underlying inverse maintenance processes and how the errors propagate through the iterations.

A Borsuk-Ulam lower bound for sign-rank

I will present a new topological argument based on the Borsuk-Ulam theorem to prove a lower bound on sign-rank. I will mention applications to communication complexity, the theory of dimension reductions, and learning theory. This talk is based on joint work with Kaave Hosseini and Xiang Meng.

Correlation Clustering with Sherali-Adams

Given a complete graph $G = (V, E)$ where each edge is labeled + or -, the Correlation Clustering problem asks to partition $V$ into clusters to minimize the number of + edges between different clusters plus the number of - edges within the same cluster. Correlation Clustering has been used to model a large number of clustering problems in practice, making it one of the most widely studied clustering formulations. The approximability of Correlation Clustering has been actively investigated, culminating in a 2.06-approximation algorithm in 2015 based on rounding the standard linear program (LP) relaxation. Since it has been known that the standard LP cannot give better than a 2-approximation, it has remained an open question to determine if the approximation factor of 2 can be reached, or even breached. In this work, we answer this question affirmatively by showing that there exists a $(1.994 + \epsilon)$-approximation algorithm based on a strengthened LP relaxation called the Sherali-Adams hierarchy.
Algorithms and Complexity aspects of Optimization  
Aspects algorithmiques et complexes de l’optimisation

SHI LI, University at Buffalo

[Saturday December 3 / samedi 3 décembre, 16:00 – Wren A]

Online Unrelated-Machine Load Balancing and Generalized Flow with Recourse

I this talk, we discuss the online unrelated-machine load balancing problem with recourse, where the algorithm is allowed to re-assign prior jobs. We give a $(2 + \epsilon)$-competitive algorithm for the problem with $O((\log n)$-amortized recourse per job. This is the first $O(1)$-competitive algorithm for the problem with reasonable recourse, and the competitive ratio nearly matches the long-standing best-known offline approximation guarantee.

We also present an $O((\log \log n / \log \log \log n)$-competitive algorithm for the problem with $O(1)$-amortized recourse, improving upon the previous best $O((\log \log n)$-competitive ratio of Gupta et al., which works only for the special case of the restricted assignment model. The algorithm is based on our recent $O((\log \log m / \log \log \log m)$-online rounding algorithm for the problem without recourse.

Both algorithms are based on producing a fractional solution online first. To do so, we introduce and study the online algorithm for the generalized network flow problem (also known as network flow problem with gains) with recourse. We give an online algorithm for the problem with amortized recourse of $(1 + \epsilon)$ and capacity-violation of $1 + \epsilon$. The $(1 + \epsilon)$-factor improves upon the corresponding $(2 + \epsilon)$-factor of Gupta et al., which only works for the ordinary network flow problem.

The talk is based on two papers: [Krishnaswany-Li-Suriyanarayana, 2022] and [Li-Xian, 2021].

ALEKSANDR NIKOLOV, University of Toronto

[Saturday December 3 / samedi 3 décembre, 8:30 – Wren A]

Computing and Using Factorization Norms

A factorization norm of a matrix $A$ is the value of an optimization problem over factorizations $A = BC$ with the objective to minimize the product of some matrix norms of $B$ and $C$. Usually in this context we think of $A$ as an operator between two non-Euclidean spaces, of $B$ and $C$ as factoring $A$ through Euclidean space, and of the factorization norm as measuring how much the factoring distorts $A$. Factorization norms and the optimal factoring then allow solving non-Euclidean problems by mapping them to more easily solvable problems in Euclidean space. Originating in functional analysis, factorization norms have found many applications, e.g., to communication complexity, discrepancy theory, and private data analysis. In this talk I will discuss some of these applications, and also how to use tools from optimization to compute some factorization norms.

RAFAEL OLIVEIRA, University of Waterloo

[Saturday December 3 / samedi 3 décembre, 18:00 – Wren A]

Optimization, Invariant Theory, Computer Science and Math

What do the following problems, from seemingly unrelated areas of mathematics, quantum information theory and computer science, have in common?
- perfect matching in bipartite graphs
- word problem for the free skew field
- optimal constant in Brascamp-Lieb inequalities
- one-body quantum marginal problem
- the Paulsen problem
- Horn’s problem
- sample complexity of matrix and tensor normal model

As it turns out, these problems are all instances of the moment polytope problem from geometric invariant theory. Moreover, these problems can be cast as (geodesically) convex optimization problems over geodesically convex Riemannian manifolds. In this talk we will discuss these connections and how a recent series of works was able to give efficient algorithms for the
problems above (via the unifying view of moment polytopes), as well as mention several open questions.

KOSTYA PASHKOVICH, University of Waterloo
[Saturday December 3 / samedi 3 décembre, 9:00 – Wren A]
Non-Adaptive Matroid Prophet Inequalities For Minor-Closed Matroid Classes

We consider the problem of matroid prophet inequalities. Kleinberg and Weinberg have constructed a 2-competitive mechanism for all matroids. However, their mechanism recomputes thresholds during its course. In other words, their mechanism is adaptive. The non-adaptive case is far from resolved. There are known constant-competitive nonadaptive mechanisms for uniform and graphical matroids, but some classes of gammoids do not admit constant-competitive nonadaptive mechanisms.

In this work, we present constant-competitive nonadaptive mechanism for all regular matroids and for further minor-closed families of matroids.
Joint work with Alice Sayutina.

ROBERT ROBERE, McGill University
[Saturday December 3 / samedi 3 décembre, 9:30 – Wren A]
On the Proof Complexity of Integer Programming Solvers

We discuss recent progress on understanding the complexity of modern integer programming solvers in optimization using tools from propositional proof complexity. In particular, we focus on the recent introduction and study of the so-called "Stabbing Planes" proof system (also known as "Branching Proofs") which very tightly model the execution of such solvers. Both lower bounds and upper bounds on various complexity measures of Stabbing Planes proofs will be discussed, as well as the close relationship between Stabbing Planes proofs and Cutting Planes proofs.

ALEX TUNG, University of Waterloo
[Saturday December 3 / samedi 3 décembre, 16:30 – Wren A]
Cheeger Inequalities for Vertex Expansion and Reweighted Eigenvalues

The classical Cheeger’s inequality relates the edge conductance $\phi$ of a graph and the second smallest eigenvalue $\lambda_2$ of the Laplacian matrix. Recently, Olesker-Taylor and Zanetti discovered a Cheeger-type inequality $\psi^2/\log |V| \lesssim \lambda_2 \lesssim \psi$ connecting the vertex expansion $\psi$ of a graph $G = (V, E)$ and the maximum reweighted second smallest eigenvalue $\lambda_2^*$ of the Laplacian matrix.

In this work, we first improve their result to $\psi^2/\log d \lesssim \lambda_2^* \lesssim \psi$ where $d$ is the maximum degree in $G$, which is optimal up to constant factor. Also, the improved result holds for weighted vertex expansion, answering an open question by Olesker-Taylor and Zanetti. Building on this connection, we then develop a new spectral theory for vertex expansion. We discover that several interesting generalizations of Cheeger inequalities relating edge conductances and eigenvalues have a close analog in relating vertex expansions and reweighted eigenvalues. These include analogs of bipartite Cheeger’s inequality, higher order Cheeger’s inequality and improved Cheeger’s inequality.

Finally, inspired by this connection, we present negative evidence to the $0/1$-polytope edge expansion conjecture by Mihail and Vazirani. We construct $0/1$-polytopes whose graphs have very poor vertex expansion. This implies that the fastest mixing time to the uniform distribution on the vertices of these $0/1$-polytopes is almost linear in the graph size. This does not disprove the conjecture, but this is in contrast with known positive results which proved poly-logarithmic mixing time to the uniform distribution on the vertices of subclasses of $0/1$-polytopes.
(Paper link: https://arxiv.org/abs/2203.06168.)
YIBIN ZHAO, University of Toronto
[Saturday December 3 / samedi 3 décembre, 17:00 – Wren A]

A Simple and Efficient Parallel Laplacian Solver

A symmetric matrix is called a Laplacian if it has nonpositive off-diagonal entries and zero row sums. Laplacian linear systems naturally appears in various optimization problems, e.g. [Daitch and Spielman, 2008, Madry, 2013, Lee and Sidford, 2014, Dong, Gao, Goranci, Lee, Peng, Sachdeva, and Ye, 2021]. Since the seminal work of Spielman and Teng [2004] on solving Laplacian linear systems in nearly linear time, several algorithms have been designed for the task. Yet, the work of Kyng and Sachdeva [2016] remains the simplest and most practical sequential solver. They presented a solver purely based on random sampling and without graph-theoretic constructions such as low-stretch trees and sparsifiers.

In this work, we extend the result of Kyng and Sachdeva [2016] to a simple parallel Laplacian solver with $O(m \log^3 n \log \log n)$ work and $O(\log^2 n \log \log n)$ depth using the ideas of block Cholesky factorization from Kyng, Lee, Peng, Sachdeva, and Spielman [2016]. Our proof is simple and based on standard matrix concentration inequalities. Compared to the best known parallel Laplacian solvers that achieve polylogarithmic depth due to Lee, Peng, and Spielman [2015], our solver achieves both better depth and, for sparse graphs, better work.

This talk is based on a joint work with Sushant Sachdeva.
Org: Damir Kinzebulatov (Université Laval) and Jie Xiao (Memorial University)

This session will bring together researchers within the analysis of PDEs arising in modeling of a variety of physical phenomena, including the problems in calculus of variations, bifurcation theory, probability theory, stochastic processes, phase transitions, fluid flow, wave propagation, heat diffusion processes, computational science, etc. with the goal of exchanging ideas and fostering possible collaborations in these fields.

Cette session réunira des chercheurs dans le domaine de l’analyse des EDP survenant dans la modélisation d’une variété de phénomènes physiques, y compris les problèmes de calcul des variations, la théorie des bifurcations, la théorie des probabilités, les processus stochastiques, les transitions de phase, l’écoulement des fluides, la propagation des ondes, les processus de diffusion de la chaleur, la science computationnelle, etc. dans le but d’échanger des idées et de favoriser d’éventuelles collaborations dans ces domaines.

Schedule/Horaire

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8:30 - 9:00  Michel Delfour (Université de Montréal), Three-dimensional model of paclitaxel release from biodegradable polymer films (p. 62)
9:00 - 9:30  Scott Rodney (Cape Breton University), Bounded Solutions and Counterexamples (p. 64)
9:30 - 10:00 Nguyen Lam (Memorial University), Sharp quantitative stability for the Uncertainty Principle (p. 62)
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16:30 - 17:00 Jeremy Quastel (University of Toronto), Integrable fluctuations in random growth (p. 64)
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Sunday December 4

8:00 - 8:30  Milivoje Lukic (Rice University), An approach to universality using Weyl m-functions (p. 63)
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9:30 - 10:00 Deping Ye (Memorial University), The Minkowski type problems for unbounded convex hypersurfaces (p. 65)
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YEGANEH BAHOO, Toronto Metropolitan University
[Saturday December 3 / samedi 3 décembre, 8:00 – Rosetti A]

Visibility: Theory and Application

Computation Geometry is a recent branch in the field of Computer Science with roots established in ancient times, exploring geometric and numeric problems which arise from the constraints imposed by modern computing methods. Computational Geometry further serves as the foundation for a wealth of real-world applications reliant on efficient and elegant solutions.

In this talk, I will begin by presenting an overview of the field and my various contributions to it, with emphasis on visibility and pursuit-evasion problems. These topics have significant research and industry interest due to their numerous applications, including wireless communications, robotics, computer graphics, and surveillance. Following this, I will discuss the interdisciplinary works which arise from close collaborations with engineering and machine learning groups, such as medical imaging, additive manufacturing, geometric deep learning.

The importance of the link between theory and application cannot be understated, as it is through the study of the theory that we can improve and expand the reach of applications; it is also through the present challenges faced in applications by which theoretical research can be informed. My ultimate goal is to extend the reach and relevance of Computational Geometry, and further its integration in new domains.

DER-CHEN CHANG, Georgetown University
[Sunday December 4 / dimanche 4 décembre, 10:00 – Rosetti A]

MICHEL DELFOUR, Université de Montréal
[Saturday December 3 / samedi 3 décembre, 8:30 – Rosetti A]

Three-dimensional model of paclitaxel release from biodegradable polymer films

In order to achieve prescribed drug release kinetics in the wall and the lumen of blood vessels over long therapeutic periods, bi-phasic and possibly multi-phasic releases from blends of biodegradable polymers are currently envisioned. The modelling of drug release in the presence of degradation of the polymer matrix and surface erosion is quite complex. Yet, simple reliable mathematical models validated against experimental data are now available to classify neat polymers and to predict the release dynamics from polymer blends [Blanchet, Delfour, Garon, Quadratic models to fit experimental data of paclitaxel release kinetics from biodegradable polymers, SIAM J. on Applied Mathematics 71 (2011), 2269-2286]. We survey our two-parameter quadratic ODE model that has been validated against experimental data for the release of paclitaxel from a broad range of biodegradable polymers and our quadratic semi-permeable membrane PDE model that mimics the ODE model and readily extends to curved complex geometries of drug eluding stents [Garon, Delfour, Three-dimensional quadratic model of paclitaxel release from biodegradable polymer films, SIAM J. Appl. Math., 74 (5) (2014), 1354-1374]. This approach avoids resorting to time-dependent or nonlinear diffusion in the polymer. In the context of drug eluting stents, it is a practical and economical tool to theoretically and numerically simulate the 3D release of drug from the thin polymer film to the integrated wall and lumen of the blood vessel for evaluation and design [Delfour, Garon, Lamontagne, Three-Dimensional Drug Release in the Stent-Polymer-Wall-Lumen of a Blood Vessel, SIAM J. Appl. Math. 79 (2019), No. 5, 1850-1871].

OSCAR DOMINGUEZ-BONILLA, Universidad Complutense Madrid, CRM-Montreal
[Saturday December 3 / samedi 3 décembre, 17:00 – Rosetti A]

Functional & geometrical analysis of logarithmic Gagliardo-Lipschitz spaces

We present novel functional and geometrical aspects of logarithmic Gagliardo-Lipschitz function spaces, including capacities, perimeters and mean curvatures. This is joint work with Liguang Liu and Jie Xiao.
NGUYEN LAM, Memorial University

[Saturday December 3 / samedi 3 décembre, 9:30 – Rosetti A]

*Sharp quantitative stability for the Uncertainty Principle*

We present some sharp versions of the quantitative stability of the Heisenberg Uncertainty Principle and several stability results of the Caffarelli-Kohn-Nirenberg inequalities. The talk is based on a recent joint work with Cristian Cazacu, Joshua Flynn and Guozhen Lu.

MILIVOJE LUKIC, Rice University

[Sunday December 4 / dimanche 4 décembre, 8:00 – Rosetti A]

*An approach to universality using Weyl m-functions*

This talk describes an approach to universality limits for orthogonal polynomials on the real line which is completely local and uses only the boundary behavior of the Weyl m-function at the point. We show that bulk universality of the Christoffel–Darboux kernel holds for any point where the imaginary part of the m-function has a positive finite nontangential limit. This approach is based on studying a matrix version of the Christoffel–Darboux kernel and the realization that bulk universality for this kernel at a point is equivalent to the fact that the corresponding m-function has normal limits at the same point. Our approach automatically applies to other self-adjoint systems with $2 \times 2$ transfer matrices such as continuum Schrodinger and Dirac operators. We also obtain analogous results for orthogonal polynomials on the unit circle. This is joint work with Benjamin Eichinger and Brian Simanek.

KODJO RAPHAEL MADOU, Université Laval

[Saturday December 3 / samedi 3 décembre, 10:00 – Rosetti A]

*On the supercritical fractional diffusion equation with Hardy-type drift.*

We study the heat kernel of the supercritical fractional diffusion equation with the drift in the critical Hölder space. We show that such a drift can have point irregularities strong enough to make the heat kernel vanish at a point for all $t > 0$.

The talk is based on joint work with D. Kinzebulatov and Yu.A. Semënov.

ROBERT MCCANN, University of Toronto

[Saturday December 3 / samedi 3 décembre, 14:30 – Rosetti A]

*Asymptotics near extinction for nonlinear fast diffusion on a bounded domain*

On a smooth bounded Euclidean domain, Sobolev-subcritical fast diffusion with vanishing boundary trace is known to lead to finite-time extinction, with a vanishing profile selected by the initial datum. In rescaled variables, we quantify the rate of convergence to this profile uniformly in relative error, showing the rate is either exponentially fast (with a rate constant predicted by the spectral gap), or algebraically slow (which is only possible in the presence of non-integrable zero modes). In the first case, the nonlinear dynamics are well-approximated by exponentially decaying eigenmodes up to at least twice the gap; this refines and confirms a 1980 conjecture of Berryman and Holland. We also improve on more recent results, by providing a new and simpler approach which is able to accommodate the presence of zero modes, such as those that occur when the vanishing profile fails to be isolated (and possibly belongs to a continuum of such profiles).

Based on work with Beomjun Choi (Postech) and Christian Seis (Münster) [80] at http://www.math.toronto.edu/mccann/publications

MING MEI, Champlain College St-Lambert

[Saturday December 3 / samedi 3 décembre, 15:00 – Rosetti A]

*Structural stability of subsonic steady-state for Euler-Poisson equations with sonic boundary*
In this talk, I first review the subsonic/supersonic/transonic steady-states for Euler-Poisson equations for semiconductor device with sonic boundary, then I will present how these physical solutions are affected by the doping profile, and the structural stability of these steady-states with a small perturbation of the doping profile. The singularities for the structural stability come from the boundary and the transonic point at the sonic line. The weighted energy method is introduced to overcome the singularities.

MATHAV MURUGAN, The University of British Columbia

Harnack inequalities and conformal walk dimension

Harnack inequalities have proved to be a powerful tool in PDE (regularity estimates), geometry (geometric flows) and probability (heat kernel estimates). The notion of conformal walk dimension clarifies the relationship between elliptic and parabolic Harnack inequalities. I will explain its definition and its universal value. We will also discuss related results on the stability of Harnack inequalities. This talk is based on joint works with Martin Barlow, Zhen-Qing Chen and Naotaka Kajino.

JEREMY QUASTEL, University of Toronto

Integrable fluctuations in random growth

I will survey asymptotic fluctuations in the KPZ class and how they are connected to integrable equations.

SCOTT RODNEY, Cape Breton University

Bounded Solutions and Counterexamples

In this talk I will give a short overview of recent results with S.F. MacDonald concerning a priori boundedness of weak solutions to Dirichlet problems for operators

$$X_p u = -\text{div} \left( \left| \sqrt{Q} \nabla u \right|^{p-2} Q \nabla u \right)$$

of p-Laplace type with a data function in an Orlicz class. Following this I will describe some relevant counterexamples.

ERIC SAWYER, McMaster University

Sums of squares of functions and matrices with application to hypoellipticity in the infinitely degenerate regime

This is joint work with Luda Korobenko. We extend the well-known theorem of Fefferman and Phong, that decomposes nonnegative C3,1 functions as finite sums of squares of C1,1 functions, to handle the case of C4,2delta functions. Additional assumptions are needed for this, and we give examples to demonstrate sharpness, in particular answering a question of Bony et al regarding elliptic such functions. These results are then extended to nonnegative matrices where they are applied to obtain new results on hypoellipticity of smooth infinitely degenerate operators. The techniques include extending a theorem of Mike Christ on sufficient conditions for smooth hypoellipticity to rough hypoellipticity, which is then applied back in the smooth case. The reason for the interest in decomposing nonnegative C4,2delta functions lies in the fact that the resulting sum is of squares of C2,delta functions, which have enough regularity to permit two differentiations in the case of second order rough operators.

ALEXEY SHEVYAKOV, University of Saskatchewan

Analytical Properties of Nonlinear Partial Differential Equations in Fluid Dynamics and Beyond
Analytical properties of partial differential equations (PDEs), in particular, models that arise in physics, engineering, and other applications, provide a fundamental counterpart to numerical solutions. Analytical methods for nonlinear PDEs have been under active development over the last hundred years; they include notions of S- and C-integrability and applications thereof, multiple other notions of integrability, Lagrangian and Hamiltonian structures, Painlevé property, symmetries, conservation laws, reductions and exact solutions including solitons, and more.

In this talk we will look at some reductions of general fluid dynamics equations, including popular and less well known shallow water PDE models. Such models arise in a wide variety of settings within and beyond fluid surface waves. We will discuss some important analytical properties of such models with emphasis on those that are systematically computable. Examples of computation and applications of elements of analytical structure will be given for several PDE systems.

REIHANEH VAFADAR, Université Laval
[Sunday December 4 / dimanche 4 décembre, 9:00 – Rosetti A]
On divergence-free (form-bounded type) drifts

We develop regularity theory for elliptic operator with drifts in a large class of divergence-free singular vector fields. A key ingredient of the proof is a new iteration procedure used within De Giorgi’s and Moser’s methods, playing the same role as e.g., the compensated compactness needed to handle $BMO^{-1}$ drifts. This is joint work with Damir Kinzebulatov.

DEPING YE, Memorial University
[Sunday December 4 / dimanche 4 décembre, 9:30 – Rosetti A]
The Minkowski type problems for unbounded convex hypersurfaces

A central object in convex geometry is the Minkowski problem which characterizes the surface area measure of convex bodies. This problem has been extended in various settings which all have close connections with partial differential equations (through the Monge-Ampere equations) and the optimal mass transport problem.

Recently, Schneider initiated the study of the Minkowski type problems for $C$-close sets, a family of (unbounded) closed convex sets contained in a cone. In this talk, I will talk about our recent progress on the Minkowski type problems for unbounded convex hypersurfaces. These Minkowski type problems generate new Monge-Ampere type equations. The solutions to these Minkowski type problems will also be presented.
Approximation Theory, Function Spaces and Harmonic Analysis  
Théorie de l’approximation, espaces de fonctions et analyse harmonique

Org: Galia Dafni (Concordia), Oscar Dominguez (Universidad Complutense de Madrid), Javad Mashreghi (Laval) and/et Sergey Tikhonov (ICREA - Centre de Recerca Matemàtica)

These three fundamental topics in analysis have been closely tied historically and continue to cross-fertilize in current research. In Canada in particular there are strong researchers as well as early career mathematicians in each of these areas who would benefit from such interaction, and several visitors from outside of Canada are also expected to participate.

Ces trois sujets fondamentaux de l’analyse ont été étroitement liés historiquement et continuent de s’enrichir mutuellement dans la recherche actuelle. Au Canada en particulier, il y a d’excellents chercheurs ainsi que des mathématiciens en début de carrière dans chacun de ces domaines qui bénéficieraient d’une telle interaction, et plusieurs visiteurs de l’extérieur du Canada sont également attendus.

Schedule/Horaire

Saturday December 3  
samedi 3 décembre

8:30 - 9:00  Michael Roysdon (CRM-ISM, Concordia), Weighted Projection Bodies (p. 69)
9:00 - 9:30  Joshua Flynn (CRM-ISM, McGill), Helgason-Fourier Analysis and Sharp Geometric Inequalities on the Rank One Symmetric Spaces (p. 67)
9:30 - 10:00 Oscar Dominguez (Universidad Complutense Madrid), Truncated smooth function spaces (p. 67)
10:00 - 10:30 Cintia Pacchiano (Calgary), Existence of parabolic minimizers to the total variation flow on metric measure spaces (p. 68)
14:30 - 15:00 Ignacio Uriarte-Tuero (Toronto), Two weight norm inequalities for singular and fractional integral operators in $\mathbb{R}^n$ (p. 70)
15:00 - 15:30 Thomas Ransford (Laval), Constructive polynomial approximation (p. 68)
16:00 - 16:30 Bin Han (Alberta), Gibbs Phenomenon of Wavelets and Quasi-projection Approximation (p. 67)
16:30 - 17:00 Feng Dai (Alberta), Marcinkiewicz-type discretization for functions from a finite dimensional space (p. 67)
17:00 - 17:30 Gord Sinnamon (Western), The Fourier transform in rearrangement-invariant spaces (p. 69)
17:30 - 18:00 Scott Rodney (Cape Breton), More Limits of Orlicz Norms (p. 68)
18:00 - 18:30 Alex Iosevich (Rochester), Frame theory and finite point configurations (p. 68)
18:30 - 19:00 Alejandro Santacruz-Hidalgo (Western), Down spaces over a measure space with an ordered core (p. 69)

Sunday December 4  
dimanche 4 décembre

8:30 - 9:00  Ryan Gibara (Cincinnati), A Dirichlet problem for unbounded domains in metric measure spaces (p. 67)
9:00 - 9:30  Michael Wilson (Vermont), Smooth approximations to the $d$-dimensional Haar system (p. 70)
9:30 - 10:00 Eric Sawyer (McMaster), Two weight $T_1$ theorems for Sobolev and $L^p$ spaces with doubling measures and Calderón-Zygmund operators. (p. 69)
10:00 - 10:30 Almut Burchard (Toronto), Strong and weak maximal extensions of $\partial$ on the Hartogs triangle (p. 66)

Abstracts/Résumés

ALMUT BURCHARD, University of Toronto
[Sunday December 4 / dimanche 4 décembre, 10:00 – Scott A]

Strong and weak maximal extensions of $\partial$ on the Hartogs triangle

The Hartogs triangle $T := \{(z, w) \in \mathbb{C}^2 : |z| < |w| < 1\}$ has been an important source of (counter-) examples in several complex variables. I will discuss recent work with J. Flynn, G. Lu, and M.-C. Shaw on properties of the Sobolev space $H^1$.
and the maximal extensions of the Cauchy-Riemann operator $\partial$ on $T$. It turns out that despite the singularity at the origin, $T$ shares many properties of Lipschitz domains.

**FENG DAI**, University of Alberta  
[Saturday December 3 / samedi 3 décembre, 16:30 – Scott A]  
*Marcinkiewicz-type discretization for functions from a finite dimensional space*

In this talk I will report some recent results on Marcinkiewicz-type discretization of integral norms for functions from finite dimensional linear spaces. In particular, I will describe the recent progress made by A. Prymak and myself on optimal polynomial meshes on convex bodies.

**OSCAR DOMINGUEZ**, Universidad Complutense Madrid, CRM-Montreal  
[Saturday December 3 / samedi 3 décembre, 9:30 – Scott A]  
*Truncated smooth function spaces*

We introduce truncated smooth function spaces. These spaces have many interesting properties and are useful to solve several outstanding questions in functional analysis and PDE’s. The talk is based on joint work with Sergey Tikhonov.

**JOSHUA FLYNN**, CRM-ISM, McGill University  
[Saturday December 3 / samedi 3 décembre, 9:00 – Scott A]  
*Helgason-Fourier Analysis and Sharp Geometric Inequalities on the Rank One Symmetric Spaces*

The Hardy-Sobolev-Maz’ya inequality combines the Hardy and Sobolev inequalities into a single inequality on the halfspace. Using conformal equivalence, this inequality is equivalent to the Poincare-Sobolev inequality on the real hyperbolic space. Using Helgason-Fourier analysis, higher order versions of these inequalities were established by G. Lu and Q. Yang for the real and complex hyperbolic spaces. With G. Lu and Q. Yang, we further established these inequalities for the quaternionic and octonionic hyperbolic spaces. In this talk we will present these results and the Fourier analytic tools used in obtaining them.

**RYAN GIBARA**, University of Cincinnati  
[Sunday December 4 / dimanche 4 décembre, 8:30 – Scott A]  
*A Dirichlet problem for unbounded domains in metric measure spaces*

Let $\Omega$ be an unbounded locally compact metric measure space that is uniform in its completion $\overline{\Omega}$. When $\Omega$ is equipped with a doubling measure satisfying a $p$-Poincaré inequality and the boundary $\partial\Omega := \overline{\Omega} \setminus \Omega$ is bounded, we solve the $p$-Dirichlet problem for boundary data in an appropriate Besov class.

This is accomplished by transforming both the metric and the measure on $\Omega$ using a weight that depends on the distance to the boundary, rendering $\Omega$ bounded while retaining many of its metric and measure properties without perturbing the space near the boundary.

This is joint work with Rikka Korte and Nageswari Shanmugalingam.

**BIN HAN**, University of Alberta  
[Saturday December 3 / samedi 3 décembre, 16:00 – Scott A]  
*Gibbs Phenomenon of Wavelets and Quasi-projection Approximation*

Most data such as images are piecewise smooth functions. It is well known that the standard Fourier series approximation suffers the unpleasant ringing effect near discontinuity, which is termed as the Gibbs phenomenon such that the $n$th Fourier partial sums overshoot a function at jump discontinuities and the overshoot does not die out as $n$ goes to infinity. Wavelets...
and framelets are known to be the mainstream multiscale sparse representation and approximation systems in data science. In this talk we study the Gibbs phenomenon of framelet/wavelet expansions and their associated quasi-projection approximation schemes at an arbitrary point. We show that the Gibbs phenomenon appears at all points for every tight or dual framelet having at least two vanishing moments and for quasi-projection approximation operators having at least three accuracy/approximation orders. This well explains the ringing effect of most wavelet approximation in applications. We shall also address how to avoid the Gibbs phenomenon for wavelets/framelets and quasi-projection approximation, as well as address the Gibbs phenomenon for approximation through sampling. This talk is based on [B. Han, Gibbs phenomenon of framelet expansions and quasi-projection approximation, Journal of Fourier Analysis and Applications, 25 (2019), 2923-2956].

ALEX IOSEVICH, University of Rochester
[Saturday December 3 / samedi 3 décembre, 18:00 – Scott A]
Frame theory and finite point configurations
We are going to discuss a series of intriguing connections between the existence and non-existence of exponential frames and point configuration problems in geometric measure theory and combinatorics.

CINTIA PACCHIANO, University of Calgary
[Saturday December 3 / samedi 3 décembre, 10:00 – Scott A]
Existence of parabolic minimizers to the total variation flow on metric measure spaces
In this project, we discuss some fine properties and the existence of variational solutions to the Total Variation Flow. Instead of the classical Euclidean setting, we intend to work mostly in the general setting of metric measure spaces. During the past two decades, a theory of Sobolev functions and BV functions has been developed in this abstract setting. A central motivation for developing such a theory has been the desire to unify the assumptions and methods employed in various specific spaces, such as weighted Euclidean spaces, Riemannian manifolds, Heisenberg groups, graphs, etc.

The total variation Flow can be understood as the process of diminishing the total variation using the gradient descent method. This idea can be reformulated using parabolic minimizers, and it gives rise to a definition of variational solutions. The approach’s advantages using a minimization formulation include much better convergence and stability properties. This is essential as the solutions naturally lie only in the space of BV functions.

We give an existence proof for variational solutions $u$ associated to the total variation flow. Here, the functions being considered are defined on a metric measure space $(X, d, \mu)$. For such parabolic minimizers that coincide with a time-independent Cauchy-Dirichlet datum $u_0$ on the parabolic boundary of a spacetime-cylinder $\Omega \times (0, T)$ with $\Omega \subset X$ an open set and $T > 0$, we prove the existence in the weak parabolic function space $L^1_{w!}(0, T; BV(\Omega))$. This is a joint project with Vito Buffa and Michael Collins.

THOMAS RANSFORD, Université Laval
[Saturday December 3 / samedi 3 décembre, 15:00 – Scott A]
Constructive polynomial approximation
Let $X$ be a function space. Here are two problems about polynomial approximation in $X$: (1) Are polynomials dense in $X$? (2) If so, then, given $f \in X$, can we find explicit polynomials $p_n$ that converge to $f$ in $X$? In this talk, I shall discuss some recent work on the second type of problem. (Joint with Javad Mashreghi and Pierre-Olivier Parisé).

SCOTT RODNEY, Cape Breton University
[Saturday December 3 / samedi 3 décembre, 17:30 – Scott A]
More Limits of Orlicz Norms
In this talk I will discuss recent work with my recent honours student A. Mailhot, where we recover $\|f\|_\infty$ as a limit of Orlicz norms of $f$ defined by a one parameter family of iterated log-bump type Young functions. I will also put this work into context with recent advances with S. F. MacDonald.

MICHAEL ROYSDON, ICERM, Brown University and CRM, Concordia University

[Saturday December 3 / samedi 3 décembre, 8:30 – Scott A]

Weighted Projection Bodies

The inequalities of Petty and Zhang are affine isoperimetric inequalities, the former of which implies that classical isoperimetric inequality and is equivalent to an affine version of the Sobolev inequality for compactly support $C^1$ functions, while the latter is a very strong reverse isoperimetric inequality. Each of these inequalities feature a certain class of convex bodies, called projection bodies, which may be described in terms of the cosine transform of the surface area measure of a given convex body.

In this talk, we will discuss a generalization of these bodies to the weighted setting (by replacing the surface area measure with different measures satisfying mild regularity conditions) and describe how they may be used to prove strong reverse isoperimetric inequalities. And, in addition, show how these results may be used to imply a reverse form of the isoperimetric inequality for certain classes of measures on the $n$-dimensional Euclidean space.

This is based on a joint work with D. Langharst and A. Zvavitch.

ALEJANDRO SANTACRUZ-HIDALGO, Western University

[Saturday December 3 / samedi 3 décembre, 18:30 – Scott A]

Down spaces over a measure space with an ordered core

We consider a measure space together with a totally ordered subset of its sigma algebra called an ordered core. Recently, this construction was used in the context of Hardy inequalities, giving a uniform treatment of many different types of Hardy operators.

We will begin by introducing a definition of monotone functions compatible with the ordered core. This allows us to extend the down space construction, a variant of the Köthe dual restricted to positive decreasing functions, to all measure spaces. We will look at their associate spaces and their relationship with a suitable version of the least decreasing majorant construction in this more general setting. We will discuss the interpolation structure of these spaces and find strong similarities to the real line case; the down spaces corresponding to $L^1$ and $L^\infty$ form an exact Calderón-Mityagin couple and as a consequence we can describe all their exact interpolation spaces in terms of the $K$–functional. We will also show an analogous result for the dual couple.

This talk is based on joint work with Gord Sinnamon.

ERIC SAWYER, McMaster University

[Sunday December 4 / dimanche 4 décembre, 9:30 – Scott A]

Two weight $T1$ theorems for Sobolev and $L^p$ spaces with doubling measures and Calderón-Zygmund operators.

This is joint work with Brett Wick. We characterize two weight norm inequalities for Calderón-Zygmund operators from one weighted space to another, when the measures are doubling. We extend an earlier result of Michel Alexis, the speaker and Ignacio Uriarte-Tuero for $L^2$ spaces, to $L^2$-Sobolev spaces of small order, and to $L^p$ spaces. In the case $p$ is not 2, we use variants of the quadratic Muckenhoupt conditions and weak boundedness properties introduced by Hytönen and Vuorinen. In particular, this proves their conjecture for the Hilbert transform in the case of doubling measures.
We will look at the Fourier transform as a map between rearrangement-invariant spaces of functions on $\mathbb{R}^n$. Restricting our attention to domain spaces that are 2-concave and range spaces that are 2-convex, we give necessary and sufficient conditions for boundedness.

IGNACIO URIARTE-TUERO, University of Toronto

Two weight norm inequalities for singular and fractional integral operators in $\mathbb{R}^n$

I will report on recent progress on the two weight problem for singular and fractional integral operators in $\mathbb{R}^n$, in particular a local Tb theorem in $\mathbb{R}^n$ for general measures with an energy side condition (joint with C. Grigoriadis, M. Paparizos, E. Sawyer and C.-Y. Shen) and a two weight T1 theorem (with no side conditions) for doubling measures (joint with M. Alexis and E. Sawyer), and briefly mention a new stability result. The talk will be self-contained.

MICHAEL WILSON, University of Vermont

Smooth approximations to the $d$-dimensional Haar system

In the late 1990s, Govil and Zalik showed how to approximate the system of Haar functions $h_{(I)}$ by smooth functions $\phi_{(I)}$, resulting in a system that was arbitrarily close to the Haar system in the sense of Bessel bounds. Later Zalik extended this result to $d$-dimensional Haar functions by taking tensor products. In 2001, Aimar, Bernardis, and Gorosito showed that the careful constructions of Govil and Zalik could be replaced (in one dimension) by convolutions with suitable smooth, even, mollifying functions. We show that “Zalik-like” approximations to the Haar system can be obtained in $d$ dimensions by convolving the multidimensional Haar functions with essentially arbitrary compactly supported “mollifiers” that do not need to be smooth or have any special symmetry. These approximations to the Haar functions are stable (in the Bessel bound sense) with respect to small errors in dilation and translation and can be replaced by fine discretizations without producing too much additional error.
This session focuses on the calculus of variations, geometric analysis, partial differential equations (PDEs) and their applications in order to present some of the more recent developments in the field. One main idea of calculus of variations is to study and describe critical points and in particular minimizers of a given functional. Variational problems are closely linked to partial differential equations for example via Euler-Lagrange equations or energy conservation. Furthermore, they share a large set of common tools and interests that will be presented in this session including the investigation of existence/uniqueness, regularity theory, geometric flows or techniques such as Γ-convergence. Often, the considered functionals and equations have a physical interpretation such as a kinetic energy, a geometric meaning, e.g. the area of a domain or can be seen as a dynamical process (or a static limit thereof). This leads to a large domain of applications, for instance in physics, material science, mechanics and engineering, biology and many more.

Cette session se concentre sur le calcul des variations, l'analyse géométrique, les équations aux dérivées partielles (EDP) et leurs applications afin de présenter certains des développements les plus récents dans le domaine. Une idée principale du calcul des variations est d’étudier et de décrire les points critiques et en particulier les minimiseurs d’une fonction donnée. Les problèmes variationnels sont étroitement liés aux équations aux dérivées partielles, par exemple via les équations d’Euler-Lagrange ou la conservation de l’énergie. En outre, ils partagent un grand nombre d’outils et d’intérêts communs qui seront présentés dans cette session, notamment l’étude de l’existence/unicité, la théorie de la régularité, les flux géométriques ou des techniques telles que Γ-convergence. Souvent, les fonctionnelles et équations considérées ont une interprétation physique, comme l’énergie cinétique, une signification géométrique, par exemple l’aire d’un domaine, ou peuvent être considérées comme un processus dynamique (ou une limite statique de celui-ci). Cela conduit à un large domaine d’applications, par exemple en physique, en science des matériaux, en mécanique et en ingénierie, en biologie et bien d’autres encore.

Schedule/Horaire

**Sunday December 4**

15:30 - 16:00  BARTEK PROTAS (McMaster University), *Searching for Singularities in Navier-Stokes Flows Using Variational Optimization Methods* (p. 74)

16:00 - 16:30  NICHOLAS KEVLAHAN (McMaster University), *Data assimilation for bathymetry in the nonlinear shallow water equations* (p. 73)

16:00 - 16:30  SULLIVAN MACDONALD (McMaster University), *Degenerate Ellipticity and Hypoellipticity for Divergence Operators* (p. 73)

17:00 - 17:30  ANDREW COLINET (McMaster University), *Zeroth Order Limiting Behaviour of the Ginzburg-Landau Functional* (p. 73)

**Monday December 5**

8:00 - 8:30  DOMINIK STANTEJSKY (McMaster University), *A finite element approach for minimizing line and surface energies arising in the study of singularities in liquid crystals* (p. 75)

8:30 - 9:00  CARRIE CLARK (University of Illinois Urbana-Champaign), *Droplet formation in a nonlocal aggregation model* (p. 72)

9:00 - 9:30  DENIS BRAZKE (University of Heidelberg), *Γ–limit for a sharp interface model related to pattern formation on biomembranes* (p. 72)

9:30 - 10:00  BLAISE BOURDIN (McMaster University), *Phase-field approximation of diffusion-driven fracture* (p. 72)

10:00 - 10:30  DMITRY PELINOVKY (McMaster University) (p. 74)

15:00 - 15:30  ZHICHAO WANG (University of British Columbia), *Min-max minimal hypersurfaces with higher multiplicity* (p. 75)

15:30 - 16:00  IVAN SALGADO (University of Toronto), *Approximate Solutions to the Superconducting Interface Model* (p. 74)
Abstracts/Résumés

BLAISE BOURDIN, McMaster University
[Monday December 5 / lundi 5 décembre, 9:30 – Austen]
Phase-field approximation of diffusion-driven fracture
This talk focuses on a class of problems where crack propagation is driven by a diffusion process. This general framework encompasses a broad range of phenomena including thermal and desiccation cracks, fracture in fluid-saturated porous media, or fracture of materials undergoing phase-change.

The main difficulty in building a rigorous phase-field model of such problems is the different time scales involved in the fracture and diffusion processes. The former is often assumed to remain in an equilibrium state at all time, whereas the later is inherently driven by its non-equilibrium nature. $\Gamma$-convergence, commonly used to derive the convergence of phase-field models to their sharp interface counterparts do not provide any insight on out-of-equilibrium evolutions. Instead, we propose to reformulate the diffusion problem in terms of the minimizing motion of an energy, and the coupled problem as a PDE-constrained optimization problem. We then propose compatible phase-field approximations of the fracture and diffusion process can be derived, and the convergence of the constrained minimization problem can be proved.

DENIS BRAZKE, University of Heidelberg
[Monday December 5 / lundi 5 décembre, 9:00 – Austen]
$\Gamma$–limit for a sharp interface model related to pattern formation on biomembranes
We derive a macroscopic limit for a sharp interface version of a model proposed by Komura, Shimokawa and Andelman to investigate pattern formation in biomembranes due to competition of chemical and mechanical forces. We identify sub- and supercritical parameter regimes and show with the introduction of the autocorrelation function that the ground state energy leads to the isoperimetric problem in the subcritical regime, which is interpreted to not form fine scale patterns.

This is joint work with Hans Knüpfer and Anna Marciniak–Czochra.

ALMUT BURCHARD, University of Toronto
[Monday December 5 / lundi 5 décembre, 16:30 – Austen]
Symmetry-breaking in isodiametric capacitor problems
A classical theorem of Szegö says that balls maximize electrostatic capacity among sets of given diameter (while minimizing capacity among sets of given volume). On the other hand, balls do not maximize Riesz-capacity (with a Riesz-potential $|x|^{-\lambda}$, for fixed $\lambda > 0$) among sets of given diameter in high dimensions. Thus symmetry-breaking occurs as the Riesz kernel transitions from the Newtonian case ($\lambda = n – 2$) to the logarithmic case (corresponding to $\lambda = 0$), once $\lambda$ is small enough relative to $n$. (Joint work with R. Choksi, E. Hess-Childs, and A. Martinez.)

CARRIE CLARK, University of Illinois Urbana-Champaign
[Monday December 5 / lundi 5 décembre, 8:30 – Austen]
Droplet formation in a nonlocal aggregation model
The study of aggregation in the physical sciences has produced a rich class of nonlocal shape optimization problems. In this talk, we will discuss droplet formation in energy minimizing configurations for a family of interaction kernels which have a "well-barrier" type shape. Short distance attraction, combined with mid distance repulsion, and long distance neutrality drives the separation into droplets.

ANDREW COLINET, McMaster University
[Sunday December 4 / dimanche 4 décembre, 17:00 – Austen]
Zeroth Order Limiting Behaviour of the Ginzburg-Landau Functional

For $\Omega \subseteq \mathbb{R}^2$ there is an extensive literature concerning the limiting behaviour of the Ginzburg-Landau energy,

$$E_\varepsilon(u) = \int_\Omega \left\{ \frac{1}{2} \| \nabla u \|^2 + \frac{1}{4\varepsilon^2} (|u|^2 - 1)^2 \right\},$$

as $\varepsilon \to 0^+$. In such works, it is shown that if a sequence of functions has vorticity concentrate, as $\varepsilon \to 0^+$, about a finite collection of interior points of $\Omega$ then the Ginzburg-Landau energy converges, after renormalizing, to the total variation of a measure supported over the same interior points. However, much less is known when the vorticity of solutions is permitted to concentrate about points along the boundary.

We consider this question for a connected open set $\Omega \subseteq \mathbb{R}^2$ with $C^{2,1}$ boundary and we prove that similar conclusions to the interior case remain true up to the boundary provided the functions we consider satisfy suitable boundary restrictions. In addition, we also show that there are necessary topological restrictions on the vorticity.

ROBERT HASLHOFER, University of Toronto
[Monday December 5 / lundi 5 décembre, 16:00 – Austen]
Classification of compact ancient noncollapsed flows in $\mathbb{R}^4$

To capture singularities under mean curvature flow one wants to understand all ancient solutions. In addition to shrinkers and translators one also encounters ancient ovals, namely compact noncollapsed solutions that are not self-similar. In this talk, I will explain that any bubble-sheet oval for the mean curvature flow in $\mathbb{R}^4$, up to scaling and rigid motion, either is the $O(2) \times O(2)$-symmetric ancient oval constructed by White, or belongs to the one-parameter family of $Z_2^2 \times O(2)$-symmetric ancient ovals constructed by Du and myself. In particular, this seems to be the first instance of a classification result for geometric flows that are neither cohomogeneity-one nor selfsimilar. This is joint work with Beomjun Choi, Toti Daskalopoulos, Wenkui Du and Natasa Sesum. I will also briefly mention the noncompact case, which is joint work with Kyeongsu Choi and Or Hershkovits.

NICHOLAS KEVLAHAN, McMaster University
[Sunday December 4 / dimanche 4 décembre, 16:00 – Austen]
Data assimilation for bathymetry in the nonlinear shallow water equations

The shallow water equations (SWE) are a widely used model for the propagation of surface waves in oceans, lakes and rivers. Common applications include modelling the propagation of tsunami waves, storm surges and flooding. We consider the problem of determining under which conditions a space-time variational data assimilation approach based on observations of the free surface is able to reconstruct the bathymetry to a given accuracy (e.g. sufficient for modelling wave propagation). We then use density-based global sensitivity analysis (GSA) to assess the sensitivity of the surface wave and reconstruction error to model parameters and second order adjoint analysis (SOA) to analyze the sensitivity of the surface wave error, given the reconstructed bathymetry, to perturbations in the observations.

This is joint work with Bartek Protas (McMaster University) and Ramsha Khan (University of Stockholm)
SULLIVAN MACDONALD, McMaster University

Degenerate Ellipticity and Hypoellipticity for Divergence Operators

We discuss differential operators of the form $L = -\text{div}(Q \nabla \cdot)$, where $Q$ is a non-negative definite symmetric matrix-valued function. Even though $L$ fails to be elliptic at points where $Q$ is singular, in some settings we can recover regularity results for weak solutions to the Dirichlet problem

$$Lu = f \quad x \in \Omega,$$

$$u = 0 \quad x \in \partial \Omega.$$  

In this talk, I will present some recent joint work with S. Rodney concerning sufficient conditions for a priori boundedness of weak solutions to these problems. We show that even if a very weak Sobolev inequality with gain on Orlicz scale holds, one can still recover boundedness under appropriate hypotheses on the data $f$.

On the other hand, if rapid degeneracy of $Q$ forbids a Sobolev inequality with gain on Orlicz scale from holding, it would still be useful to understand qualitative behaviours of the operator $L$. To this end, I also discuss recent work at finding sufficient conditions for hypoellipticity of second-order divergence operators by using decompositions of H"{o}lder continuous functions into sums of squares. This work complements some recent results by Sawyer and Korobenko, which show that $L = -\text{div}(Q \nabla \cdot)$ is hypoelliptic when the matrix $Q$ admits a suitable decomposition.

DMITRY PELINOVKY, McMaster University

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

This investigation concerns a systematic computational search for potentially singular behavior in 3D Navier-Stokes flows. 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 asserting that the quantity $\mathcal{L}_{q,p} := \int_0^T \|u(t)\|_{L^q(\Omega)}^p \, dt$, where $2/p + 3/q \leq 1, q > 3$, must remain bounded if the solution is smooth on the interval $[0,T]$. However, there are no finite a priori bounds available for these quantities and hence the regularity problem for the 3D Navier-Stokes system remains open.

To quantify the maximum possible growth of $\mathcal{E}(T)$ and $\mathcal{L}_{q,p}$, 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 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 the maximum growth of $\mathcal{E}(T)$ and $\mathcal{L}_{q,p}$ appears finite. Thus, in the worst-case scenarios the two quantities remain bounded for all times and there is no evidence for singularity formation in finite time.

[Joint work with Dongfang Yun and Di Kang]

IVAN SALGADO, University of Toronto

Approximate Solutions to the Superconducting Interface Model

The superconducting interface model is a semilinear hyperbolic system of PDEs introduced in 2016 by Kyle Thompson. It proposes a more tractable, yet closely related alternative to a 1984 model of Edward Witten for cosmic strings carrying a
superconducting current. In the superconducting interface model, we consider the system

\[ \begin{cases} 
\epsilon^2 (\partial_t^2 \varphi - \Delta_x \varphi) + \lambda_\varphi (\varphi^2 - 1) \varphi + \beta_\varphi \sigma |^2 = 0 \\
\epsilon^2 (\partial_t^2 \sigma - \Delta_x \sigma) + \lambda_\sigma (|\sigma|^2 - m_\sigma^2) \sigma + \beta_\sigma \sigma^2 = 0
\end{cases} \]

where \( 0 < \epsilon \ll 1, (\lambda_\varphi, \lambda_\sigma, m_\sigma, \beta) \in (0, \infty)^4 \) are parameters, and

\[ \varphi : [0, T] \times \mathbb{R}^n \to \mathbb{R} \text{ and } \sigma : [0, T] \times \mathbb{R}^n \to \mathbb{C}, \]

for some \( T > 0 \) and \( n \in \mathbb{N} \) with \( n \geq 2 \). We are interested in solutions \((\varphi, \sigma)\) such that

\[ \varphi \approx \begin{cases} 
+1 & \text{in } \mathcal{O}^+ \\
-1 & \text{in } \mathcal{O}^-
\end{cases} \]

where \( \mathcal{O}^+ \) and \( \mathcal{O}^- \) are disjoint open subsets of \([0, T] \times \mathbb{R}^n\) separated by an “interface” with thickness of order \( \epsilon \), and the current-carrying field \( \sigma \) decays exponentially away from the interface. The problem is of particular interest when \( \sigma \) showcases a clear interaction with the geometry of the interface.

The purpose of this talk is to present a methodology for finding solutions to the superconducting interface model by first constructing approximate solutions, and then linearizing the system of PDEs around these approximations. We will talk about some of the results regarding the construction of the approximate solutions and the laws of motion which represent the coupling between the current supported around the interface and the geometry of the interface.

DOMINIK STANTEJSKY, McMaster University
[Monday December 5 / lundi 5 décembre, 8:00 – Austen]

A finite element approach for minimizing line and surface energies arising in the study of singularities in liquid crystals

I will present an algorithm designed to calculate minimizers \( T \) of a geometric energy arising in the theory of liquid crystal colloids. The energy involves the two dimensional area of \( T \) outside an obstacle, a contribution from \( T \) on the obstacle surface, and the length of the boundary \( \partial T \) reduced by a prescribed curve to make the problem nontrivial. It can be seen as a generalization of both the obstacle and Plateau problem. We discretize the energy by a finite element method and apply an ADMM scheme to carry out the minimization. We validate our algorithm in the case of a spherical obstacle and give examples of minimizing configurations in the case of a peanut- and croissant-shaped obstacle.

ZHICHAO WANG, The University of British Columbia
[Monday December 5 / lundi 5 décembre, 15:00 – Austen]

Min-max minimal hypersurfaces with higher multiplicity

Recently, X. Zhou proved that the Almgren-Pitts min-max solution has multiplicity one for bumpy metrics (Multiplicity One Theorem). In this talk, we exhibit the first set of examples of non-bumpy metrics on the \((n + 1)\)-sphere \((2 \leq n \leq 6)\) in which the varifold associated with the two-parameter min-max construction must be a multiplicity-two minimal \( n \)-sphere. This is proved by a new area-and-separation estimate for certain minimal hypersurfaces with Morse index two inspired by an early work of Colding-Minicozzi. This is a joint work with X. Zhou.
Community building in instructor training

Renforcement de la communauté dans la formation des instructeurs

Org: Carmen Bruni (Waterloo), Amenda Chow (York) and et Fok-Shuen Leung (University of British Columbia)

After two years of a deeply affecting and culture-changing pandemic, what do our instructor communities look like, and where do we go from here? In this session, we invite a wide variety of mathematicians to discuss instructor training, particularly in the context of community-building. How do mathematicians learn to teach at departments across Canada? What is the role of community-building in their training? What is the impact on students, novice teachers and veteran instructors? Are there any ideas and connections you can bring back to your own institution?

Après deux ans d’une pandémie qui a profondément affecté et changé la culture, à quoi ressemblent nos communautés d’instructeurs, et où allons-nous maintenant ? Dans cette séance, nous invitons une grande variété de mathématiciens à discuter de la formation des instructeurs, en particulier dans le contexte de la création de communautés. Comment les mathématiciens apprennent-ils à enseigner dans les départements du Canada ? Quel est le rôle du renforcement de la communauté dans leur formation ? Quel est l’impact sur les étudiants, les enseignants novices et les instructeurs chevronnés ? Y a-t-il des idées et des liens que vous pouvez rapporter dans votre propre établissement ?

Schedule/Horaire
Room/Salle: Wren C

Sunday December 4
dimanche 4 décembre

8:00 - 8:30 Thomas Wong (Heriot-Watt University), Fostering Global Teaching Teams in a pandemic. (p. 78)
8:30 - 9:00 Caroline Junkins & Jessie Meanwell (McMaster University), Takeaways from MacPRIME: partnering with undergraduates to foster and sustain a mathematical learning community (p. 77)
9:00 - 9:30 Chelsea Uggenti (University of Waterloo), Training graduate teaching assistants on active learning (p. 78)
9:30 - 10:00 Matthew Coles, Katie Faulkner and Jaye Sudweeks (University of British Columbia), Incorporating sustained community building in graduate TA experience (p. 77)
10:00 - 10:30 Emily Braley (Johns Hopkins University), A Distributed Leadership Model for Course Design and Building Community within an Instructional Team (p. 76)
15:30 - 16:00 Vanessa Radzimski (University of the Fraser Valley), A Team Teaching Model for Graduate Students’ Development as Instructors (p. 78)
16:00 - 16:30 Jason Siefken (University of Toronto), Active Learning and the Novice Instructor (p. 78)
16:30 - 17:00 James Charbonneau (University of British Columbia), Experiences In Instructor Development Through Paired Teaching (p. 77)
17:00 - 17:30 Fok-Shuen Leung (University of British Columbia), Panel for Community Building in Instructor Training (p. 77)

Abstracts/Résumés

EMILY BRALEY, Johns Hopkins University

[A Distributed Leadership Model for Course Design and Building Community within an Instructional Team]

Distributed leadership is a theoretical framework that has been applied to analyze teachers and their professional networks at both the K-12 and postsecondary levels. In this session I will present a structure based on a distributed leadership model that can be used to support course staff, and create space for multiple voices in course design. This model can build leadership capacity, let folks bring their strengths and expertise to course design and help create a teaching community within an instructional environment.
Community building in instructor training
Renforcement de la communauté dans la formation des instructeurs

In this structure, community-building begins at a pre-semester orientation and is sustained through activities during weekly coordination meetings in the term.

JAMES CHARBONNEAU, University of British Columbia

Experiences In Instructor Development Through Paired Teaching

Paired teaching (Stang 2017) is a collaborative model where two instructors are assigned to the same class with the intent of learning new teaching skills and pedagogical techniques while honing the ones that exist. Both instructors are responsible for all aspects of teaching, attend all classes, and both are given full credit for teaching. The most common pairing is a new faculty member with an experienced faculty member. New faculty get vital professional development and support while senior faculty get experience with mentorship and space to reflect on their own practice.

I will talk about my own extensive experience with paired teaching as a member of the Physics and Astronomy Department at the University of British Columbia. I will also share a very concrete tool "The Setlist" that arose from a paired teaching collaboration and has become the cornerstone of my teaching practice.


MATTHEW COLES, KATIE FAULKNER AND JAYE SUDWEEKS, University of British Columbia

Incorporating sustained community building in graduate TA experience

Over the past few years, we have focused on incorporating community building throughout the entirety of our graduate TA experience. We explore three stages of their development: on arrival, early in-service, and late in-service. In particular, we describe TA training, structured mentorship, TA check-ins and needs assessments, and systems for incorporating senior TAs in the running of community building activities. We are especially interested in community building components that are sustainable and reproducible so that these efforts can be long lived. We further comment on how to foster connection across different levels of the department, especially undergraduate TAs.

CAROLINE JUNKINS & JESSIE MEANWELL, McMaster University

Takeaways from MacPRIME: partnering with undergraduates to foster and sustain a mathematical learning community

With growing interest in STEM fields such as Data Science and Financial Mathematics, enrollment in undergraduate Math and Stats programs at McMaster University has been increasing over the past several years. As numbers grow, how can we be more intentional about fostering and sustaining an effective learning community? In 2022, the Department of Mathematics and Statistics piloted a summer bridge program aimed to build community and prepare students for university. The McMaster Peer-Run Inclusive Math Experience (MacPRIME) is a 4-week online program for incoming first-year Math and Stats students, developed and facilitated in partnership with upper-level undergraduates. In this talk, we will describe key takeaways from our development process, including:
1. Tailoring evidence-based teaching and learning strategies to a mathematically-inclined audience
2. Translating program objectives into interactive lessons using teacher.desmos.com
3. Setting up a sustainable ecosystem where undergraduates can move through the community from MacPRIME participants to instructors.
Community building in instructor training
Renforcement de la communauté dans la formation des instructeurs

FOK-SHUEN LEUNG, University of British Columbia
[Sunday December 4 / dimanche 4 décembre, 17:00 – Wren C]
Panel for Community Building in Instructor Training

In this segment of our special session, we will look back on some of the ideas raised during the day. Through a semi-structured moderated discussion, we will invite speakers and participants to compare, contrast and assess those ideas, particularly with the goal of adapting some of them for community building in instructor training at our own institutions.

VANESSA RADZIMSKI, University of the Fraser Valley
[Sunday December 4 / dimanche 4 décembre, 15:30 – Wren C]
A Team Teaching Model for Graduate Students’ Development as Instructors

Pedagogical training of mathematics graduate students is often disconnected from the actual experience of teaching, which can be time-consuming, logistically numbing and generally overwhelming for novice instructors. In this session, we discuss features of instructor training that support mathematics graduate students’ pedagogical development, empowering them to focus on their students’ learning and their own growth as teachers. Using self-reported experiences of mathematics graduate students who taught in a novel, team-teaching model, we describe three values built into the structure of the model and relate these values to previously identified obstacles to graduate students’ pedagogical development. We argue that these values can be integrated into existing training models to support instructor development.

JASON SIEFKEN, University of Toronto
[Sunday December 4 / dimanche 4 décembre, 16:00 – Wren C]
Active Learning and the Novice Instructor

The multi-section Linear Algebra I at the University of Toronto is structured as an “active learning” class. It is coordinated and instructors are provided with detailed lesson plans and in-class worksheets for every day of class. Though active learning is new to most instructors, they express a uniform willingness to try teaching in an active learning style—but the novices’ teaching is far from perfect. This talk will outline the structure provided to Linear Algebra I instructors as well as discuss some of the common difficulties they encounter and potential solutions.

CHELSEA UGGENTI, University of Waterloo
[Sunday December 4 / dimanche 4 décembre, 9:00 – Wren C]
Training graduate teaching assistants on active learning

One important and, at times, overlooked component of instructor training is the training of our graduate students in their roles as graduate teaching assistants. Although decades of research into evidence-based active learning activities are regularly shared between and practiced by instructors, this is not always introduced to our graduate students. Since some graduate students will be instructors someday, it is crucial that they are aware of and learn effective pedagogical practices like active learning early in their careers; these early teaching experiences tend to establish enduring teaching skills and approaches. A workshop on active learning techniques in the mathematical and statistical sciences was developed for graduate teaching assistants from those fields at the University of Western Ontario. A survey study of graduate teaching assistant perceptions about active learning before and after participating in the workshop was performed in September 2021 and September 2022. Learnings from this study are discussed.

THOMAS WONG, Heriot-Watt University
[Sunday December 4 / dimanche 4 décembre, 8:00 – Wren C]
Fostering Global Teaching Teams in a pandemic.
The pandemic created opportunities for us to reflect and develop new effective teaching collaborations. With campuses in UK, Dubai, and Malaysia, cross-campus teaching teams became a necessity at Heriot-Watt University to address the pedagogical and technological challenges required to teach effectively in this new medium. Within courses, we leveraged this opportunity to develop strong collegial collaborations and student-led initiatives that provides a sustainable teaching/mentoring model as we transition to a post-pandemic world.
There is a close relationship between complex geometry and the geometry of many moduli spaces appearing in mathematics. Indeed, when studying complex structures on a given topological space (such as a manifold), one considers their moduli spaces as these give information about the geometry and classification of the structures. On the other hand, moduli spaces of objects on complex spaces – such vector bundles, sheaves, or connections, to name a few – themselves inherit complex structures from the underlying spaces. Such moduli therefore often provide important examples of complex spaces that have specific geometric structures. For instance, moduli spaces of Higgs bundles on Riemann surfaces are examples of hyperkähler manifolds and algebraically completely integrable systems, which have been extensively over the past 35 years and play a key role in complex algebraic geometry, gauge theory, mirror symmetry and the geometric Langlands program. The purpose of this session is to gather geometers studying complex spaces and/or moduli spaces to present some of the recent developments in these interrelated fields.

Il existe une relation étroite entre la géométrie complexe et la géométrie de nombreux espaces de moduli apparaissant en mathématiques. En effet, lorsqu’on étudie des structures complexes sur un espace topologique donné (tel qu’une variété). D’autre part, les espaces de moduli d’objets sur des espaces complexes - tels que les faisceaux de vecteurs, les gerbes ou les connexions, pour n’en citer que quelques-uns - héritent eux-mêmes de structures complexes des espaces sous-jacents. Ces espaces moduli fournissent donc souvent des exemples importants d’espaces complexes ayant des structures géométriques spécifiques. Par exemple, les espaces moduli des faisceaux de Higgs sur les surfaces de Riemann sont des exemples de manifolds hyperkähler et de systèmes algébriquement complètement intégrables, qui ont été largement étudiés au cours des 35 dernières années et jouent un rôle clé dans la géométrie algébrique complexe, la théorie de la jauge, la symétrie miroir et le programme géométrique de Langlands. L’objectif de cette session est de réunir les géomètres étudiant les espaces complexes et/ou les espaces de moduli afin de présenter certains des développements récents dans ces domaines interdépendants.

Schedule/Horaire

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Abstracts/Résumés
E-polynomials of character varieties associated to a real curve

Given a Riemann surface $\Sigma$ denote by $M_n(F) := \text{Hom}_\xi(\pi_1(\Sigma), GL_n(F))/\text{GL}_n(F)$ the $\xi$-twisted character variety for $\xi \in F$ a $n$-th root of unity. An anti-holomorphic involution $\tau$ on $\Sigma$ induces an involution on $M_n(F)$ such that the fixed point variety $M^\tau_n(F)$ can be identified with the character variety of “real representations” for the orbifold fundamental group $\pi_1(\Sigma, \tau)$. When $F = \mathbb{C}$, $M^\tau_n(\mathbb{C})$ is an ABA-brane: a half-dimensional complex subvariety of $M_n(\mathbb{C})$ which is sent to a Lagrangian submanifold of the moduli space of Higgs bundles under the non-abelian Hodge correspondence.

The E-polynomial of $M_n(\mathbb{C})$ was determined by Hausel and Rodriguez-Villegas by counting points in $M_n(F_q)$ for finite fields $F_q$. I will show how the same methods are used to calculate a generating function for the E-polynomial of $M^\tau_n(\mathbb{C})$ using the representation theory of $\text{GL}_n(F_q)$.

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Moduli spaces of sheaves on Kodaira surfaces

Moduli spaces of stable sheaves on Kodaira surfaces give examples of compact holomorphic symplectic manifolds. The only known examples of non-Kähler holomorphic symplectic manifolds are Bogomolov-Guan manifolds or Douady spaces of points on Kodaira surfaces. In this talk we show that there exist compact moduli spaces in each even dimension, and that in the rank-2 case they are not Kähler but not deformation equivalent to Bogomolov-Guan manifolds. We also discuss some steps toward determining if these moduli spaces are deformation equivalent to Douady spaces of points on Kodaira surfaces.

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Symmetric instantons

During his MMATH study under my supervision, Spencer Whitehead developed a systematic framework to study instantons on $R^4$ that are invariant under groups of isometries. In this presentation, I will describe this framework and some results obtained using it.

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Tangent cones of admissible Hermitian-Yang-Mills connections

Admissible Hermitian-Yang-Mills(HYM) connections are singular HYM connections with natural geometric bounds. In higher dimensional gauge theory, they naturally appear on the boundary of the moduli space of Hermitian-Yang-Mills connections over Kaehler manifolds. A fundamental problem was to study the uniqueness of the tangent cones of admissible HYM connections. I will explain joint work with Song Sun which confirms the uniqueness by showing that the tangent cones are algebraic invariants of the underlying reflexive sheaf.

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Moduli of K3 surfaces with cyclic nonsymplectic automorphisms

K3 surfaces, as a 2-dimensional analog of elliptic curves, belong to an important class of varieties/complex-manifolds. Just as for the elliptic curves, K3 surfaces can be classified by using various invariants/viewpoints. In this talk, extending the idea from
Alexeev and Engel for lattice-polarized K3 surfaces, I will explain how different viewpoints lead to different compactifications of the moduli of K3 surfaces with cyclic actions and then describe their birational relations. In particular, I will focus on the case of Kondo’s sextic K3 surfaces and provide examples of boundary members of various compactifications. This talk is based on joint works in progress with Valery Alexeev, Anand Deopurkar, and Philip Engel.

CLAUDE LEBRUN, Stony Brook University
[Saturday December 3 / samedi 3 décembre, 10:00 – Gerrard]
Twistors, Hyper-Kähler Manifolds, and Complex Moduli

A theorem of Kuranishi guarantees that the moduli space of complex structures on any smooth compact manifold is locally a finite-dimensional space. Globally, however, this finite-dimensionality can fail. Indeed, I will describe examples in which the moduli space contains a sequence of regions for which the local dimension tends to infinity. These examples, which naturally arise from the twistor theory of hyper-Kähler manifolds, also display other surprising behaviors. I will highlight several of these, and put the entire story in a context that contrasts high-dimensional complex manifolds with complex surfaces, and non-Kähler manifolds with complex algebraic varieties.

ALESSANDRO MALUSÀ, University of Toronto
[Saturday December 3 / samedi 3 décembre, 9:00 – Gerrard]
Quantisation on hyper-Kähler spaces

Moduli spaces offer fertile ground for geometric quantisation. In that context, complex structures are commonly regarded as auxiliary data to be added to a symplectic form, the "true" classical structure. They also often come in families, and since they are extrinsic to quantisation one tries to remove them from the picture by constructing appropriate connections.

In the presence of a hyper-Kähler structure, however, there is no fixed underlying symplectic form: instead, there is a family of them, each coming with its own complex structure. In a joint work with J.E. Andersen and G. Rembado, we proposed a new approach to this problem, under sufficient symmetry assumptions, by introducing a holomorphic structure, rather than a connection, on the family of quantum Hilbert spaces, and tested it on a few interesting spaces. Furthermore, ongoing work with M. Mayrand has led to results in the case of Nahm moduli spaces, as well as insights on the problem of "quantisation commutes with reduction" for this new scheme.

In this presentation, I will give a panoramic of the new hyper-Kähler quantisation construction, and new results depending on time.

MAXENCE MAYRAND, Université de Sherbrooke
[Saturday December 3 / samedi 3 décembre, 9:30 – Gerrard]
Twistor constructions of hyperkähler and hypercomplex structures near complex submanifolds

We discuss generalizations of the Feix-Kaledin theorem on the existence of hyperkähler structures on cotangent bundles of Kähler manifolds. Using twistor theory, we show that the problem of constructing a hyperkähler structure on a neighbourhood of a complex Lagrangian submanifold in a holomorphic symplectic manifold reduces to the existence of certain deformations of holomorphic symplectic structures. Similarly, hypercomplex structures near half-dimensional complex submanifolds can be constructed from certain deformations of complex structures. By combining these results with Hitchin’s unobstructedness theorem on the deformation of holomorphic Poisson structures, we show that every holomorphic symplectic groupoid over a compact Kähler Poisson manifold has a hypercomplex structure on a neighbourhood of its identity section, and that there is a compatible hyperkähler metric if the Poisson manifold has complex dimension two.

BRENT PYM, McGill University
[Saturday December 3 / samedi 3 décembre, 16:00 – Gerrard]
(Shifted) Poisson structures from noncommutative surfaces
I will describe a canonical, nonperturbative recipe for the deformation quantization of rational/ruled surfaces, obtained by twisting a natural semi-orthogonal decomposition of the derived category by a Morita automorphism of an anticanonical curve. The moduli spaces of “sheaves” on the resulting “noncommutative surfaces” have natural Poisson structures, generalizing the classical constructions of Bottacin and Mukai (in the commutative case), Nevins–Stafford (in the case of elliptic quantum planes) and more recent works of Rains (in the case of simple sheaves). The proof of the Jacobi identity for the Poisson bracket leverages and extends recent developments in the theory of shifted symplectic/Poisson structures in derived algebraic geometry, due to Brav–Dyckerhoff, (Calaque–)Pantev–Toën–Vaquié–Vezzosi, Melani–Safronov and Toën. This talk is based on joint work with Eric Rains.

ETHAN ROSS, University of Toronto
[Saturday December 3 / samedi 3 décembre, 14:30]
An Introduction to Stratified Vector Bundles

Stratified spaces are a class of singular spaces arising in contexts like algebraic geometry and equivariant topology. In this talk, I will be discussing a natural class of stratified spaces, namely stratified vector bundles. I will give three major classes of examples and two equivalent definitions.

CARLO SCARPA, CIRGET
[Sunday December 4 / dimanche 4 décembre, 16:00 – Rosetti C]
Special representatives of complexified Kähler classes

Motivated by constructions appearing in mirror symmetry, we consider the problem of finding canonical representatives for a complexified Kähler class on a compact complex manifold. These are cohomology classes of the form $\beta + i \alpha$, for $\alpha$ a Kähler class and $\beta$ an arbitrary real $(1,1)$-class. As is often the case in complex geometry, one way to fix a representative of such a class is to impose an elliptic PDE. In this talk, I will explain why a natural choice of PDE is given by coupling the deformed Hermitian Yang-Mills equation and the constant scalar curvature equation. We will then see how to prove the existence of solutions in some special cases. Based on arXiv:2209.14157, joint work with Jacopo Stoppa.

XI SISI SHEN, Columbia University
[Sunday December 4 / dimanche 4 décembre, 16:30 – Rosetti C]
The Continuity Equation on Hopf and Inoue Surfaces

We discuss the continuity equation of La Nave-Tian, extended to the Hermitian setting by Sherman-Weinkove, on Hopf and Inoue surfaces. We briefly outline the proof of a priori estimates for solutions in both cases, and Gromov-Hausdorff convergence of Inoue surfaces to a circle. This is joint work with Kevin Smith.

JEREMY USATINE, Brown University
[Saturday December 3 / samedi 3 décembre, 17:30 – Gerrard]
Motivic integration for Artin stacks

A standard method for studying a singular variety is to resolve it by a smooth variety and to then relate invariants of the singular variety to invariants of the smooth one. Motivic integration provides powerful tools for obtaining such a relationship. Motivated by the McKay correspondence, I will describe a context in which interesting varieties admit natural resolutions of singularities by Artin stacks. This suggests a need for versatile tools in studying these “stacky” resolutions of singularities. I will discuss joint work with M. Satriano in which we use motivic integration to provide such tools, and I will also explain how our work leads to a notion of crepantness for stacky resolutions of singularities.
"Control theory has received increasing attention in the last decades, both from the engineering and the mathematical communities. Multiple factors have contributed to this successful spread, including, on one hand, progresses in the understanding of the structural/theoretical aspects of control systems, that have provided a newer and deeper insight on the control properties of complex systems; on the other hand, the impressive growth in computational power and algorithms, that has allowed to cope with exciting real-life applications, varying from industrial processes to biological phenomena, from fluid dynamics to decision making, from robotics to social sciences.

Through a diverse set of invited and contributed speakers, the main goal of this session is to bring together researchers focusing on mathematical foundations of control of dynamical systems with a wide range of expertise. Indeed, the session will welcome presentations on nonlinear feedback control, optimal control, controllability and observability properties of differential equations, as well as mean-field control and applications of machine learning to control design."

"La théorie du contrôle a fait l’objet d’une attention croissante au cours des dernières décennies, tant de la part de la communauté des ingénieurs que de celle des mathématiciens. De multiples facteurs ont contribué à ce succès, notamment, d’une part, les progrès dans la compréhension des aspects structurels/théoriques des systèmes de contrôle, qui ont fourni une vision nouvelle et plus profonde des propriétés de contrôle des systèmes complexes; d’autre part, la croissance impressionnante de la puissance de calcul et des algorithmes, qui a permis de faire face à des applications réelles passionnantes, allant des processus industriels aux phénomènes biologiques, de la dynamique des fluids à la prise de décision, de la robotique aux sciences sociales.

Par le biais d’un ensemble diversifié de conférenciers invités et contributeurs, l’objectif principal de cette session est de réunir des chercheurs se concentrant sur les fondements mathématiques du contrôle des systèmes dynamiques avec un large éventail d’expertise. En effet, la session accueillera des présentations sur le contrôle par rétroaction non linéaire, le contrôle optimal, les propriétés de contrôlabilité et d’observabilité des équations différentielles, ainsi que le contrôle du champ moyen et les applications de l’apprentissage automatique à la conception du contrôle."

### Schedule/Horaire

**Room/Salle: Rosetti A**

#### Sunday December 4

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<td>Jun Liu (University of Waterloo)</td>
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<td>Michel Delfour (Université de Montréal)</td>
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#### Monday December 5

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<td>Michel Duprez (Inria, Université de Strasbourg)</td>
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<td>10:00 - 10:30</td>
<td>Stevan Dubljevic (University of Alberta)</td>
<td>Observer-based model predictive control for a class of well-posed linear systems (p. 85)</td>
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### Abstracts/Résumés
**ALA’ ALALABI**, University of Waterloo

[Monday December 5 / lundi 5 décembre, 9:00 – Rosetti A]

*Boundary Stabilization of a Parabolic-Elliptic System Using Backstepping Approach*

We consider the boundary stabilization of a parabolic partial differential equation coupled with an elliptic partial differential equation. Even in the situation when these equations are exponentially stable when uncoupled, the coupled system may be unstable. In fact, increasing the coupling factor tends to destabilize the dynamics of the system. A backstepping approach is used to design a boundary control that will stabilize the system, or more generally, improve the decay rate in the situation when the original system is stable. The result is illustrated with simulations.

**MIREILLE BROUCKE**, University of Toronto

[Monday December 5 / lundi 5 décembre, 8:00 – Rosetti A]

*Principles and Paradoxes of Systems Neuroscience*

The talk will give an overview of control theoretic problems arising in the field of systems neuroscience. We present three case studies regarding the reflex paradox, the use it or lose it principle, and the principle of optimal steady-state. We show how these principles and paradoxes give rise to new challenges for control theory, and we discuss how we are addressing them.

**MICHEL DELFOUR**, Université de Montréal

[Sunday December 4 / dimanche 4 décembre, 16:30 – Rosetti A]

*Control, Shape, and Topological Derivatives via Minimax Differentiability of Lagrangians*

In Control Theory, the semidifferential (a one-sided directional derivative) of a state constrained objective function can be obtained by introducing a Lagrangian and an adjoint state. This problem is equivalent to the one-sided derivative of the minimax of the parametrized Lagrangian with respect to a positive parameter as it goes to 0 (for instance, Delfour and Zolésio, Shape and Geometries, Metrics, Analysis, Differential Calculus and Optimization, SIAM Ser. Advance in Control and Design, 2011) and Sturm, SIAM J. on Control and Optim., 53, no. 4, 2017-2039). In this talk new simpler conditions that predict the occurrence of an extra term (the polarization term in Mechanics) are given in term of the standard adjoint [Delfour, Control, shape, and topological derivatives via minimax differentiability of Lagrangians, Springer INdAM Series Vol. 29, 2018]. They are applied to the computation of semidifferentials with respect to the control and the shape and the topology of the underlying domain [Delfour, Topological Derivative of State Constrained Objective Functions: a Direct Approach, SIAM J. on Control and Optim. (1) 60 (2022), 22-47]. The shape derivative is a differential while the topological derivative usually obtained by expansion methods is not. It is a semidifferential obtained by perturbations arising from dilatations of points, curves, surfaces and, potentially, microstructures by using the notion of d-dimensional Minkowski content. Examples of such perturbations are the d-rectifiable sets and the sets of positive reach of Federer [Delfour, Topological derivatives via one-sided derivative of parametrized minima and minimax, Engineering Computations (1) 39 (2022), 34-59].

**STEVAN DUBLJEVIC**, University of Alberta

[Monday December 5 / lundi 5 décembre, 10:00 – Rosetti A]

*Observer-based model predictive control for a class of well-posed linear systems*

We consider observer-based model predictive control (MPC) for well-posed linear systems that are exponentially stabilizable and detectable using distributed state feedback and output injection. The proposed MPC controller is motivated by classical output MPC designs for finite-dimensional systems and comprises of dynamic output feedback and open-loop MPC. The dynamic output feedback will be obtained as an output of a Luenberger-type observer, and the open-loop MPC will be solved based on a nominal system which is essentially a copy of the actual plant. The proposed MPC design is applicable to any well-posed system satisfying the stabilability and detectability assumptions, which includes various reaction-convection-diffusion equations with boundary controls and observations as well as all exponentially stable well-posed linear systems. A one-dimensional diffusion
Control of dynamical systems  
Contrôle des systèmes dynamiques

equation will be considered as an illustrative example. Moreover, we will comment on possible extensions to more general classes of systems, e.g., if the assumptions on distributed state feedback and output injection are lifted.

MICHEL DUPREZ, Inria  
[Monday December 5 / lundi 5 décembre, 8:30 – Rosetti A]  
Models of mosquito population control strategies for fighting against arboviruses

In the fight against vector-borne arboviruses, an important strategy of control of epidemic consists in controlling the population of the vector, Aedes mosquitoes in this case. Among possible actions, a technique consist in releasing sterile mosquitoes to reduce the size of the population (Sterile Insect Technique). This talk is devoted to studying the issue of optimizing the dissemination protocol for each of these strategies, in order to get as close as possible to these objectives. Starting from a mathematical model describing the dynamic of a mosquitoes population, we will study the control problem and introduce the cost function standing for sterile insect technique. In a second step, we will consider a model with several patches modeling the spatial repartition of the population. Then, we will establish some properties of these two optimal control problems. Finally, we will illustrate our results with numerical simulations.

MARTIN GUAY, Queen’s University  
[Monday December 5 / lundi 5 décembre, 9:30 – Rosetti A]

PIERRE LISSY, Université Paris-Dauphine  
[Sunday December 4 / dimanche 4 décembre, 15:30 – Rosetti A]  
Desensitizing controls for the heat equation with respect to boundary variations

In this talk, I will present some recent results obtained in collaboration with Sylvain Ervedoza and Yannick Privat concerning desensitizing controls for the heat equation posed on a bounded domain of $\mathbb{R}^d$. The desensitization problem roughly consists in finding a control function, distributed on a subdomain, such that some functional depending on the solution of the heat equation (in our case, the $L^2$ norm of the solution on another subdomain) is locally insensitive to some perturbation of the equation. Here, the main originality of our work relies on the fact that the perturbation is the domain itself, in the sense that its boundary can be subject to some small variations. I will present various definitions of the desensitization problem and give some positive and negative results related to them.

JUN LIU, University of Waterloo  
[Sunday December 4 / dimanche 4 décembre, 16:00 – Rosetti A]  
Neural Lyapunov Control with Stability Guarantees

Learning for control of dynamical systems with formal guarantees remains a challenging task. In this talk, we introduce a learning framework to simultaneously stabilize an unknown nonlinear system with a neural controller and learn a neural Lyapunov function to certify a region of attraction for the closed-loop system. The algorithmic structure consists of two neural networks and a satisfiability modulo theories (SMT) solver. The first neural network is responsible for learning the unknown dynamics. The second neural network aims to identify a valid Lyapunov function and a provably stabilizing nonlinear controller. The SMT solver then verifies that the candidate Lyapunov function indeed satisfies the Lyapunov conditions. We provide theoretical guarantees of the proposed learning framework in terms of the closed-loop stability for the unknown nonlinear system. We illustrate the effectiveness of the approach with a set of numerical experiments. The talk is based on a recent paper published in NeurIPS 2022 (joint work with Ruikun Zhou, Thanin Quartz, and Hans De Sterck).
Event-Triggered Control for Linear Time-Delay Systems

Event-triggered control offers a practical method to update the control signals at a series of discrete-time moments determined by certain execution rules, often referred to as an event. The key benefit is to improve the efficiency of control implementations while still maintaining the desired performance levels for closed-loop control systems. In this talk, we present an event-triggered control method for the stabilization of linear time-delay systems. Based on two new Halanay-type inequalities, the global asymptotic stability of the event-triggered control system can be guaranteed, and a lower bound of the inter-event times, the intervals between successive control updates, can be derived to ensure the practical implementation of the proposed event-triggering condition. Two examples are given to demonstrate the suggested control method.
Diophantine Arithmetic Geometry and Number Theory
Géométrie de l’arithmétique diophantienne et Théorie des nombres

Org: Nathan Grieve and/et Patrick Ingram (York)

The session will consist of a collection of lectures from researchers who work at the intersection of number theory and arithmetic geometry. The session will feature lectures that are within the traditional areas of these fields. It will also place some emphasis on overlapping areas of arithmetic dynamics and complex geometry.

La session consistera en un ensemble de conférences données par des chercheurs qui travaillent à l’intersection de la théorie des nombres et de la géométrie arithmétique. La session présentera des conférences qui se situent dans les domaines traditionnels de ces domaines. Elle mettra également l’accent sur les domaines de chevauchement de la dynamique arithmétique et de la géométrie complexe.

Schedule/Horaire

Room/Salle: Carlyle B

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8:30 - 9:00  Keping Huang (MSU), Greatest Common Divisors on the Complement of Numerically Parallel Divisors (p. 89)
9:00 - 9:30  Matt Olechnowicz (University of Toronto), Dynamically improper hypersurfaces for endomorphisms of projective space (p. 91)
9:30 - 10:00 Xiao Zhong (University of Waterloo), p-Adic interpolation of orbits under rational maps (p. 92)
10:00 - 10:30 Borys Kadets (University of Georgia), Subspace configurations and low degree points on curves (p. 89)
10:30 - 11:00 David McKinnon (University of Waterloo), Rational curves and rational points (p. 91)
11:00 - 12:00 Hyungseop Kim (University of Toronto), Thomason filtration via $T(1)$-local topological cyclic homology (p. 89)
12:00 - 14:00  Lunch Break
14:00 - 14:30  Subham Roy (University of Montreal), Generalized Mahler measure of Laurent polynomials (p. 90)
14:30 - 15:00  Manoj Kummini (University of Utah), On a question of Katz and Poonen (p. 89)
15:00 - 15:30  Debanjana Kundu (PIMS/UBC), Studying Hilbert's 10th problem via explicit elliptic curves (p. 90)
15:30 - 16:00  Ruiran Sun (CRM/McGill, postdoc), Isotriviality of algebraic fiber spaces and the distribution of entire curves (p. 92)
16:00 - 16:30  Debanjana Kundu (PIMS/UBC), Studying Hilbert’s 10th problem via explicit elliptic curves (p. 90)
16:30 - 17:00  Sina Zabanfahm (University of Toronto), Cluster pictures for Hitchin fibers of rank two Higgs bundles (p. 92)
17:00 - 17:30  Sun Kai Leung (University of Montreal), Dirichlet law for factorization of integers, polynomials and permutations (p. 90)
17:30 - 18:00  Siva Sankar Nair (University of Montreal), An Invariant Property of Mahler Measures (p. 91)
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Sunday December 4

8:00 - 8:30  Michael Groechenig (University of Toronto), Arithmetic properties of rigid local systems (p. 89)
8:30 - 9:00  WanLin Li (University of Washington St. Louis), Ordinary Reductions of Abelian Varieties (p. 90)
9:00 - 9:30  Siva Sankar Nair (University of Montreal), An Invariant Property of Mahler Measures (p. 91)
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Abstracts/Résumés
**JASON BELL**

[Saturday December 3 / samedi 3 décembre, 8:00 – Carlyle B]

*Intersections of orbits of self-maps with subgroups in semiabelian varieties*

Let $G$ be a semiabelian variety defined over an algebraically closed field $K$, endowed with a rational self-map $\Phi$. Let $\alpha \in G(K)$ and let $\Gamma \subseteq G(K)$ be a finitely generated subgroup. We show that the set $\{ n \in \mathbb{N} : \Phi^n(\alpha) \in \Gamma \}$ is a union of finitely many arithmetic progressions along with a set of Banach density equal to 0. In addition, assuming $\Phi$ is regular, we prove that the set $S$ must be finite.

**MICHAEL GROECHENIG**, University of Toronto

[Sunday December 4 / dimanche 4 décembre, 8:00 – Carlyle B]

*Arithmetic properties of rigid local systems*

An irreducible local system is called rigid, if it cannot be deformed to a non-isomorphic local system. According to a conjecture by Simpson, rigid local systems on smooth projective varieties are expected to be of geometric origin, which leads to a swathe of surprising arithmetic and geometric properties for rigid local systems. In this talk I will explain how some of those properties can be established directly. This is joint work with Esnault.

**KEPING HUANG**, Michigan State University

[Saturday December 3 / samedi 3 décembre, 8:30 – Carlyle B]

*Greatest Common Divisors on the Complement of Numerically Parallel Divisors*

We prove inequalities involving greatest common divisors of functions at integral points with respect to numerically parallel divisors, generalizing a result of Wang and Yasufuku (after work of Bugeaud-Corvaja-Zannier, Corvaja-Zannier, and Levin). After applying a result of Vojta on integral points on subvarieties of semiabelian varieties, we use geometry and the theory of heights to reduce to the (known) case of $\mathbb{G}_m^n$. In addition to proving results in a broader context than previously considered, we also study the exceptional set in this setting, for both the counting function and the proximity function. This is a joint work with Aaron Levin.

**BORYS KADETS**, University of Georgia

[Saturday December 3 / samedi 3 décembre, 10:00 – Carlyle B]

*Subspace configurations and low degree points on curves*

The arithmetic irrationality $a_{\text{irr}}_k X$ of a curve $X$ over a number field $k$ is the smallest integer $d$ such that $X$ has infinitely many points of degree $d$. Hyperelliptic curves $y^2 = f(x)$ of genus $g \geq 2$ have $a_{\text{irr}}_k = 2$. Similarly, double covers of elliptic curves of positive rank have arithmetic irrationality 2; conversely, Harris and Silverman have shown that a curve with $a_{\text{irr}}_k X = 2$ is geometrically hyperelliptic or bielliptic. Soon after Abramovich and Harris proved that a similar statement holds for curves with $a_{\text{irr}}_k X = 3$. However, Debarre and Fahlaoui discovered that for all $d \geq 4$ there are families of curves with $a_{\text{irr}}_k X = d$ which do not admit degree $d$ or less maps to other curves. The existence of these Debarre-Fahlaoui curves makes it difficult to obtaining general results on curves with $a_{\text{irr}}_k X = d$.

I will report on a recent joint work with Isabel Vogt (arXiv:2208.01067), in which we prove some results towards classifying curves of arithmetic irrationality $d$. We show that this classification problem can be reduced to a study of curves of low genus, and use this reduction to obtain a classification for $d \leq 5$. These results are obtained by studying a new discrete-geometric invariant — the subspace configuration — attached to curves of arithmetic irrationality $d$. 

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2022 CMS WINTER MEETING | RÉUNION D'HIVER 2022 DE LA SMC
HYUNGSEOP KIM, University of Toronto

Saturday December 3 / samedi 3 décembre, 15:00 – Carlyle B

Thomason filtration via $T(1)$-local topological cyclic homology

Thomason’s result tells us that algebraic K-theory of schemes on which $p$ is invertible can be studied, after $T(1)$-localization (or morally etale sheafification), through $p$-adic etale cohomology. In this talk, I will explain how one can construct a filtration on $T(1)$-local TC of schemes through prismatic complexes, in a way compatible with Thomason’s filtration.

DEBANJANA KUNDU, UBC Department of Mathematics

Saturday December 3 / samedi 3 décembre, 16:30 – Carlyle B

Studying Hilbert’s 10th problem via explicit elliptic curves

N. Garcia-Fritz and H. Pasten showed that Hilbert’s 10th problem is unsolvable in the ring of integers of number fields of the form $\mathbb{Q}(\sqrt[3]{p}, \sqrt{-q})$ for positive proportions of primes $p$ and $q$. In joint work with A. Lei and F. Sprung, we improve their proportions and extend their results to the case of other number fields. We achieve this by replacing their Iwasawa theory arguments by a more direct method.

MATILDE LALIN, Université de Montréal

Sunday December 4 / dimanche 4 décembre, 10:00 – Carlyle B

On the Northcott property for zeta functions over function fields and number fields

The Northcott property implies that a set of algebraic numbers with bounded height and bounded degree must be finite. Pazuki and Pengo introduced a variant of the Northcott property for number fields using special values of the Dedekind zeta function to measure the height. We consider this question for global function fields with constant field $\mathbb{F}_q$, evaluating the zeta function at any complex number. We also reconsider the question for Dedekind zeta functions with arbitrary evaluations. This is joint work with Xavier Généreux and Wanlin Li.

SUN KAI LEUNG, University of Montreal

Sunday December 4 / dimanche 4 décembre, 9:30 – Carlyle B

Dirichlet law for factorization of integers, polynomials and permutations

Let $k \geq 2$ be an integer. We prove that factorization of integers into $k$ parts follows the Dirichlet distribution Dir $(\frac{1}{k}, \ldots, \frac{1}{k})$ by multidimensional contour integration, thereby generalizing the Deshouillers-Dress-Tenenbaum (DDT) arcsine law on divisors where $k = 2$. The same holds for the factorization of polynomials or permutations. Dirichlet distribution with arbitrary parameters can be modelled similarly. If time permits, we will also explore the evolution from the Dirichlet distribution to the multivariate normal distribution by restricting to smooth numbers.

WANLIN LI, Washington University in St. Louis

Sunday December 4 / dimanche 4 décembre, 8:30 – Carlyle B

Ordinary Reductions of Abelian Varieties

Given an abelian variety $A$ defined over a number field $L$, a conjecture attributed to Serre states that the density of primes of $L$ at which $A$ admits ordinary reduction is of positive density. This conjecture had been proved for elliptic curves (Serre, 1977), abelian surfaces (Katz 1982, Sawin 2016) and certain higher dimensional abelian varieties (Pink 1983, Fite 2021, etc). We will discuss some of the ideas behind these results and recent progress for abelian varieties with non-trivial endomorphisms, including the case of those with almost complex multiplication by an abelian CM field. This talk is based on joint work in progress with Victoria Cantoral-Farfan, Elena Mantovan, Rachel Pries, and Yunqing Tang.
On $\ell$-torsion of superelliptic Jacobians over finite fields

For a prime $\ell \geq 3$, we study the $\ell$-torsion subgroup of Jacobians $J$ of curves $y^d = f(t)$ over a finite field $\mathbb{F}_q$. When $f(t)$ is a monic irreducible polynomial and $q$ and $d := \deg(f)$ are both coprime to $\ell$, we give an upper bound on the $\ell$-rank of $J(\mathbb{F}_q)$ that depends only on $q$ and $d$. Using tools from Galois cohomology, we prove that the $\ell$-rank achieves this upper bound whenever $q^2 \equiv 1 \mod \ell$, and we find congruence conditions that can often be used to determine the $\ell$-rank when the upper bound alone is not sufficient. This is joint work with Wanlin Li and Eric Stubley.

Rational curves and rational points

Good approximations to rational points line up on rational curves. This, at least, is the conjecture, and it’s been verified in a whole bunch of cases. In this talk, I’ll discuss some cases where we know this, and even more cases where we could figure this out more if only we knew more about Vojta’s Conjecture.

An Invariant Property of Mahler Measures

The Mahler measure of a polynomial $P(x_1, x_2, \ldots, x_n)$ is the average value of $\log |P|$ along the unit $n$-torus $\mathbb{T}^n$ (defined by $|x_i| = 1$ for all $i$). Interest in this quantity arose from the fact that Mahler measures of certain polynomials are quite remarkable and not just arbitrary real numbers. If $P$ is univariate, this measure is given by Jensen’s formula in terms of its roots, and in the multivariable case, it has been observed that it evaluates to special values of $L$-functions. Oftentimes, a numerical experiment leads to a conjecture equating the Mahler measures of certain polynomials to these special values. In this talk, we shall investigate an interesting invariant property that provides a method to extend identities involving Mahler measures and also resolve some conjectures along the way. This is joint work with Matilde Lalín.

Dynamically improper hypersurfaces for endomorphisms of projective space

Most nonlinear endomorphisms of $\mathbb{P}^n$ have no nontrivial preperiodic subvarieties (that is, aside from preperiodic points and the whole space), which presents an obstacle to generalizing certain phenomena from $\mathbb{P}^1$. For instance, the statement that post-critically finite (PCF) maps are Zariski dense in the parameter space $\text{End}_{\mathbb{P}^1}^d$ (of degree-$d$ endomorphisms of $\mathbb{P}^1$) is true when $n = 1$ but false when $n > 1$.

Motivated by these observations, we are led to consider an alternative generalization of the notion of preperiodicity, from points in $\mathbb{P}^1$ to hypersurfaces in $\mathbb{P}^n$, which we call dynamical improperness. In this talk, we will define what it means for a hypersurface to be dynamically improper and explain the connection to preperiodicity. We will show that every nonlinear endomorphism of $\mathbb{P}^n$ has infinitely many dynamically improper hypersurfaces. We will also show that maps with dynamically improper critical loci (which coincide with PCF maps when $n = 1$) are Zariski dense in the parameter space $\text{End}_{\mathbb{P}^n}^d$ for all $n > 1$ and $d > 2$. 

Generalized Mahler measure of Laurent polynomials

Most nonlinear endomorphisms of $\mathbb{P}^n$ have no nontrivial preperiodic subvarieties (that is, aside from preperiodic points and the whole space), which presents an obstacle to generalizing certain phenomena from $\mathbb{P}^1$. For instance, the statement that post-critically finite (PCF) maps are Zariski dense in the parameter space $\text{End}_{\mathbb{P}^1}^d$ (of degree-$d$ endomorphisms of $\mathbb{P}^1$) is true when $n = 1$ but false when $n > 1$.

Motivated by these observations, we are led to consider an alternative generalization of the notion of preperiodicity, from points in $\mathbb{P}^1$ to hypersurfaces in $\mathbb{P}^n$, which we call dynamical improperness. In this talk, we will define what it means for a hypersurface to be dynamically improper and explain the connection to preperiodicity. We will show that every nonlinear endomorphism of $\mathbb{P}^n$ has infinitely many dynamically improper hypersurfaces. We will also show that maps with dynamically improper critical loci (which coincide with PCF maps when $n = 1$) are Zariski dense in the parameter space $\text{End}_{\mathbb{P}^n}^d$ for all $n > 1$ and $d > 2$. 

Generalized Mahler measure of Laurent polynomials
The (logarithmic) Mahler measure of a non-zero rational polynomial $P$ in $n$ variables is defined as the mean of $\log |P|$ restricted to the standard $n$-torus ($\mathbb{T}^n = \{(x_1, \ldots, x_n) \in (\mathbb{C}^*)^n : |x_i| = 1, \forall 1 \leq i \leq n\}$). The Mahler measure has been related to special values of L-functions, and this has been explained in terms of regulators. In 2018, Lalín and Mittal considered the generalized Mahler measure (where the mean of $\log |P|$ is restricted to arbitrary $n$-torus) to obtain relations between certain polynomials mentioned in Boyd’s paper. In this talk, we shall investigate the definition of the generalized Mahler measure for all Laurent polynomials in two variables when they do not vanish on the integration torus. We will then discuss few results we obtained involving the relation between the standard Mahler measure and the generalized Mahler measure of such polynomials.

RUIRAN SUN, CRM/McGill

[Saturday December 3 / samedi 3 décembre, 16:00 – Carlyle B]
Isotriviality of algebraic fiber spaces and the distribution of entire curves

It is conjectured that a quasi-projective manifold containing a non-degenerate entire curve is "special", and consequently any families of polarized manifolds over it should be isotrivial. In this talk we discuss a relative version of this "isotriviality conjecture". This is a joint work with Steven Lu and Kang Zuo.

SINA ZABANFAHM, University of Toronto

[Saturday December 3 / samedi 3 décembre, 17:00 – Carlyle B]
Cluster pictures for Hitchin fibers of rank two Higgs bundles

Let $\varphi \colon X \to Y$ be a degree two Galois cover of smooth curves over a local field $F$ of odd characteristic. Assuming that $Y$ has good reduction, we describe a semi-stability criterion for the curve $X$, using the data of the branch locus of the covering $\varphi$. In the case that $X$ has semi-stable reduction, we describe the dual graph of the minimal regular model of $X$ over $F$. We do this by adopting the notion of cluster picture defined for hyperelliptic curves for the case where $Y$ is not necessarily a rational curve. Using these results, we describe the variation of the $p$-adic volume of Hitchin fibers over the semi-stable locus of the moduli space of rank 2 twisted Higgs bundles.

XIAO ZHONG, University of Waterloo

[Saturday December 3 / samedi 3 décembre, 9:30 – Carlyle B]
p-Adic interpolation of orbits under rational maps

Rivera-Letelier’s characterization of possible analytic uniformizations of $p$-adic analytic maps has played an important role within arithmetic dynamics over the past fifteen years. The characterization is given by a trichotomy of indifferent, attracting and superattracting cases near a fixed point of a map.

In this talk, we present that if we are only interested in the orbit of a rational map on a point $c$ of $\mathbb{P}^1$ over a characteristic zero global field, we could always $p$-adically interpolate the orbit in the sense similar to the indifferent case of the trichotomy. This is done by working with a finitely generated field extension of $\mathbb{Q}$ and choosing suitable primes for embedding into local fields. We also present an application to the dynamical Mordell-Lang conjecture.

This project is a joint work with Prof. Jason P. Bell (arxiv: 2202.01673).
This session will include submissions on mathematical modelling and analysis of problems in environmental and geophysical fluid dynamics. The scope is broad and can include theoretical and computational work on any aspect of atmosphere, ocean, lake, or climate dynamics.

Cette session comprendra des soumissions sur la modélisation mathématique et l’analyse des problèmes de dynamique des fluides environnementaux et géophysiques. Le champ d’application est large et peut inclure des travaux théoriques et informatiques sur tout aspect de la dynamique de l’atmosphère, des océans, des lacs ou du climat.

Abstracts/Résumés

JORDAN FAZIO, University of Toronto

[Monday December 5 / lundi 5 décembre, 16:15 – Wren B]

Differential Geometric Formalism for GFD Coordinate Transformation Applications

This talk will focus on the use and importance of the methods and formalism of differential geometry in geophysical fluid dynamical settings. There are specific applications to work done on residual flows by Young (2012) and some extensions to other systems. The purpose of this is to elucidate the applicability of a more formal and complete use of differential geometric methods in GFD contexts, and particularly in coordinate transformations widely used throughout applications of GFD. Though coordinate transformations are explicitly geometric in nature, the full power of differential geometry is often skimmed over or altogether left out of discussion on the topic. However, to paint a more complete picture of applications of GFD involving coordinate transformations, the formalism can be useful.

In this talk, we go over the common basic ideas and structures in differential geometry such as the metric tensor and derivative operators such as the gradient curl and divergence, and by applying these ideas formally we find a more general framework for
changing between various coordinate systems commonly used in literature. To demonstrate our ideas, we extend residual flow work done by Young (2012) both by extending this work to use the full formalism of differential geometry as well as applying Young’s thickness-weighted averaging (TWA) formalism to other simple systems in the ocean and atmosphere, all involving coordinate transformations to common GFD quantities. In particular, Young’s work depends on the use of a vertical buoyancy coordinate, while our applications replace the horizontal coordinate with potential vorticity.

**ANDREW GRACE**, University of Waterloo

*Gravity Currents in the Cabbeling Regime*

Recently, the dynamics of flows beneath ice cover in lakes has garnered much interest in the GFD community. Much focus has gone into characterizing vertical flows beneath ice, while less has gone into characterizing the impact of horizontal flows beneath ice. We know that horizontal flows play a major role in the transport of nutrients, as well as impacting CML temperature. In this talk, we describe one such example of the interactions of horizontal flows and vertical flows induced from freshwater cabbeling (the mixing of parcels with equal density but different temperature). This talk presents numerical simulations of the evolution of freshwater gravity currents where intruding and ambient temperatures are on different sides of the temperature of maximum density. A setup like this might occur in the springtime from a riverine inflow. We will highlight how the initial intrusion flows along the upper surface of the domain and mixes with ambient water, and due to cabbeling, generates a coherent bottom current. We will introduce a control parameter (essentially the inverse of the non-dimensional temperature of maximum density), which is key to the evolution of the system, and we will show how the maximum horizontal extent of the initial intrusion varies with it. We show that for some cases, the maximum extent of the initial intrusion controls some of the important characteristics of the coherent bottom current. Finally, we will highlight some of the key characteristics (head height and temperature distribution) of the bottom current.

**NICOLAS GRISOUARD**, University of Toronto

*Causes and diagnostics of internal tide scattering by balanced vortices*

Internal tides are oceanic internal waves that oscillate approximately at tidal frequencies. However, their scattering by the turbulent oceanic eddy field leads to a modulation in amplitude and frequency. Satellite altimeters, which are our most reliable measurements to track internal tides globally, suffer from a sampling that is too coarse in time to capture the tidal oscillations when these modulations are important. This talk will describe our attempts to shed light on these processes from two complementary approaches: one idealized and one data-driven. I will first present numerical experiments of tidal wave scattering by isolated barotropic balanced vortices and propose a scaling law for how much scattering happens for a given wave/vortex pair. In a second part, I will describe how our group trained and tested a deep-learning algorithm to produce snapshots of the tidal wave’s signature based on raw snapshots of synthetic sea surface heights containing both eddies and waves.

**NICHOLAS KEVLAHAN**, McMaster University

*Realistic Modelling of the Gulf Stream Using Brinkman Penalization*

The advantage of a smooth representation of bathymetry in terrain-following $\sigma$-coordinate ocean models is compromised by the need to avoid numerical errors on steep slopes associated with horizontal pressure gradient discretization. Geopotential $z$-coordinate models avoid these errors, but greatly underrepresent the interaction of flow with a topographic slope, especially when the bathymetry is underresolved. Hybrid coordinate models are also deficient because it is difficult to find a satisfactory compromise between $z$ and $\sigma$ coordinates. With volume penalization, we do not seek a compromise, but rather a correction to the usual coordinate systems that realistically recovers continuous and steep bathymetry. We derive and apply a new volume penalization method to the Gulf Stream separation problem that has puzzled modellers for decades. The method improves the
representation of the flow-topography interaction and achieves realistic separation of the Gulf Stream at resolutions as coarse as 1/8 degrees. In addition, it provides a tool to separate the effect of eddy activity and topographic slope when changing grid resolution. Our results show that realistic bathymetry is more important than eddy activity in ensuring realistic Gulf Stream separation. We anticipate that a successful topographic slope correction will be valuable to climate models, as their current resolution is far from sufficient to represent western boundary currents (WBCs) using traditional coordinate systems. Our results suggest that a climate model using penalization with 1/4 degree resolution would represent ocean circulation much more realistically.

GREG LEWIS, Ontario Tech University
[Monday December 5 / lundi 5 décembre, 8:25 – Wren B]

Numerical continuation of amplitude-modulated rotating waves in sheared annular electroconvection

We investigate amplitude-modulated rotating waves (often referred to as amplitude vacillating flow) using numerical bifurcation methods based on time-integration. In particular, we study these flows as they occur in a model that simulates the flow of a liquid crystal film suspended between two annular electrodes, and subjected to an electric potential difference and a radial shear. This system is a close analogue of some laboratory-scale geophysical flow experiments (e.g. the differentially-heated rotating annulus), and to simplified models of the rotating equatorial regions of planetary atmospheres and planetary interiors. Although sheared annular electroconvection shares many characteristics with its geophysical counterparts, including their SO(2) symmetry, a crucial difference is in the two-dimensional nature of electroconvection. In particular, because the liquid crystal that is employed is in smectic A phase, its motion can be effectively modelled using the 2-D incompressible Navier-Stokes equations coupled with an equation for charge continuity.

The numerical method uses a Newton-Krylov approach for the continuation of solutions, and linear stability analysis of a flow map is used to identify the flow transitions that result due to changes in the model parameters. The amplitude-modulated waves equilibrate via a transition from rotating waves, and lose stability via a symmetry-breaking bifurcation. An appropriate choice of preconditioner enables the computation of the solution branch of modulated waves through a large range of parameter values regardless of the stability of the solutions.

KELLY OGDEN, Western University
[Monday December 5 / lundi 5 décembre, 15:00 – Wren B]

Mixing and Structure of Internal Hydraulic Jumps

Internal hydraulic jumps result in localized, intense mixing, affecting water properties and nutrient distributions. In some locations, the distribution of water properties can have severe negative effects on the local ecosystem; for example, in Hood Canal, low levels of dissolved oxygen result in periodic fish kills. To better understand how to mitigate these events, and how they might change in response to climate change, a better understanding of the behaviour of internal hydraulic jumps is required. Internal hydraulic jumps in the environment are complicated by many details, such as topographic variation, continuously varying velocity and density profiles, and Earth’s rotation. This work describes the results of idealized simulations that show how the structure and mixing of internal hydraulic jumps varies with upstream shear in a straight channel, with channel width variations, and with rotation. Idealized simulations are employed to isolate individual effects. Large Eddy Simulations are conducted using the CFD code Gerris, allowing turbulence statistics to be calculated. The scalar variance production from the turbulent scalar variance equation is used to quantify and compare mixing between simulations.

JASON OLSTHOORN, Queen’s University

Optimal Heat Flux Estimates

Temperature-chain data provide a lot of information about the physical processes occurring in lakes. These measurements characterise the thermal stratification, which has important consequences for the vertical transport of tracers. The evolution
of the thermal stratification \( T(z,t) \) is often modelled as a one-dimensional process obeying a diffusion equation,

\[
\frac{\partial T}{\partial t} = \nabla \cdot \left( \kappa_c \frac{\partial T}{\partial z} \right)
\]

for an eddy diffusivity \( \kappa_c \), assuming a fixed cross-sectional area. The value of \( \kappa_c \) is estimated through an empirical formal. We propose a new way to determine the optimal \( \kappa_c \) directly from the temperature profile data. Using an adjoint-loop, we can determine the best coefficient that minimizes the error between the diffusion equation and the observed data. Preliminary results show that the method is robust to low-level noise in the temperature record. Our hope is that this optimal method may help to quantify and clarify the physical processes occurring in lakes.

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**FRANCIS POUVIN, University of Waterloo**

[Monday December 5 / lundi 5 décembre, 8:50 – Wren B]

*The Dynamics of Magnetic Vortices*

The solar tachocline is a thin layer of the sun that is located between the radiative interior and the convective exterior. The dynamics is nearly two-dimensional and dominated by strong vorticity and shear. In this talk, we present recent investigations that use the Quasi-Geostrophic Magnetohydrodynamic (QG MHD) model to describe the dynamics of the solar tachocline since the deformations in the layer depth are small and the ambient rotation is strong compared to the local rotation rates. In particular, we revisit the classical test problems of Weiss (1966) to study the dynamics of magnetic vortices in the context of QG MHD that allows for an evolving magnetic field and weak deformations in the layer depth. It is determined that increasing magnetic fields tends to disrupt coherent vortices and forces energy to travel more to smaller scales.

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**ERICA ROSENBLUM, University of Manitoba**

[Monday December 5 / lundi 5 décembre, 15:50 – Wren B]

*Observed and simulated surface salinity under transitioning ice cover in the Canada Basin*

Climate models, which have been analyzed extensively to assess and predict current and future climate change and to inform policy, struggle to accurately simulate the rapid decline in Arctic sea ice. One possible source of this bias could be related to the vertical distribution of salt in the ocean, which controls the exchange of heat between the surface and deeper ocean. We compare simulations from two climate models to ocean observations collected below sea ice in the Canada Basin. In 1975, observations were collected by scientists living in ice camps, and in 2006–2012, they were obtained by automated instruments attached to sea ice. The observations indicate as much as six times greater surface freshening than the models between 1975 and 2006–2012. We show that the salt bias can be partly attributed to the models’ tendency to mix fresh water from the surface deeper than in observations, resulting in a saltier ocean surface. The results may provide insight for climate model improvement that could have wide-reaching implications because the vertical distribution of salt in the ocean directly impacts the vertical transport of heat and nutrients.

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**MAREK STASTNA, University of Waterloo**

[Monday December 5 / lundi 5 décembre, 10:05 – Wren B]

*Rotation effects in long-thin lakes*

While the effect of rotation on linear propagating waves and modes in closed basins (e.g. lakes) has a clear theory, the picture for nonlinear, dispersive waves is far from clear. After reviewing the effects of rotation on linear waves, I will use the example of Cayuga Lake, NY, USA during the temperature stratified season as a motivator for discussing nonlinear adjustment problems in long thin lakes. Here the idea is that the narrow dimension of the lake is smaller than than the internal Rossby deformation radius, but the long dimension of the lake is far larger compared to the internal Rossby deformation radius. Wave trains formed by stratified adjustment thus have time for all of nonlinear steepening, short-wave dispersion and rotation to play a role in their evolution. I will discuss the results of pseudospectral simulations of an idealized lake to discuss what kinds of wave forms
are spontaneously generated. I will then put these into context with respect to existing literature on stratified and geostrophic adjustment. Time permitting I will speculate on the effects of departures from an idealized geometry.

MICHAEL WAITE, University of Waterloo
[Monday December 5 / lundi 5 décembre, 16:40 – Wren B]
Viscous generation of potential enstrophy in breaking gravity waves

Ertel’s potential vorticity (PV) is an important quantity in the study of stratified flows in environmental and geophysical fluid dynamics. In the absence of viscosity, diffusion, and forcing, PV is materially conserved. In the quasi-geostrophic regime, the entire flow can be found by inverting the PV. But even for unbalanced flows at higher Rossby numbers, PV is useful for identifying vortical motions and distinguishing them from gravity waves. In turbulence, viscous effects are generally dissipative and restricted to small length scales. But because PV is quadratic in the flow variables, viscosity and diffusion can affect it in unexpected ways. Herring, Kerr and Rotunno (1994) showed that viscous and diffusive effects are not necessarily dissipative or restricted to small scales; instead, they can generate large-scale PV. In this work, we revisit this problem in high-resolution direct numerical simulations of stratified turbulence. The initial condition is a standing internal gravity wave, which is a linear solution to the equations of motion that notably has zero PV. However, the wave eventually breaks, generating small-scale stratified turbulence. We explore the growth of potential enstrophy (squared PV) and its dependence on Froude and Reynolds numbers. Results are interpreted using scale analysis and cascade theories for stratified turbulence. Implications for the use of PV to identify vortices in stratified turbulence are discussed.
Operator Algebras consists of the study of algebras of bounded linear operators on Hilbert spaces. It was initially developed in the late 1920s and early 1930s in an attempt to formalize the algebra of observables in quantum mechanics. The field has since become a fundamental part of modern mathematics and theoretical physics, as the natural setting for quantum information theory and quantum computing. In the last four decades there have been enormous advances in the field, such as the completion of a landmark in the Elliott classification program for nuclear C*-algebras, Jones and Popa’s breakthrough work in the classification of finite factors, and the solution of Tsirelson’s problem in quantum information theory. Moreover, work in operator algebras and noncommutative geometry has influenced many diverse areas of mathematics, such as number theory, harmonic analysis, model theory, group theory, knot theory, and ergodic theory. The goal of the session will be to have the participants report on recent advances in the area, interesting open questions, and new connections to explore.

Schedule/Horaire

Saturday December 3

8:00 - 8:30 KENNETH DAVIDSON (University of Waterloo), Positive Maps and Entanglement in Real Hilbert Spaces (p. 99)

8:30 - 9:00 REMUS FLORICEL (University of Regina), $C^*$-subproduct and product systems (p. 100)

9:00 - 9:30 MARCELO LACA (University of Victoria), Equilibrium on $C^*$-algebras of product systems (p. 101)

9:30 - 10:00 MASoud KHALKHALI (Western University), Double scaling limits of Dirac ensembles and Liouville quantum gravity (p. 100)

10:00 - 10:30 JANANAN ARulseelan (McMaster University), Computable Continuous Logic, QWEP, and Type III Factors (p. 99)

14:30 - 15:00 AARON TIKUISIS (University of Ottawa), Groupoids with prescribed torsion homology (p. 103)

15:00 - 15:30 DILIAN YANG (University of Windsor), Topological full groups of ample groupoids (p. 103)

16:00 - 16:30 CAMila FABRE SEHNM (University of Waterloo), A uniqueness theorem for Toeplitz algebras of semigroups (p. 102)

16:30 - 17:00 JASON CRANN (Carleton University), Quantum teleportation and subfactors (p. 99)

17:00 - 17:30 ARUNDIATHI KRISHNAN (University of Waterloo), Markovianity and the Thompson Group $F$ (p. 101)

17:30 - 18:00 DOLAPO OYETUNBI (University of Ottawa), On $\ell$-open and $\ell$-closed $C^*$-algebras. (p. 102)

18:00 - 18:30 JINTAO DENG (University of Waterloo), The coarse Baum-Connes conjecture for certain relative expanders (p. 100)

Sunday December 4

8:00 - 8:30 JAMES MINGO (Queen’s University), The Infinitesimal Distribution of Commutators and Anti-commutators (p. 102)
Facets of Operator Algebras
Facettes des algèbres opérateurs

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Abstracts/Résumés

MASSOUD AMINI, Tarbiat Modares University
[Sunday December 4 / dimanche 4 décembre, 17:30 – Scott B]

JANANAN ARULSEELAN, McMaster University
[Saturday December 3 / samedi 3 décembre, 10:00 – Scott B]

Computable Continuous Logic, QWEP, and Type III Factors

By the recent MIP*=RE result, the QWEP conjecture is known to be false. Consequently, the universal theory of the hyperfinite $II_1$ factor is not computable. We discuss the uncomputability of the universal theories of other Powers factors and the lack of an effective axiomatization of QWEP $C^*$ algebras. As an application we show that there is a ultraproduct of non-QWEP algebras with QWEP. This is joint work with Isaac Goldbring and Bradd Hart.

JASON CRANN, Carleton University
[Saturday December 3 / samedi 3 décembre, 16:30 – Scott B]

Quantum teleportation and subfactors

We will introduce quantum teleportation schemes in the commuting operator framework, in which locality is modelled by commuting observable algebras. For a large class of inclusions $N \subset M$ of tracial von Neumann algebras, we obtain a correspondence between "tight" teleportation schemes for the relative commutant $N' \cap M$ and unitary Pimsner-Popa bases for $M$ over $N$. Time permitting, we will discuss applications to the representation theory of linking algebras of quantum automorphism groups. This is joint work with Alexandre Conlon, David Kribs and Rupert Levene.

KENNETH DAVIDSON, U. Waterloo & U. Ottawa
[Saturday December 3 / samedi 3 décembre, 8:00 – Scott B]

Positive Maps and Entanglement in Real Hilbert Spaces

Quantum mechanics is formulated as a complex theory, but our perception of the world is real. This was part of our motivation for studying positive maps on real Hilbert spaces. There are positive, hermitian maps on real spaces whose complexification is not positive. The notion of a separable map has a real version and a complex version, and there are real maps which are complex separable but not real separable. Finally we look at entanglement breaking maps and a real version of the PPT$^2$ conjecture.
Facets of Operator Algebras
Facettes des algèbres opérateurs

ANDREW DEAN, Lakehead University
[Sunday December 4 / dimanche 4 décembre, 8:30 – Scott B]
Structure and classification of real C*-algebras
We shall discuss recent progress on the structure and classification of real C*-algebras.

JINTAO DENG, University of Waterloo
[Saturday December 3 / samedi 3 décembre, 18:00 – Scott B]
The coarse Baum-Connes conjecture for certain relative expanders
In 2000, G. Yu proved the coarse Baum-Connes conjecture for the metric space which admits a coarse embedding Hilbert space. However, there are counterexamples which are not coarsely embeddable into Hilbert spaces. Those counterexamples are so-called relative expanders. In this talk, I will talk about the coarse Baum-Connes conjecture for the relative expanders constructed by G. Arzhantseva and R. Tessera, based a joint work with Qin Wang and Guoliang Yu.

REMUS FLORICEL, University of Regina
[Saturday December 3 / samedi 3 décembre, 8:30 – Scott B]
C*-subproduct and product systems
We introduce and discuss two-parameter subproduct and product systems of C*-algebras as the operator-algebraic analogues of, and in relation to, Tsirelson’s two-parameter product systems of Hilbert spaces. This is joint work with Brian Ketelboeter.

CRISTIAN IVANESCU, MacEwan University
[Sunday December 4 / dimanche 4 décembre, 9:30 – Scott B]
The Cuntz semigroup and the structure of C*-algebras
In the early 2000s, Rordam and Toms constructed examples of non-isomorphic C*-algebras, which cannot be distinguished using K-theory, tracial simplexes and natural pairings, summed up as the Elliott invariant. Toms’s algebras can be distinguished by their Cuntz semigroup. In subsequent work, Perera and Toms conjectured that adding Cuntz semigroup to the Elliott invariant classifies the class of simple, separable and nuclear C*-algebras. To date, no counter-examples to this conjecture are known. In my talk, I will explore various properties of the Cuntz semigroup. The ultimate goal is to make progress in the Perera-Toms conjecture.

MASOUD KHALKHALI, Western
[Saturday December 3 / samedi 3 décembre, 9:30 – Scott B]
Double scaling limits of Dirac ensembles and Liouville quantum gravity
In this work we study ensembles of finite real spectral triples equipped with a path integral over the space of possible Dirac operators. In the noncommutative geometric setting of spectral triples, Dirac operators take the center stage as a replacement for a metric on a manifold. Thus, this path integral serves as a noncommutative analogue of integration over metrics, a key feature of a theory of quantum gravity. From these integrals in the so-called double scaling limit we derive critical exponents of minimal models from Liouville conformal field theory coupled with gravity. Additionally, the asymptotics of the partition function of these models satisfy differential equations such as Painlevé I, as a reduction of the KDV hierarchy, which is predicted by conformal field theory. This is all proven using well-established and rigorous techniques from random matrix theory. (Based on joint work with H. Hessam and N. Pagliaroli in arXiv:2204.14206)
Facets of Operator Algebras
Facettes des algèbres opératrices

FEODOR KOGAN, University of Toronto
[Sunday December 4 / dimanche 4 décembre, 15:30 – Scott B]
Groupoid models of the irrational rotation algebra

Building on a paper by George Elliott and Dickson Wong where the authors give a groupoid construction of the Rieffel projection, we will take a look at a sequence of groupoid models of the irrational rotation algebra and compute the K-theory of the corresponding groupoid algebras by modifying the proof of the Pimsner-Voiculescu six term exact sequence.

ARUNDHATHI KRISHNAN, University of Waterloo
[Saturday December 3 / samedi 3 décembre, 17:00 – Scott B]
Markovianity and the Thompson Group F

We show that representations of the Thompson group F yield a large class of bilateral stationary noncommutative Markov processes. As a partial converse, bilateral stationary Markov processes in tensor dilation form (and in particular, in the commutative setting) are shown to yield representations of F. We point out analogous results between unilateral stationary Markov processes and representations of the Thompson monoid F+. This is joint work with Claus Koestler and Stephen J. Wills.

MARCELO LACA, University of Victoria
[Saturday December 3 / samedi 3 décembre, 9:00 – Scott B]
Equilibrium on C*-algebras of product systems

We generalize recent work of Afsar, Larsen and Neshveyev [ALN] describing KMS states of quasi-free dynamics on the Toeplitz C*-algebras of product systems over quasi-lattice ordered semigroups. KMS states are parametrized by traces on the coefficient algebra that satisfy a positivity condition. This positivity condition can be reduced to a finite set of inequalities for a wide class of right LCM monoids that properly contains finite-type Artin monoids, answering a question raised in [ALN]. This allows us to exhibit a finite-type Artin monoid with a gap in its inverse temperature space. Our main technical result uses a certain tree recently constructed by Boyu Li to study dilations of contractive representations. For Noetherian right LCM monoids we also obtain a reduction of the positivity condition to inequalities arising from a minimal subset. This is joint work with Luca E. Gazdag and Nadia S. Larsen.

THERESE LANDRY, Fields Institute for Research in Mathematical Sciences
[Sunday December 4 / dimanche 4 décembre, 16:00 – Scott B]
Noncommutative Solenoids, Length Functions on Twisted Group C*-Algebras, and Inductive Limits of Spectral Triples

Noncommutative solenoids are inductive limit algebras built from rotation algebras. By viewing noncommutative solenoids as twisted group C*-algebras, we construct compact quantum metric spaces, as well as spectral triples. Building on the work of Christ and Rieffel, Long and Wu defined length functions on twisted group C*-algebras. Both of our constructions rely on such length functions. In particular, our spectral triples on noncommutative solenoids can also be shown, in the sense of Floricel and Ghorbanpour, to be inductive limit spectral triples on rotation algebras. This is joint work with C. Farsi, N. Larsen, and J. Packer.

JAVAD MASHREGHI, Laval University
[Sunday December 4 / dimanche 4 décembre, 10:00 – Scott B]
Lebesgue’s constants in local Dirichlet spaces

The partial Taylor sums \( S_n \), \( n \geq 0 \), are finite rank operators on any Banach space of analytic functions on the open unit disc. In the classical setting of disc algebra \( A \), the precise value of \( \|S_n\|_{A \rightarrow A} \) is not known. These numbers are referred as the
Lebesgue constants and they grow like $\log n$, modulo a multiplicative constant, when $n$ tends to infinity. We study $\|S_n\|$ when it acts on the local Dirichlet space $D_\zeta$. There are several distinguished ways to put a norm on $D_\zeta$ and each choice naturally leads to a different operator norm for $S_n$, as an operator on $D_\zeta$. We consider three different norms on $D_\zeta$ and, in each case, evaluate the precise value of $\|S_n\|_{D_\zeta \to D_\zeta}$. In each case, we also show that the maximizing function is unique.

**JAMES MINGO**, Queen's University

*The Infinitesimal Distribution of Commutators and Anti-commutators*

Given a unitarily invariant random matrix $X_N$ and a fixed finite rank matrix $F_N$, it is known from the work of Sklyakhtenko (2018) and Collins, Hasabe, and Sakuma (2018) that $X_N$ and $F_N$ are asymptotically infinitesimally free. In joint work with Pei-Lun Tseng (NYU Abu Dhabi), we consider the commutator $i(X_N F_N - F_N X_N)$ and the anti-commutator $X_N F_N + F_N X_N$ and present a simple formula for their asymptotic infinitesimal distributions.

**ZHUANG NIU**, University of Wyoming

*Weak Rokhlin Property and Weak Tracial Approximation*

Consider a minimal $C^*$-dynamical system $(A, \Gamma)$, where $A$ is a unital $C^*$-algebra and $\Gamma$ is a discrete amenable group. Let us study the structure of the crossed product $C^*$-algebra $A \rtimes \Gamma$. Assume the system $(A, \Gamma)$ has the Weak Rokhlin Property (WRP), then the crossed product $C^*$-algebra $A \rtimes \Gamma$ is shown to be weakly tracially approximated by matrix algebras over hereditary sub-$C^*$-algebras of $A$. As a consequence, if $A$ locally has finite nuclear dimension, then $C^*$-algebra $A \rtimes \Gamma$ is $Z$-stable if, and only if, $Cu(A \rtimes \Gamma) \cong Cu((A \rtimes \Gamma) \otimes Z)$. Moreover, in the case that $|\Gamma| = \infty$, the $C^*$-algebra $A \rtimes \Gamma$, $Z$-stable or not, always has stable rank one if $(A, \Gamma)$ has the property of Cuntz comparison of Open Sets (COS). It is also studied when the properties (WRP) and (COS) hold. This is a joint work with George Elliott, Chun Guang Li, and Qingyun Wang.

**DOLAPO OYETUNBI**, University of Ottawa

*On $\ell$-open and $\ell$-closed $C^*$-algebras.*

A separable $C^*$-algebra $A$ is said to be $\ell$-open ( or $\ell$-closed) when the image of Hom($A$, $B$) is open (or closed) in Hom($A$, $B/I$), for all separable $C^*$-algebras $B$ and ideals $I$. The concept of semiprojectivity has been used many times in the classification of $C^*$-algebras. Bruce Blackadar introduced $\ell$-open and $\ell$-closed $C^*$-algebras as a superclass of semiprojective $C^*$-algebras.

In recent work with A. Tikuisis, we characterize $\ell$-open and $\ell$-closed $C^*$-algebras and deduce that $\ell$-open $C^*$-algebras are $\ell$-closed as conjectured by Blackadar. Moreover, we show that the notion of $\ell$-open $C^*$-algebras and semiprojective $C^*$-algebras coincide for commutative unital $C^*$-algebras.

**CAMILA FABRE SEHNEM**, University of Waterloo

*A uniqueness theorem for Toeplitz algebras of semigroups*

I will report on recent work with M. Laca, in which for each submonoid $P$ of a group we define a universal Toeplitz $C^*$-algebra $T_u(P)$ via generators and relations that is canonically isomorphic to Li’s semigroup $C^*$-algebra when independence holds and works as expected when independence fails. I will focus on faithfulness of representations and uniqueness theorems for Toeplitz $C^*$-algebras, presenting results that are new also for monoids that satisfy independence.
Joint Majorization in Continuous Matrix Algebras

The notion of majorization of one self-adjoint $n \times n$ matrix by another appears in many different results in mathematics. A "multivariate majorization" often called joint majorization occurs by generalizing the notion of majorization from self-adjoint matrices to tuples of commuting self-adjoint matrices. In this talk, various notions of joint majorization will be examined in continuous matrix algebras. The relative strengths of these notions are established via proofs and examples. In addition, the closed convex hulls of joint unitary orbits are completely characterized in continuous matrix algebras via notions of joint majorization. Some of these characterizations are extended to subhomogeneous C*-algebras. (This is joint work with Xavier Mootoo and was funded by an NSERC USRA).

Groupoids with prescribed torsion homology

The 0\(^{th}\) homology group of an étale groupoid is an invariant closely connected to the C*-algebraic $K_0$-group. I will discuss a construction of étale groupoids with certain prescribed abelian groups as this invariant. Interestingly, we are able to arrange for a mixture of torsion and non-torsion. This is joint work with Hung-Chang Liao.

Topological full groups of ample groupoids

In this talk, I will report an ongoing joint work with Armstrong-Clark-Ghandehari-Kang on topological full groups of ample groupoids. Given an ample groupoid, there is a natural representation of its topological full group. I will talk about the injectivity and surjectivity of its lifting in the algebraic setting.
Inclusive Practices in Large Classes
Pratiques inclusives dans les grandes classes

Org: Katherine Daignault (University of Toronto) and Marie MacDonald (Cornell)

Many instructors are eager to incorporate new teaching strategies to create inclusive learning environments such as using active learning techniques which require more student check-ins. In large-scale classes with hundreds of students, it can be challenging to implement new teaching techniques without overburdening ourselves in the face of limited teaching resources/supports. This session will discuss inclusive practices that scale up well for large classes and will provide advice on the strategic use of teaching assistants to aid in the creation and implementation of diverse assessments.

De nombreux instructeurs sont désireux d'intégrer de nouvelles stratégies d'enseignement pour créer des environnements d'apprentissage inclusifs, comme l'utilisation de techniques d'apprentissage actif qui nécessitent davantage de contrôles de la part des étudiants. Dans les classes à grande échelle comptant des centaines d’étudiants, il peut être difficile de mettre en œuvre de nouvelles techniques d'enseignement sans se surmener face à des ressources/soutiens pédagogiques limités. Cette session abordera les pratiques inclusives qui s'adaptent bien aux grandes classes et fournira des conseils sur l'utilisation stratégique des assistants d’enseignement pour aider à la création et à la mise en œuvre d’évaluations diverses.

Schedule/Horaire

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<td>Diana Skrzydlo (University of Waterloo)</td>
<td>Universal Design for Learning in Stats (p. 105)</td>
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Abstracts/Résumés

ANDRIJANA BURAZIN, UTM
[Monday December 5 / lundi 5 décembre, 15:00 – Wren C]

making learning math great again for everyone

I will share the inclusive practices that I use in large classes. Some things work. Others do not. But my teaching practice and course design change over time to hopefully fit my diverse math learners. Most students actually enjoy the experience of learning math. :)

GROUP DISCUSSION.
[Monday December 5 / lundi 5 décembre, 16:00 – Wren C]

GROUP DISCUSSION.
[Monday December 5 / lundi 5 décembre, 10:00 – Wren C]
Inclusive Practices in Large Classes
Pratiques inclusives dans les grandes classes

CAROLINE JUNKINS, McMaster University
[Monday December 5 / lundi 5 décembre, 15:30 – Wren C]

ALYSSA LUMLEY, York University
[Wren C]

ANTON MOSUNOV AND GRAEME TURNER, University of Waterloo
[Monday December 5 / lundi 5 décembre, 9:30 – Wren C]

Following Principles of UDL When Authoring Electronic Textbooks and Auto-Graded Assessments

Providing students with multiple means of acquiring information agrees with the principles of Universal Design for Learning (UDL). One way this can be achieved is by developing electronic textbooks in addition to standard PDF course notes or physical textbooks. We present two such electronic textbooks created for Introduction to Proofs and Linear Algebra I courses at the University of Waterloo. Developed with Mobius courseware delivery tool, these textbooks contain narrated slideshows in accessible format, interactive exercises, as well as algorithmic concept check questions with instant feedback. We also discuss how auto-graded assessments assembled from such algorithmic questions can be used in large classes so to reduce the marking load and provide students with more opportunity to practice core concepts.

DIANA SKRZYDLO, University of Waterloo
[Monday December 5 / lundi 5 décembre, 8:30 – Wren C]

Universal Design for Learning in Stats

The last few times I have taught Statistics courses, I’ve employed several Universal Design for Learning (UDL) principles to make it more equitable, including multiple ways to access course material, demonstrate engagement, and submit assessments. As it turned out, students this term who normally require several accessibility accommodations was able to engage with my course exactly as it was designed, because the barriers they normally face were already removed. In this talk I will share my approach and overall thoughts.

JAIMAL THIND, University of Toronto Mississauga
[Monday December 5 / lundi 5 décembre, 9:00 – Wren C]
Low-dimensional Topology
Topologie en basses dimensions

Org: Hans U. Boden (McMaster) and/Duncan McCoy (UQAM)

The focus will be on geometry and topology of manifolds in low dimensions. Topics of interest include knots and links, geometric structures on manifolds in dimensions 3 and 4, gauge theory, geometric group theory.

L’accent sera mis sur la géométrie et la topologie des collecteurs en basse dimension. Les sujets d’intérêt comprennent les nœuds et les liens, les structures géométriques sur les collecteurs en dimensions 3 et 4, la théorie de la jauge, la théorie des groupes géométriques.

Schedule/Horaire  

Saturday December 3  
samedi 3 décembre

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STEVE BOYER (UQAM), The JSJ graph of knot exteriors and the L-space conjecture (p. 106)

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ALBERTO CAVALLO (UQAM), Slice links and smooth 4-manifolds (p. 107)

10:00 - 10:20  
PATRICK NAYLOR (Princeton), Doubling Gluck twists (p. 108)

14:30 - 14:50  
ALEXANDER KOLPAKOV (Neuchâtel), Subspace stabilizers in hyperbolic lattices (p. 108)

15:00 - 15:20  
KEEGAN BOYLE (UBC), Equivariant slice disks for symmetric knots (p. 107)

16:00 - 16:20  
DROR BAR-NATAN (Toronto), Simple, Concise, Powerful, and Not Understood (p. 106)

16:30 - 16:50  
TY GHASWALA (Waterloo), Small covers of big surfaces (p. 107)

17:00 - 17:20  
YVON VERBERNE (Toronto), Automorphisms of the fine curve graph (p. 109)

17:30 - 17:50  
HOMAYUN KARIMI (McMaster), Concordance invariants of null-homologous knots in thickened surfaces (p. 108)

18:00 - 18:20  
MATT STOFFREGEN (Michigan State), Concordance of cables of the figure eight knot (p. 109)

18:30 - 18:50  
MIKE WONG (LSU/Ottawa), Ribbon homology cobordism (p. 109)

Sunday December 4  
dimanche 4 décembre

8:00 - 8:20  
CHARLES DAILY (Brown), Projective Rigidity of Dehn-Surgery on the Figure Eight Knot (p. 107)

8:30 - 8:50  
JIE CHEN (McMaster), FlatKnotInfo: A Table of Flat Knots (p. 107)

9:00 - 9:20  
ROBERT HARRIS (Waterloo), Non-cyclic branched covers of the complex projective plane (p. 108)

9:30 - 9:50  
PATRICIA SORYA (UQAM), Pentes caractérisantes et nœuds satellites / Characterizing slopes for satellite knots (p. 109)

10:00 - 10:20  
PUTTIPONG PONGTANAPAISSAN (Saskatchewan), Behaviors of meridional ranks under various operations (p. 109)

Abstracts/Résumés

DROR BAR-NATAN, University of Toronto, Mathematics

[Saturday December 3 / samedi 3 décembre, 16:00 – Austen]

Simple, Concise, Powerful, and Not Understood

I will give a simple and concise description of a strong and fast to compute knot invariant which seems to actually see some topology. Your homework will be to explain why it makes sense for a topologist to invert a presentation matrix for the Alexander module of a knot and consider quadratic combinations of the entries of said inverse.
Low-dimensional Topology
Topologie en basses dimensions

STEVE BOYER, UQAM

[Saturday December 3 / samedi 3 décembre, 9:00 – Austen]
The JSJ graph of knot exteriors and the L-space conjecture

We report on joint work with Cameron Gordon and Ying Hu which shows that the underlying space of the JSJ graph of a knot in the 3-sphere is an interval if it admits an irreducible surgery which is either an L-space or has non-left-orderable fundamental group. The L-space conjecture predicts that a similar conclusion holds for knots having irreducible surgeries admitting no co-oriented taut foliations and we discuss to what extent we can prove this.

KEEGAN BOYLE, UBC

[Saturday December 3 / samedi 3 décembre, 15:00 – Austen]
Equivariant slice disks for symmetric knots

A symmetric knot $K$ is equivariantly slice if there is an extension of the symmetry to the 4-ball and $K$ bounds a smooth disk with respect to this extension. In this talk I will discuss this notion for several types of symmetric knots, and applications of these ideas to 4-manifold topology. This is joint work: some with Ahmad Issa, and some with Wenzhao Chen.

ALBERTO CAVALLO, Universite du Quebec a Montreal

[Saturday December 3 / samedi 3 décembre, 9:30 – Austen]
Slice links and smooth 4-manifolds

An appropriate variation of the trace embedding lemma allows us to prove results about smooth, closed, simply connected 4-manifolds; studying smoothly slice links in them. We focus on homotopy 4-spheres, which are potential counterexamples to the smooth 4-dimensional Poincaré conjecture. In particular, we split them, in the same way as exotic $\mathbb{R}^4$’s, in large and small 4-spheres and show that links cannot distinguish the latter ones from the standard $S^4$.

JIE CHEN, McMaster University

[Sunday December 4 / dimanche 4 décembre, 8:30 – Austen]
FlatKnotInfo: A Table of Flat Knots

Flat knots (aka virtual strings) are homotopy classes of immersed curves on surfaces up to stabilization. They naturally arise in studying unknotting operations applied to virtual knots. By work of Turaev, Hass and Scott, and others, there is a known algorithm for classifying flat knots, and in this talk I will present the results of implementing the algorithm on the set of flat knots with up to eight crossings. In prior work, Gibson had classified flat knots up to four crossings, and I will discuss the invariants that were most helpful in distinguishing the flat knots, their symmetry type, and questions about concordance and sliceness. I will also showcase a web-based tool called FlatKnotInfo that gives users access to a table of flat knots and their invariants. This talk represents joint work with L. White.

CHARLES DALY, Brown University

[Sunday December 4 / dimanche 4 décembre, 8:00 – Austen]
Projective Rigidity of Dehn-Surgery on the Figure Eight Knot

A celebrated result of Thurston states that for all but finitely many relatively prime integers $p$ and $q$, the $(p, q)$-Dehn Surgery of the Figure Eight Knot yields a closed hyperbolic manifold. Mostow Rigidity prevents this hyperbolic structure from being deformed in the sense that any two faithful representations of its fundamental group into $\text{PSL}(2, \mathbb{C})$ are conjugate. Identifying $\text{PSL}(2, \mathbb{C})$ with $\text{PSO}(3, 1)$ which sits in the larger projective linear group, $\text{PGL}(4, \mathbb{R})$, we provide evidence that representations of the fundamental group of these surgered manifolds do not admit non-trivial deformations in the larger projective linear group.
Low-dimensional Topology  
Topologie en basses dimensions

TY GHASWALA, University of Waterloo  
[Saturday December 3 / samedi 3 décembre, 16:30 – Austen]
Small covers of big surfaces

Imagine the plane $\mathbb{R}^2$ where every point with integer coordinates has been removed. Call this surface $X$. Which surfaces arise as finite-sheeted covers of $X$? Which surfaces can $X$ cover by finitely-many sheets?

I will talk about work Alan McLeay investigating the above seemingly innocent questions, and the more general version: Given two surfaces, when does there admit a finite-sheeted cover of one over the other? A complete answer is available if the two surfaces are of finite type. In the infinite-type world, the question is less innocent than one might expect.

ROBERT HARRIS, University of Waterloo  
[Sunday December 4 / dimanche 4 décembre, 9:00 – Austen]
Non-cyclic branched covers of the complex projective plane

We will discuss the construction of 4-manifolds by means of non-cyclic abelian branched covers. In particular, if we choose our branch locus to be a line arrangement in $\mathbb{C}P^2$ then we will see conditions under which the branch cover is a surface of general type. We also look at when these surfaces can have non-negative signature. Furthermore, we see how this relates to the geography problem for simply connected non-spin symplectic 4-manifolds and mention the speaker’s recent joint work with his collaborators.

HOMAYUN KARIMI, McMaster University  
[Saturday December 3 / samedi 3 décembre, 17:30 – Austen]
Concordance invariants of null-homologous knots in thickened surfaces

In this talk, we describe the concordance properties of signature and determinant invariants for knots in thickened surfaces. If $K \subset \Sigma \times I$ is $\mathbb{Z}/2$ null-homologous and slice, we show that its signatures vanish and its determinants are perfect squares. These statements are derived from a cobordism result for closed unoriented surfaces in certain 4-manifolds. This talk is based on joint work with Hans U. Boden.

ALEXANDER KOLPAKOV, Université de Neuchâtel  
[Saturday December 3 / samedi 3 décembre, 14:30 – Austen]
Subspace stabilizers in hyperbolic lattices

I will speak about a recent joint work with Mikhail Belolipetsky (IMPA, Brazil), Nikolay Bogachev (University of Toronto) and Leone Slavich (University of Pavia). It turns out that properly immersed totally geodesic $m$-dimensional suborbifolds of $n$-dimensional arithmetic hyperbolic orbifolds ($m < n$) correspond to finite subgroups of the commensurator given a simple condition on $m$ and $n$. We refer to such suborbifolds as "finite commensurator subgroup subspaces" (or fc-subspaces for short) and use them to formulate an arithmeticity criterion: a hyperbolic orbifold is arithmetic if and only if it contains infinitely many fc-subspaces. I will start by providing a short survey of arithmetic manifolds, and then move to showcasing some of the results that we obtained. Time permitting, I will also discuss some ideas behind the proofs.

PATRICK NAYLOR, Princeton University  
[Saturday December 3 / samedi 3 décembre, 10:00 – Austen]
Doubling Gluck twists

The Gluck twist of an embedded 2-sphere in the 4-sphere is a 4-manifold that is homeomorphic, but not obviously diffeomorphic to the 4-sphere. Despite considerable study, these homotopy spheres have resisted standardization except in special cases. In
this talk, I will discuss some conditions that imply the double of a Gluck twist is standard, i.e., is diffeomorphic to the 4-sphere. This is based on joint work with Dave Gabai and Hannah Schwartz.

PUTTIPONG PONGTANAPAISAN, University of Saskatchewan

Behaviors of meridional ranks under various operations

The meridional rank of a knot is the minimum number of nice generators needed to generate the fundamental group of the knot complement. It is not known whether the meridional rank of knots is additive under connected sum. The definition of meridional rank generalizes naturally to higher dimensional knots. In this talk, we will show that the meridional rank is not necessarily additive for surface knots. We will also discuss the exact values of the meridional ranks of some deform-spun knots and satellite 2-knots. This is joint work with Jason Joseph.

PATRICIA SORYA, Université du Québec à Montréal (UQÀM)

Pentes caractérisantes et nœuds satellites / Characterizing slopes for satellite knots

Une pente \( p/q \) est dite caractérisante pour un nœud \( K \) si la classe d’homéomorphisme de la \( p/q \)-chirurgie de Dehn le long de \( K \) détermine ce dernier à isotopie près. Des travaux antérieurs de Lackenby et McCoy donnent une condition pour que \( p/q \) soit caractérisante pour un nœud hyperbolique ou torique \( K \). En étudiant la décomposition JSJ d’extérieurs de nœuds, nous étendons ce résultat aux nœuds satellites afin d’obtenir une condition caractérisante pour tout nœud \( K \) donné.

A slope \( p/q \) is said to be characterizing for a knot \( K \) if the homeomorphism type of the \( p/q \)-Dehn surgery along \( K \) determines the knot up to isotopy. Previous work of Lackenby and McCoy gives a condition for \( p/q \) to be characterizing for a hyperbolic or torus knot \( K \). By studying the JSJ decomposition of knot exteriors, we extend this result to satellite knots and obtain a characterizing condition for any given knot \( K \).

MATT STOFFREGEN, Michigan State University

Concordance of cables of the figure eight knot

We say a little about what "Equivariant involutive knot Floer homology" is, and then discuss how it may be applied to show that the (2,1)-cable of the figure eight knot is not slice. This is joint work with Irving Dai, Sungkyung Kang, Abhishek Mallick, and JungHwan Park.

YVON VERBERNE, University of Toronto

Automorphisms of the fine curve graph

The fine curve graph of a surface was introduced by Bowden, Hensel and Webb. Its vertices are essential simple closed curves in the surface and the edges are pairs of disjoint curves. We show that the group of automorphisms of the fine curve graph is isomorphic to the group of homeomorphisms of the surface, which shows that the fine curve graph is a combinatorial tool for studying the group of homeomorphisms of a surface. This theorem is analogous to the seminal result of Ivanov that the group of automorphisms of the (classical) curve graph is isomorphic to the extended mapping class group of the corresponding surface. This work is joint with Adele Long, Dan Margalit, Anna Pham, and Claudia Yao.

MIKE WONG, Louisiana State University

Ribbon homology cobordism
A cobordism between 3-manifolds is ribbon if it has no 3-handles. Such cobordisms arise naturally from several different topological and geometric contexts. In this talk, we describe a few obstructions to their existence, from Thurston geometries, character varieties, and instanton and Heegaard Floer homologies, and some applications.
Machine learning in finance  
L’apprentissage automatique en finance

Org: Michael Chen (York), Hyejin Ku (York), George Lai (WLU) and/et Hongmei Zhu (York)

With increased power of Machine Learning/AI/Deep Learning, as well as the increased acceptance by both industries and consumers, more research topics are exposed and are challenging the community, especially on accuracy, privacy, and protection. This session is devoted to this highly promising and wide open research frontier.

With l’augmentation de la puissance de l’apprentissage automatique, de l’IA et de l’apprentissage profond, ainsi que l’acceptation croissante par les industries et les consommateurs, de nouveaux sujets de recherche sont exposés et mettent la communauté au défi, notamment en ce qui concerne la précision, la confidentialité et la protection. Cette session est consacrée à cette frontière de recherche très prometteuse et largement ouverte.

Schedule/Horaire

Room/Salle: Carlyle A

Monday December 5  
lundi 5 décembre

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<td>Chifeng Shen (York University)</td>
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<td>10:00 - 10:30</td>
<td>Yongzeng Lai (Wilfrid Laurier University)</td>
<td><strong>Stock indices and prices prediction using CNN-BiLSTM-Attention model</strong> (p. 112)</td>
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Abstracts/Résumés

MICHAEL CHEN, York University  
[Carlyle A]

VICTOR HUANG, York University  
[Carlyle A]

YINGYAN JIA, Wilfrid Laurier University  
[Monday December 5 / lundi 5 décembre, 9:30 – Carlyle A]

ROY KWON, University of Toronto  
[Monday December 5 / lundi 5 décembre, 8:00 – Carlyle A]  
**Data-driven Integration of Norm Penalized Mean-variance Optimization**

Mean-variance optimization (MVO) is known to be sensitive to estimation error in its inputs. Norm penalization of MVO programs is a regularization technique that can mitigate the adverse effects of estimation error. We augment the standard MVO program with a convex combination of parameterized L1 and L2 norm penalty functions. The resulting program is a parameterized quadratic program (QP) whose dual is a box-constrained QP. We make use of recent advances in neural network architecture for differentiable QPs and present a data-driven framework for optimizing parameterized norm-penalties.
to minimize the downstream MVO objective. Historical simulations using US stocks and global futures data demonstrate the benefit of the integrated data-driven approach.

YONGZENG LAI, Wilfrid Laurier University
[Monday December 5 / lundi 5 décembre, 10:00 – Carlyle A]
Stock indices and prices prediction using CNN-BiLSTM-Attention model

Stock price prediction is important and challenging. Accurate prediction of stock price helps investors to make investment strategies. Based on characteristics of stock data such as nonlinearity and time series, a stock price prediction method based on CNN-BiLSTM-Attention model is presented. In our study, first, the convolutional neural networks (CNN) and Bi-directional long short-term memory (BiLSTM) networks are used to extract time-series features of serial data. Then, the attention mechanism is introduced to fit weight assignments to information features, and last, the prediction results are output through the dense layer. Empirical studies using historical data from China and North American markets will be presented. This is joint work with L. Ye, J. Zhang, and Y. Lai

CHIFENG SHEN, York University
[Monday December 5 / lundi 5 décembre, 8:30 – Carlyle A]
Bayesian Online Changepoint Detection in Finance

Changepoints are utilized to split a data sequence into non-overlapping segments. The Online detection of changepoints method can be applied in many fields, especially in finance. In this talk, the case where the parameters between the segments are independent is examined, and an online algorithm for computing the probability of the most recent changepoint is derived.

YAODE SUI, Wilfrid Laurier University
[Carlyle A]

WEI XU, Toronto Metropolitan University
[Monday December 5 / lundi 5 décembre, 9:00 – Carlyle A]
Random Willow Tree with Application in Risk Management

Derivatives underlying a portfolio is popular on the market to diversify the market risk. However, existing method, the nested simulation, is quite time-consuming for pricing and managing the risk. In this article, we propose an efficient approach, randomized willow tree method. There are three main stages for our approach, portfolio distribution approximation, randomized willow tree construction and managing the risk of derivatives. We first generate some simulated paths to describe the evolution of dynamic portfolio values. Then, the minimal relative entropy (MRE) method is applied to approximate the distribution of portfolio values at each time based on the simulated data. After the approximated distributions are determined, a randomized willow tree can be constructed for pricing and managing the risk of derivatives underlying the portfolio. Finally, we apply the proposed approach to calculate annual dollar delta, 99% VaR and CVaR of a particular derivative, i.e., a 19-year variable annuity with guarantee riders. This application demonstrates the efficiency and accuracy of the proposed approach compared with the common nested simulation technique, especially for a large pool of derivatives underlying the same portfolio.
Mathematical Modeling and Analysis in Spatial Ecology and Epidemiology
Modélisation et analyse mathématiques en écologie et épidémiologie spatiales

Org: Yu Jin (University of Nebraska-Lincoln), Hao Wang (University of Alberta) and/et Xiaoqiang Zhao (Memorial University)

Mathematical modeling and analysis have been powerful in discovering novel dynamics and understanding driving mechanisms for observed phenomena in ecology and epidemiology. Recently, emerging ecological or epidemiological challenges such as those in the context of climate changes or disease outbreaks need urgent attention and lead to new demanding and tough mathematical problems. In this special session, we propose to invite researchers to present recent advances on mathematical modeling and analysis in spatial ecology and epidemiology. The proposed session mainly focuses on mathematical investigation of long-term dynamics and spatial spread of populations or diseases using reaction-diffusion equations (local dispersal) and integrodifferential equations (nonlocal dispersal). This session will serve as a platform for researchers to exchange new ideas and initiate potential collaborations.

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ELENA BRAVERMAN, University of Calgary
[Monday December 5 / lundi 5 décembre, 8:30]
The influence of the choice of a diffusion strategy on the harvesting outcome for spatially heterogeneous populations

We describe a diffusion strategy as the tendency to have a distribution proportional to a certain positive prescribed function, once a diffusion coefficient grows infinitely. The talk is focused on the interplay of heterogeneity, variable diffusion strategies and populations’ exploitation.

MICAH BRUSH, University of Alberta
[Monday December 5 / lundi 5 décembre, 16:30]
Modelling long term mountain pine beetle dynamics with changing tree resilience

Over the last few decades, mountain pine beetle (MPB) have spread beyond their historical range into Alberta and threaten further spread North and East. This expansion has led MPB into novel species of pine as hosts, and their success in these species is not well understood. Climate change is also affecting pine resilience to MPB, particularly through increased drought. Accurate models predicting the long term dynamics of MPB in forests with changing tree resilience are therefore critical in assessing the risk of further expansion and informing management strategies.

In this talk, I will present a model that couples MPB population dynamics with forest growth that aims to understand how MPB dynamics will change on longer time scales and with different levels of host resilience. The model incorporates key aspects of MPB biology to realistically capture single outbreak behaviour, and has an age structured forest that regrows after MPB infestations. I will show that as forest resilience decreases, there is a fold bifurcation occurs and a stable fixed point appears.
with a non-zero MPB population. Simulations show that with initial conditions just above the Allee threshold, the number of beetles approaches this fixed point over a long time with transient outbreaks driven by the age structure of the forest. I will also show how adding a small number of lower vigor trees can lead to an additional stable fixed point with a small endemic population of beetles, and how with decreasing resilience can result in large outbreaks from this endemic population.

STEPHEN CANTRELL, University of Miami
[Monday December 5 / lundi 5 décembre, 8:00]
Resource matching in spatial ecology and evolutionary advantage

A convergence of concepts from game theory (evolutionary stable strategy), ecological theory (the ideal free distribution), and mathematics (line sum-symmetry and its functional analytic generalizations) combine to explain how resource matching in spatially heterogeneous but temporally constant habitats can convey evolutionary advantage robustly across a range of modeling formats. The ideal free distribution (IFD) is an ecological construct that posits that when organisms have full knowledge of the landscape they inhabit (ideal) and are able to locate themselves as they wish (free), they will locate themselves to maximize reproductive fitness. The IFD can readily be translated into mathematical terms for models wherein the environment is spatially varying but temporally constant. In this talk we will discuss how this is done across a range of modeling formats and how it consequently leads to predictions of evolutionary advantage in such modeling formats. We then report on ongoing efforts to define the ideal free distribution mathematically in cases when the environment varies in both space and time, focusing on the case wherein habitats vary periodically in time.

YUMING CHEN, Wilfrid Laurier University
[Saturday December 3 / samedi 3 décembre, 16:00]
Global dynamics of an advective Lotka-Volterra competition-diffusion system

This talk is based on the Joint works with Professor De Tang. We consider a Lotka-Volterra competition-diffusion model in a one-dimensional advective environment. The two species are assumed to have the same population dynamics and advective rates but different diffusion rates. Moreover, the upstream end is supposed to be Neumann type boundary condition and the downstream end has a net loss of individuals measured by $b$. In the homogeneous case, if $0 < b < 1$, then the faster diffuser wins; if $b > 1$, then the slower diffuser wins (if it exists); and if $b = 1$, there is a compact global attractor consisting of a continuum of steady states. For the heterogeneous case, it is shown that the species with slower diffusion rate (if it exists) is always selected when $1 \leq b \leq \infty$.

FREDERIC HAMELIN, Institut Agro
[Monday December 5 / lundi 5 décembre, 9:30]
Host Diversification May Split Epidemic Spread into Two Successive Fronts Advancing at Different Speeds

Host diversification methods such as within-field mixtures (or field mosaics, depending on the spatial scale considered) are promising methods for agroecological plant disease control. We explore disease spread in host mixtures (or field mosaics) composed of two host genotypes (susceptible and resistant). The pathogen population is composed of two genotypes (wild-type and resistance-breaking). We show that for intermediate fractions of resistant hosts, the spatial spread of the disease may be split into two successive fronts. The first front is led by the wild-type pathogen and the disease spreads faster, but at a lower prevalence, than in a resistant pure stand (or landscape). The second front is led by the resistance-breaking type, which spreads slower than in a pure resistant stand (or landscape). The wild-type and the resistance-breaking genotypes coexist behind the invasion fronts, resulting in the same prevalence as in a resistant pure stand. This study shows that host diversification methods may have a twofold effect on pathogen spread compared to a resistant pure stand (or landscape): on the one hand, they accelerate disease spread, and on the other hand they slow down the spread of the resistance-breaking genotype. This work contributes to a better understanding of the multiple effects underlying the performance of host diversification methods in agroecology. This is joint work with Y. Mammeri, Y. Aigu, S. E. Strelkov, and M. A. Lewis.
Niche differentiation in the light spectrum promotes coexistence of phytoplankton species: a spatial modelling approach

The paradox of the plankton highlights the apparent contradiction between Gause’s law of competitive exclusion and the observed diversity of phytoplankton. It is well known that phytoplankton dynamics depend heavily on two main resources: light and nutrients. Here we treat light as a continuum of resources rather than a single resource by considering the visible light spectrum and its attenuation through the water column. We propose a spatially explicit reaction-diffusion-advection model to explore under what circumstances coexistence is possible from mathematical and biological perspectives. Furthermore, we provide biological context as to when coexistence is expected based on the degree of niche differentiation within the light spectrum and overall turbidity of the water.

Pattern formation in non-local population models

Non-local advection is a key process in a range of biological systems, from cells within individuals to the movement of whole organisms. There has been increasing attention on pattern formation in non-local partial differential equations. The emergent patterns appear as local minimisers of a corresponding energy functional. Here we give approximate methods for determining the qualitative structure of local energy minimisers. These include a mixture of territory-like segregation patterns, full mixed cases, as well as narrow spike-type solutions. (joint work with V. Giunta, MA. Lewis, J. Potts)

Modelling of disease spread through heterogeneous population

We present a simple model for the spread of an infection that incorporates spatial variability in population density. Starting from first-principle considerations, we explore how a novel partial differential equation with state-dependent diffusion can be obtained. This model exhibits higher infection rates in the areas of higher population density—a feature that we argue to be consistent with epidemiological observations. The model also exhibits an infection wave, the speed of which varies with population density. In addition, we demonstrate the possibility that an infection can ‘jump’ (i.e. tunnel) across areas of low population density towards areas of high population density. We briefly touch upon the data reported for coronavirus spread in the Canadian province of Nova Scotia as a case example with a number of qualitatively similar features as our model. Lastly, we propose a number of generalizations of the model towards future studies.

Invasion of open space by multiple competing species

I will discuss a question raised by Shigesada and Kawasaki concerning the stacked invasion fronts of two or more competing species on the real line when the initial values are null or exponentially decaying in a right half-line. In the case of compactly supported initial values, we prove that the first species spreads with the KPP speed of the single species, whereas the speed of the second species can be given by an exact formula depending on the speed of the first species. Generalization to three species case is also discussed.
species, and the relation to the Fisher-KPP waves in shifting habitats will also be discussed. This is joint work with Leo Girardin (Lyons, France), Qian Liu (Shaoyang Univ.) and SHuang Liu (Beijing Inst. Tech., China).

MARK LEWIS, University of Victoria
[Sunday December 4 / dimanche 4 décembre, 15:30]
Models and empirical evidence for the use of memory in animal movement patterns

Animal movement modelling provides unique insight about how animals perceive their landscape and how this perception influences their space use. This subject has recently been investigated by a variety of theoretical models from the perspective of pattern formation using coupled partial differential equation models. However, most of these models lack a solid empirical foundation. In this talk I focus on empirical evidence for the use of memory by animals while being tracked via radiotelemetry and how the data can incorporated into a step-selection function that can potentially connect back to partial differential equation models. I focus on patrolling behaviour in wolves (Canis lupus) in the foothills of the Rocky Mountains and on foraging behaviour in brown bears (Ursus arctos) in the Canadian Arctic.

BINGTUAN LI, University of Louisville
[Monday December 5 / lundi 5 décembre, 9:00]
Effects of a barrier zone on invasion of a population with a strong Allee effect

We consider integro-difference and reaction-diffusion models to study the effects of a barrier zone on invasion of a population with a strong Allee effect. It is assumed that inside the barrier zone a certain proportion of the population is killed. We provide a formula for the critical width L* of barrier zone. We show that when a barrier zone is set properly at the front of a population, if the width of barrier zone is bigger than L* then the barrier zone can stop the population invasion, and if the width of barrier zone is less than L* then the population crosses the barrier zone and eventually occupies the entire space. The results are proven by establishing the existence and attractivity of three types of equilibrium solutions. The mathematical proofs involve phase plane analysis and comparison.

MING MEI, Champlain College St-Lambert
[Saturday December 3 / samedi 3 décembre, 18:00]
Sharp traveling waves for degenerate viscosity Burgers equations with time-delay

In this talk, we are concerned with Burgers equations with degenerate viscosity and time-delay. The main issue is to investigate the structure of traveling waves. The waves are sharp caused by the degeneracy of viscosity, and oscillating caused by the large time-delay.

CHUNhua OU, Memorial University of Newfoundland
[Monday December 5 / lundi 5 décembre, 16:00]
Selection of the asymptotic spreading speed to the diffusive Lotka-Volterra competition model

In this talk, we will summarize our recent findings on the invasion speed (asymptotic spreading speed) to the the diffusive Lotka-Volterra competition model. This speed happens to be the minimal speed of traveling waves of the system, an important phenomenon in the study of mathematical biology, but the determinacy of the speed is challenging. By using both the parabolic and elliptic techniques in partial differential equations as well as a perturbation argument in a weighted functional space, we first derived a necessary and sufficient condition on the nonlinear selection which solves the conjecture raised by Roques et al. (J. Math. Biol., 2015). Furthermore, we established some easy-to apply criteria for linear and nonlinear selections in terms of lower (or upper) solutions with specific fast (slow) decay rate only, and we don’t need to construct the couple of them simultaneously. This helped to easily obtain a number of explicit( analytic) results which gives estimates of the transition value in various situations. In particular, we established new results on the linear selection that doesn’t require the system to be
sub-linear on the direction of the positive eigenvector (Lewis, Li and Weinberger, 2002). Under certain conditions, we proved the Hosono’s conjecture, but also pointed out failures of the conjecture in some cases. Our methods don’t rely on the classical phase plane analysis and can be extended to work on any inhomogeneous system (including periodic systems and periodic habitats). This is a joint work of my team consisting of graduate students and visiting scientists.

SHIGUI RUAN, University of Miami

On the Dynamics of a Diffusive Foot-and-Mouth Disease Model with Nonlocal Infections

Foot-and-mouth disease (FMD) is an acute and highly contagious infectious disease of cloven-hoofed animals. In order to reveal the transmission dynamics and explore effective control measures of FMD, we formulate a diffusive FMD model with a fixed latent period and nonlocal infections. The threshold dynamics of the FMD model is determined by using the basic reproduction number $R_0$, if $R_0 < 1$ then the disease-free equilibrium $E_0$ is globally asymptotically stable; otherwise $E_0$ is unstable and there exists an endemic equilibrium $E^*$. Numerical simulations confirm the theoretical results and suggest that reducing the direct contact rate $\beta_1$ and the indirect contact rate $\beta_2$ is important in relieving FMD outbreaks. By carrying out some sensitivity analysis of $R_0 (> 1)$ and the equilibrium value of the infectious individuals $I^*$ in terms of $\beta_1$ and $\beta_2$, it is found that the $(\beta_1, \beta_2)$-plane is divided into two regions by the intersection of two parameter-related surfaces, the sensitivity of $R_0$ and $I^*$ varies when $\beta_1$ and $\beta_2$ belong to different regions. When the values of both $\beta_1$ and $\beta_2$ are very large or very small, $\beta_1$ plays a more significant role on the transmission of FMD. These results indicate that stamping out the infected individuals and blocking the epidemic spots and areas are effective in preventing and controlling the spread of FMD.

YURIJ SALMANIW, University of Alberta

Modelling habitat loss with partial differential equations: the effects of habitat fragmentation on survival and abundance

It is well known that habitat loss is one of the major contributing factors to the decline of biodiversity worldwide. Partial differential equations offer one method to study the effects of habitat loss in a spatially explicit setting. Often, we identify three primary forms of habitat loss: degradation, destruction, and fragmentation. In this talk, I will briefly introduce two related competition diffusion systems subject to either habitat degradation or destruction. With these models as motivation, we shift our focus to the effects of habitat fragmentation through a careful study of the effect of habitat arrangement in two spatial dimensions. On one hand, we may consider the effect of fragmentation through survival of the population. This perspective allows one to define a quantitative measure of fragmentation. It is then possible to compare differing habitat arrangements of fixed volume. On the other hand, we may consider the effect of fragmentation through population abundance at the steady state. While this perspective does not lend itself to defining a measure of fragmentation, it does provide an interesting compliment to the first perspective. These mathematical insights in turn provide some interesting biological insights to the problem of fragmentation, and in fact highlight some key areas where confusion in the ecological literature may materialize.

ZHONGWEI SHEN, University of Alberta

Population dynamics under climate change

Reaction-diffusion equations in shifting environments are used to model the evolution of single species under climate change. Questions of theoretical importance are the effects of the shifting environment on the long-term dynamics of solutions. In this talk, I will report some relevant results about such equations without or with Allee effect.

JUNPING SHI, College of William & Mary

Evolution of dispersal in advective patchy environments
The classical Lotka-Volterra competition model predicts competition exclusion occurs when the competition is strong, and species can coexist when the competition is weak. In a spatially heterogeneous environment, the dispersal rates of species and the spatial heterogeneity could change or uphold the outcome of the competition. We show in a two-species Lotka-Volterra competition model in a patchy advective environment, where the species are subject to both directional drift and undirectional random dispersal between patches, under what conditions on the advection and random dispersal rates that a mutating species can or cannot invade the resident species. This is a joint work with Shanshan Chen, Zhisheng Shuai and Yixiang Wu.

OLGA VASILYEVA, Grenfell Campus, Memorial University of Newfoundland
[Sunday December 4 / dimanche 4 décembre, 17:00]

Phase-plane analysis of steady states of a spruce budworm model with advection

The classical non-spatial Ludwig-Jones-Holling model and its reaction-diffusion version, the Ludwig-Aronson-Weinberger model, describe population dynamics of spruce budworm. Due to the complexity of the reaction term, under certain conditions, these models admit both endemic and outbreak steady state solutions. We explore the reaction-diffusion-advection version of the Ludwig-Aronson-Weinberger model, where advective term is interpreted as biased movement due to prevailing wind. Such a model can also describe other ecological settings where a logistically growing population is subject to diffusion, advection and predation by a generalist. We use phase-plane analysis to determine conditions for the existence of the outbreak solutions. In particular, we observe that increasing advection can prevent outbreaks while allowing persistence in the form of an endemic state. We obtain upper and lower bounds for the critical advection for outbreak steady state solutions. This is a joint work with Abby Anderson.

JAMES WATMOUGH, University of New Brunswick
[Monday December 5 / lundi 5 décembre, 15:30]

JIANHONG WU, York University
[Saturday December 3 / samedi 3 décembre, 14:30]

SHUWEN XUE, Northern Illinois University
[Monday December 5 / lundi 5 décembre, 10:00]

Global existence, persistence and spreading speeds of a parabolic-parabolic chemotaxis model with logistic source

Chemotaxis models are used to describe the evolution of species in response to certain chemical substances in their living environments. In this talk, we will first introduce chemotaxis model. Then, we talk about the global existence and persistence of classical solutions under the condition that chemotaxis is small relative to the logistic damping. Next, under the same condition, we show that the spreading speed is the same as that of Fisher-KPP equation which implies that chemotaxis neither speeds up nor slows down the spatial spreading in the Fisher-KPP equation.

XINGFU ZOU, University of Western Ontario
[Monday December 5 / lundi 5 décembre, 15:00]

Evolution of anti-predation response of prey in a general patchy environment

In this talk, I report some recent results on the evolution of anti-predation responses of a prey when perceiving the presence of its predator in a patch environment. To this end, we consider a ODE model on the patches in which two subspecies with distinct anti-predation response levels that affect the respective growths (cost) and predating rate (benefit) as well as their dispersion rates. We derive formulas for the invasion exponent and evolutionarily stable strategy. Our main techniques are from the theory of adaptive dynamics and a graph-theoretic approach based on the tree-cycle identity. In the scenario that
the dispersion rate is increasing in fear level and the growth rate is decreasing in the fear level, our results indicate that the prey species with lower fear effect will invade in the heterogeneous environment. We also present some numerical simulations results to testify our theoretical findings, and discuss the effects of the monotonicity of mobility and fitness on evolutionarily stable strategy and convergence stable strategy. This is a joint work with Dan Huang.
"Machine learning is having a profound impact on many different sectors including scientific research, industry, and policymaking. Yet, its mathematical foundations are still far from being well understood. While techniques such as deep learning have produced outstanding success on a wide range of real-world applications, it is increasingly well known that such methods may exhibit unpredictable performance or instabilities, and generally lack interpretability. Moreover, although stochastic optimization algorithms are ubiquitous in machine learning, their convergence properties are still not fully understood in the nonconvex framework. These and other gaps between theory and practice raise the pressing need for a broader, more comprehensive mathematical foundations for machine learning. This session will mark the third in a series of sessions at CMS meetings on this theme. Its aim is to bring together a diverse group of leading experts in mathematics of machine learning. The session will be a forum for discussing and exploring emerging ideas in this fast-growing and exciting field."

"L'apprentissage automatique a un impact profond sur de nombreux secteurs différents, notamment la recherche scientifique, l’industrie et l’élaboration des politiques. Pourtant, ses fondements mathématiques sont loin d’être bien compris. Alors que des techniques telles que l’apprentissage profond ont donné des résultats remarquables dans un large éventail d’applications du monde réel, il est de plus en plus connu que ces méthodes peuvent présenter des performances imprévisibles ou des instabilités, et manquent généralement d’interprétabilité. En outre, bien que les algorithmes d’optimisation stochastique soient omniprésents dans l’apprentissage automatique, leurs propriétés de convergence ne sont toujours pas entièrement comprises dans le cadre non convexe. Ces lacunes, ainsi que d’autres écarts entre la théorie et la pratique, soulignent le besoin urgent d’une base mathématique plus large et plus complète pour l’apprentissage automatique. Cette session sera la troisième d’une série de sessions sur ce thème lors des réunions de la SMC. Son objectif est de réunir un groupe diversifié d’experts de premier plan en mathématiques de l’apprentissage automatique. La session sera un forum de discussion et d’exploration des idées émergentes dans ce domaine passionnant et en plein essor.

Schedule/Horaire

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ANDERSEN ANG, University of Waterloo

[Sunday December 4 / dimanche 4 décembre, 9:30 – Rosetti C]

Imhomogeneous graph signal estimation via a cardinality penalty

A challenge in signal estimation of piecewise smooth signals over a graph is to handle the inhomogeneous levels of smoothness of the signal over the clusters (i.e., communities) of the graph.

We propose a group $\ell_2$-0-norm-like penalized Graph Trend Filtering (GTF) framework to tackle such inhomogeneity in the graph signal estimation. We prove that solving such penalized GTF is equivalent to jointly performing a k-means clustering on the graph signal (solely based on the signal on nodes, ignoring the graph) and finding a minimum graph cut (solely based on the graph structure, ignoring the signal on nodes), in which the clustering and the cut share the same assignment matrix, indicating that the solution of such GTF graph signal estimation problem is finding a trade-off between k-means clustering on the graph signal and a minimum cut on the graph.

We develop methods (a spectral method and a probabilistic method) to solve such proposed GTF model and present numerical results to support the effectiveness of the methods.

AARON BERK, McGill University

[Saturday December 3 / samedi 3 décembre, 17:30 – Rosetti C]

Compressed sensing with generative models and Fourier measurements: provable guarantees under incoherence

In work by Bora et al. (2017), a mathematical framework was developed for compressed sensing guarantees when the measurement matrix is Gaussian and the signal structure is the range of a Lipschitz function (with applications to generative neural networks (GNNs)). We consider measurement matrices derived by sampling uniformly at random rows of a unitary matrix (including subsampled Fourier measurements as a special case). We prove the first known restricted isometry guarantee for compressed sensing with GNNs and subsampled isometries, and provide recovery bounds. Recovery efficacy is characterized by the coherence, a new parameter, which measures the interplay between the range of the network and the measurement matrix.

Furthermore, we propose a regularization strategy for training GNNs to have favourable coherence with the measurement operator. We provide compelling numerical simulations that support this regularized training strategy: our strategy yields low coherence networks that require fewer measurements for signal recovery. This, together with our theoretical results, supports coherence as a natural quantity for characterizing generative compressed sensing with subsampled isometries.

QUENTIN BERTRAND, Mila

[Sunday December 4 / dimanche 4 décembre, 8:30 – Rosetti C]

Synergies Between Disentanglement and Sparsity: a Multi-Task Learning Perspective
Although disentangled representations are often said to be beneficial for downstream tasks, current empirical and theoretical understanding is limited. In this work, we provide evidence that disentangled representations coupled with sparse base-predictors improve generalization. In the context of multi-task learning, we prove a new identifiability result that provides conditions under which maximally sparse base-predictors yield disentangled representations. Motivated by this theoretical result, we propose a practical approach to learn disentangled representations based on a sparsity-promoting bi-level optimization problem. Finally, we explore a meta-learning version of this algorithm based on group Lasso multiclass SVM base-predictors, for which we derive a tractable dual formulation. It obtains competitive results on standard few-shot classification benchmarks, while each task is using only a fraction of the learned representations.

JASON BRAMBURGER, Concordia University

[Saturday December 3 / samedi 3 décembre, 14:30 – Rosetti C]

Deep Learning of Conjugate Mappings

Despite many of the most common chaotic dynamical systems being continuous in time, it is through discrete time mappings that much of the understanding of chaos is formed. Henri Poincaré first made this connection by tracking consecutive iterations of the continuous flow with a lower-dimensional, transverse subspace. The mapping that iterates the dynamics through consecutive intersections of the flow with the subspace is now referred to as a Poincaré map, and it is the primary method available for interpreting and classifying chaotic dynamics. Unfortunately, in all but the simplest systems, an explicit form for such a mapping remains outstanding. In this talk I present a method of discovering explicit Poincaré mappings using deep learning to construct an invertible coordinate transformation into a conjugate representation where the dynamics are governed by a relatively simple chaotic mapping. The invertible change of variable is based on an autoencoder, which allows for dimensionality reduction, and has the advantage of classifying chaotic systems using the equivalence relation of topological conjugacies. We illustrate with low-dimensional systems such as the Rössler systems, while also demonstrating the utility of the method on the infinite-dimensional Kuramoto–Sivashinsky equation.

KILIAN FATRAS, Mila - Québec AI Institute, McGill University

[Sunday December 4 / dimanche 4 décembre, 8:00 – Rosetti C]

Minibatch Optimal Transport distances meets Deep Learning

Optimal transport distances have found many applications in machine learning for their capacity to compare non-parametric probability distributions. Yet their algorithmic complexity generally prevents their direct use on large scale datasets. Among the possible strategies to alleviate this issue, practitioners can rely on computing estimates of these distances over minibatches of data. In this talk, we present an analysis of this practice. We notably argue that it is equivalent to an implicit regularization of the original problem, with appealing properties such as unbiased estimators, gradients and a concentration bound around the expectation. We also highlight in this talk some limits of this strategy, arguing it is not a distance and it can lead to undesirable smoothing effects. As an alternative, we suggest that the same minibatch strategy coupled with unbalanced optimal transport can yield more robust behaviours while preserving the same theoretical properties. Our experimental study shows that in challenging problems associated to domain adaptation, the use of unbalanced optimal transport leads to significantly better results, competing with or surpassing recent baselines.

MARINA GARROTE-LOPEZ, University of British Columbia

[Sunday December 4 / dimanche 4 décembre, 9:00 – Rosetti C]

Algebraic Optimization of Sequential Decision Problems

In this talk, we study the optimization of the expected long-term reward in finite partially observable Markov decision processes over the set of stationary stochastic policies. We focus on the case of deterministic observations, where the problem is equivalent to optimizing a linear objective subject to quadratic constraints. We characterize the feasible set of this problem as the intersection of a product of affine varieties of rank one matrices and a polytope, which allows us to obtain bounds on the number of critical points of the optimization problem. Finally, we will explain some experiments in which we solve the KKT
equations or the Lagrange equations over different boundary components of the feasible set to solve the optimization problem and compare the result to the theoretical bounds and to other constrained optimization methods.

**MANUELA GIROTTI**, Saint Mary’s University  
[Saturday December 3 / samedi 3 décembre, 15:00 – Rosetti C]

*Neural Networks Efficiently Learn Low-Dimensional Representations with SGD*

We study the problem of training a two-layer neural network (NN) of arbitrary width using stochastic gradient descent (SGD) where the input $x \in \mathbb{R}^d$ is Gaussian and the target $y \in \mathbb{R}$ follows a multiple-index model, i.e., $y = g(\langle u_1, x \rangle, \ldots, \langle u_k, x \rangle)$ with a noisy link function $g$. We prove that the first-layer weights of the NN converge to the $k$-dimensional principal subspace spanned by the vectors $u_1, \ldots, u_k$ of the true model, when online SGD with weight decay is used for training. This phenomenon has several important consequences when $k \ll d$. First, by employing uniform convergence on this smaller subspace, we establish a generalization error bound of $O(\sqrt{kd/T})$ after $T$ iterations of SGD, which is independent of the width of the NN. We further demonstrate that, SGD-trained ReLU NNs can learn a single-index target of the form $y = f(\langle u, x \rangle) + \epsilon$ by recovering the principal direction, with a sample complexity linear in $d$ (up to log factors), where $f$ is a monotonic function with at most polynomial growth, and $\epsilon$ is the noise. This is in contrast to the known $d^{\Omega(p)}$ sample requirement to learn any degree $p$ polynomial in the kernel regime, and it shows that NNs trained with SGD can outperform the neural tangent kernel at initialization. Finally, we also provide compressibility guarantees for NNs using the approximate low-rank structure produced by SGD.

This is a joint work with Alireza Mousavi-Hosseini (UofT, Vector), Sejun Park (Korea Univeristy), Ioannis Mitliagkas (UdeM, Mila), and Murat A. Erdogdu (UofT, Vector).

**DIANE GUIGNARD**, University of Ottawa  
[Saturday December 3 / samedi 3 décembre, 10:00 – Rosetti C]

*Nonlinear approximation of high-dimensional anisotropic analytic functions*

The usual approach to model reduction for parametric/random partial differential equations is to construct a linear space of (hopefully small) dimension $n$ which accurately approximates the parameter-to-solution map. This linear reduced model can then be used for various tasks such as building a forward solver or estimating the state or the parameters from data observations. It is well-understood in other problems of numerical computation that nonlinear methods may provide improved numerical efficiency, suggesting the use of nonlinear methods for model reduction as well. In a so-called library approximation, the single linear space is replaced by a collection of affine spaces and the best space may be chosen for each parameter query. In this talk, we present a specific example of library approximation where the parameter domain is split into a finite number of cells and where different reduced affine spaces of dimension $m$ are assigned to each cell. Given $m$, we derive an upper bound on the dimension of the library needed to achieve a target accuracy and illustrate the performance of the method through several numerical examples. Finally, we extend this strategy to approximate a general class of anisotropic analytic functions.

**RONGJIE LAI**, Rensselaer Polytechnic Institute  
[Saturday December 3 / samedi 3 décembre, 9:00 – Rosetti C]

*Learning Manifold-structured Data using Deep networks: Theory and Algorithms*

Deep neural networks have made tremendous success in many problems in science and engineering. In this talk, I will discuss our recent efforts on learning non-trivial manifold information hidden in data. Inspired by differential geometry, we propose a Chart Auto-Encoder (CAE) for manifold-structured data representation using a multi-chart latent space. CAE admits desirable manifold properties that auto-encoders with a flat latent space fail to obey. Theoretically, we conduct approximation and nonparametric analysis to understand the proposed CAE. We also verify the effectiveness of the proposed CAE on synthetical and real-world data.
Deep neural Networks are effective at learning high-dimensional Banach-valued functions from limited data

Recently, there has been an increasing interest in applying Deep Learning (DL) to computational science and engineering, e.g., computer vision, genetics and computational uncertainty quantification (UQ). In particular, for UQ, high-dimensional problems are often posed in terms of parameterized partial differential equations (PDE) whose solutions take values in abstract spaces. Over the last five years, impressive results have been achieved on such problems using DL techniques, i.e., machine learning based on training Deep Neural Networks (DNN). However, little is known about the efficiency and reliability of DL from the perspectives of stability, robustness, accuracy, and sample complexity. This work focuses on approximating high-dimensional smooth functions taking values in a typically infinite-dimensional Banach space, where training data for such problems is often scarce and may be corrupted by errors. Moreover, obtaining samples is often expensive and involves a complicated black-box PDE solver and high problem dimensionality. Our results provide arguments for DNN approximation of such functions, with both known and unknown parametric dependence, that overcome the main challenge of the curse of dimensionality and account for all sources of error, i.e., sampling, optimization, approximation, and physical discretization. We assert the existence of a class of DNNs with dimension-independent architecture size and training procedures based on minimizing the regularized or unregularized $L_2$-loss, which achieves near-optimal dimension-independent algebraic convergence rates. We provide numerical results illustrating the practical performance of DNNs on Hilbert-valued functions and preliminary numerical results on Banach-valued functions arising as solutions to parametric PDEs.

Robust Active Learning via Leverage Score Sampling

Active learning is a promising approach to fitting machine learning models in "data starved" applications, where the cost of collecting data labels is the primary cost of model training. In many of these applications, including in computational science and ML guided engineering, we need active learning methods that work in the challenging agnostic or "adversarial noise" setting. In this setting, collected labels might not match the model being trained, even in expectation. Nevertheless, we seek methods that are robust enough to find the best possible fit with as little data as possible. In this talk, I will discuss recent developments on a flexible class of active learning algorithms based on so-called "leverage score sampling". I will show how leverage score based methods can provably address the challenging agnostic learning problem in a variety of settings, including for linear models, kernel regression models, and also simple neural networks with non-linearities. I will highlight future directions for research and challenging open directions. Based on joint work with Aarshvi Gajjar, Tamás Erdélyi, Chinmay Hegde, Raphael Meyer, Cameron Musco David Woodruff, Taisuke Yasuda, and Samson Zhou.

FourierFormer: Transformer Meets Generalized Fourier Integral Theorem

Multi-head attention empowers the recent success of transformers, the state-of-the-art models that have achieved remarkable success in sequence modeling and beyond. These attention mechanisms compute the pairwise dot products between the queries and keys, which results from the use of unnormalized Gaussian kernels with the assumption that the queries follow a mixture of Gaussian distribution. There is no guarantee that this assumption is valid in practice. In response, we first interpret attention in transformers as a nonparametric kernel regression. We then propose the FourierFormer, a new class of transformers in which the dot-product kernels are replaced by the novel generalized Fourier integral kernels. Different from the dot-product kernels, where we need to choose a good covariance matrix to capture the dependency of the features of data, the generalized Fourier integral kernels can automatically capture such dependency and remove the need to tune the covariance matrix. We theoretically prove that our proposed Fourier integral kernels can efficiently approximate any key and query distributions. Compared to the conventional transformers with dot-product attention, FourierFormers attain better accuracy and reduce the redundancy.
between attention heads. We empirically corroborate the advantages of FourierFormers over the baseline transformers in a variety of practical applications including language modeling and image classification.

ESHA SAHA, University of Waterloo  
[Saturday December 3 / samedi 3 décembre, 9:30 – Rosetti C]  
SPADE4: Sparsity and Delay Embedding based Forecasting

Predicting the evolution of diseases is challenging, especially when the data availability is scarce and incomplete. The most popular tools for modelling and predicting infectious disease epidemics are compartmental models. They stratify the population into compartments according to health status and model the dynamics of these compartments using dynamical systems. However, these predefined systems may not capture the true dynamics of the epidemic due to the complexity of the disease transmission and human interactions. In order to overcome this drawback, we propose Sparsity and Delay Embedding based Forecasting (SPADE4) for predicting epidemics. SPADE4 predicts the future trajectory of an observable variable without the knowledge of the other variables or the underlying system. We use sparsity based random feature model to handle the data scarcity issue and employ Takens’ delay embedding theorem to capture the nature of the underlying system from the observed variable. We show that our approach outperforms compartmental models when applied to both simulated and real data.

TANYA SCHMAH, University of Ottawa  
[Saturday December 3 / samedi 3 décembre, 16:30 – Rosetti C]  
Diffeomorphic image matching with a preference for “simple” transformations

Image alignment, i.e. registration, is a fundamental problem in computer vision, including in medical imaging, where it allows comparison of images from different subjects or different times. While deep learning has made an important impact on this problem, the gold standard is still the geometric, or variational, approach which is based on geodesic flows in a diffeomorphism group (or in the group orbit of a particular image). A right-invariant Riemannian metric is used both to define the geodesics and to regularize the optimization problem by penalizing larger deformations.

We consider variants of diffeomorphic image registration that prefer “simple” deformations, defined as those in a pre-specified subgroup $G$, for example the affine group or a projective linear group. One approach is to use a Riemannian metric (or degenerate metric) that penalizes velocities tangent to $G$ only very mildly (or not at all). While theoretically satisfying, this makes computing geodesics more difficult, so we also consider flows of fixed vector fields.

CHRYSTAL SMITH, York University  
[Saturday December 3 / samedi 3 décembre, 16:00 – Rosetti C]  
Natural Language Processing in the field of Medical Translation

Advances in artificial intelligence and machine learning, such as deep learning neural networks, embed syntactic and semantic information using vectors to achieve accuracy of response and human understanding of discourse and sentiment for Natural Language Processing (NLP). Despite its use in the field of medical translation the mathematical foundations of this approach is not well understood and lingering problems persist. In this talk I review current methods and consider how Statistical NLP systems and neural networks produce natural language for the field of medical translation.

WEIQI WANG, Concordia University  
[Sunday December 4 / dimanche 4 décembre, 10:00 – Rosetti C]  
Compressive Fourier collocation methods for high-dimensional diffusion equations with periodic boundary conditions.

High-dimensional Partial Differential Equations (PDEs) are a popular mathematical modelling tool. However, standard numerical techniques for solving High-dimensional PDEs are typically affected by the curse of dimensionality. In this work, we tackle this challenge while focusing on stationary diffusion equations defined over a high-dimensional domain with periodic
boundary conditions. Inspired by recent progress in high-dimensional sparse function approximation, we propose a new method called compressive Fourier collocation. Combining ideas from compressive sensing and spectral collocation, our method uses Monte Carlo sampling and employs sparse recovery techniques, such as orthogonal matching pursuit and $l^1$ minimization, to approximate the Fourier coefficients on given index sets of the PDE solution. We conduct a rigorous theoretical analysis showing that the approximation error of the proposed method is comparable with the best $s$-term approximation (with respect to the Fourier basis) to the solution and mitigates the curse of dimensionality with respect to the number of collocation points under sufficient conditions on the regularity of the diffusion coefficient. We present numerical experiments that illustrate the accuracy and stability of the method for the approximation of sparse and compressible solutions. In our current work, noticing that a bottleneck towards improving the solution accuracy is the choice of the index set, we develop a method using orthogonal matching pursuit to adaptively select the elements of the index set. In addition, we seek an efficient neural network model to solve the high-dimensional PDE, with the goal of comparing the performance of the adaptive method with a deep learning-based approach.
Matrix Analysis and Operator Theory (Bilingual Session)
Analyse matricielle et théorie des opérateurs

Org: Ilia Binder (University of Toronto), Ludovick Bouthat (L’Université Laval) and/et Frédéric Morneau-Guérin, (Université TÉLUQ)

Please note that this session will be bilingual and proposals in either French or English will be accepted.
The main goal of this session is to bring together researchers sharing an interest in various aspects of matrix theory and to offer them the opportunity to discuss recent developments in this sub-discipline. The session also aims to foster interactions between researchers whose research lies at the interface between matrix theory and its concrete applications (in statistics, numerical analysis, physics, neuroscience, number theory, bioinformatics, etc.) and those working in fundamental mathematics.

Veuillez noter que cette session sera bilingue et les propositions en français ainsi qu’en anglais seront acceptées.
L’objectif de cette session est de réunir des chercheurs partageant un intérêt pour divers aspects de la théorie des matrices et de leur offrir l’opportunité de discuter des développements récents dans cette sous-discipline. La session vise également à favoriser les interactions entre les chercheurs dont les travaux se situent à l’interface entre la théorie des matrices et ses applications concrètes (en statistiques, en analyse numérique, en physique, en neuroscience, en théorie des nombres, en bio-informatiques, etc.) et ceux œuvrant en mathématiques fondamentales.

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Abstracts/Résumés

LUDOVICK BOUTHAT, Université Laval
[Monday December 5 / lundi 5 décembre, 15:30 – Scott]
The convergence of Doubly Stochastic Markov Chains

In recent years, some interest has been devoted to studying doubly stochastic Markov chains. These chains appears naturally in many real-life applications such as quantum measurements. In this note, we proceed to characterize the asymptotic behavior of an homogeneous doubly stochastic Markov chains. In particular, we characterize the doubly stochastic matrices whose associated Markov chain (1) describes a cycle; (2) converges to a given matrix; and (3) diverges. We also provide a new sufficient condition for the infinite product of doubly stochastic matrices $A_1 A_2 A_3 \cdots$ to converge to a scalar multiple of the all-ones matrix, thus improving a result of Schwarz.
GALIA DAFNI, Concordia University
[Monday December 5 / lundi 5 décembre, 8:00 – Scott]

**Approximate moment conditions for \( h^p \) atoms and molecules, and the boundedness of inhomogeneous Calderón–Zygmund operators**

In joint work with Chun Ho Lau (Concordia), Tiago Picon (Universidade São Paulo), and Claudio Vasconcelos (Universidade Federal de São Carlos), we show that atoms and molecules for the local Hardy spaces \( h^p(\mathbb{R}^n) \), \( 0 < p \leq 1 \), must satisfy certain logarithmic-type moment conditions. From this one can obtain the necessity of the approximate cancellation conditions we have previously imposed in order to show the boundedness of inhomogeneous Calderón–Zygmund operators on these spaces.

DAVID FEDER, Calgary
[Monday December 5 / lundi 5 décembre, 8:30 – Scott]

DAVID KRIBS, University of Guelph
[Monday December 5 / lundi 5 décembre, 16:00 – Scott]

**Graph theory, matrix theory, and operator theory, and distinguishing quantum states via LOCC**

In this talk, I’ll discuss my ongoing work with collaborators on a basic topic in quantum communication theory: Given a set of known quantum states, when can two parties distinguish the states via the hybrid classical-quantum communication protocol called local (quantum) operations and classical communication (LOCC). I’ll focus on the case of quantum product states, and will show how we’ve been able to make use of aspects of graph theory, matrix theory, and operator theory to develop techniques for distinguishing such states in the one-way LOCC framework. This talk is based on joint works with Comfort Mintah, Michael Nathanson, and Rajesh Pereira.

MILIVOJE LUKIC, Rice University
[Monday December 5 / lundi 5 décembre, 9:00 – Scott]

**Stahl–Totik regularity for Schrödinger operators**

This talk describes a theory of regularity for one-dimensional continuum Schrödinger operators. For any half-line Schrödinger operator with a bounded potential \( V \), we obtain universal thickness statements for the essential spectrum, in the language of potential theory and Martin functions (which will be defined in the talk). Namely, we prove that the essential spectrum is not polar, it obeys the Akhiezer–Levin condition, and moreover, the Martin function at infinity obeys the two-term asymptotic expansion \( \sqrt{-z} + \frac{a}{2\sqrt{-z}} + o\left(\frac{1}{\sqrt{-z}}\right) \) as \( z \to -\infty \). The constant \( a \) in its asymptotic expansion plays the role of a renormalized Robin constant and enters a universal inequality \( a \leq \liminf_{x \to -\infty} \frac{1}{2} \int_0^x V(t)dt \). This leads to a notion of regularity, with connections to the exponential growth rate of Dirichlet solutions and limiting eigenvalue distributions for finite restrictions of the operator, and applications to decaying and ergodic potentials. This is joint work with Benjamin Eichinger.

FRÉDÉRIC MORNEAU-GUÉRIN, TÉLUQ
[Monday December 5 / lundi 5 décembre, 16:30 – Scott]

**Sur une question posée par Erdös au sujet des matrices doublement stochastiques**

Dans un célèbre article de Marvis Marcus et Rimhak Ree datant de 1958, on démontre que pour toute matrice doublement stochastique \( A \) on a que le carré de la norme de Frobenius de \( A \) est inférieur est borné par la trace d’une diagonale de \( A \). Paul Erdös a ensuite posé la question suivante : sous quelle(s) condition(s) cette inégalité est-elle stricte ?

Au cours de cette présentation, nous présenterons une réponse partielle de Marcus et Ree s’appliquant dans le cas général ainsi qu’une réponse explicite, complète et détaillée s’appliquant dans un cas particulier.

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Matrix Analysis and Operator Theory (Bilingual Session)
Analyse matricielle et théorie des opérateurs
Matrix Analysis and Operator Theory (Bilingual Session)
Analyse matricielle et théorie des opérateurs

MARCU-ANTONE ORSONI, University of Toronto
[Monday December 5 / lundi 5 décembre, 15:00 – Scott]

Separation of singularities for the Bergman space and reachable space of the heat equation.

Let \( \Omega_1 \) and \( \Omega_2 \) be two open sets of the complex plane with non empty intersection. The separation of singularities problem can be stated as follows: if \( f \) belongs to the Bergman space of \( \Omega_1 \cap \Omega_2 \), can we find \( f_1 \) and \( f_2 \) belonging respectively to the Bergman spaces of \( \Omega_1 \) and \( \Omega_2 \), such that \( f = f_1 + f_2 \)? In this talk, we will see general settings in which the previous question has a positive answer and we will apply these results to the description of the reachable space of the heat equation. Joint work with Andreas Hartmann.

PIERRE-OLIVIER PARISÉ, University of Hawaii at Manoa
[Monday December 5 / lundi 5 décembre, 9:30 – Scott]

Infinite Matrices of Operators

A summability method can be given as an infinite matrix of the form

\[
A = \begin{pmatrix}
a_{0,0} & a_{0,1} & a_{0,2} & \cdots \\
a_{1,0} & a_{1,1} & a_{1,2} & \cdots \\
a_{2,0} & a_{2,1} & a_{2,2} & \cdots \\
\vdots & \vdots & \vdots & \ddots
\end{pmatrix}, \quad a_{i,j} \in \mathbb{C}.
\]

In this talk, based on A. Robinson’s article On Functional Transformation and Summability, I will present a generalization of a summability method where each entry \( a_{i,j} \) is replaced by a bounded linear operator on a Banach space. I will also show a generalization of the Silverman-Toeplitz Theorem in this new framework.

Note: I will present in English, but the slides will be in French.

IGNACIO URIARTE-TUERO, University of Toronto
[Monday December 5 / lundi 5 décembre, 10:00 – Scott]

An operator theoretic application of two weight norm inequalities for SIOs in \( \mathbb{R}^n \)

I will report on recent progress on the two weight problem for singular and fractional integral operators in \( \mathbb{R}^n \), in particular a new stability result for boundedness of certain operators (joint with M. Alexis, J.L. Luna Garcia, and E. Sawyer). The talk will be self-contained.
Pursuit-evasion games on graphs
Jeux de poursuite-évasion sur les graphes

Org: Anthony Bonato (TMU) and Andrea Burgess (UNB)

In pursuit-evasion games on graphs, a set of pursuers attempts to locate or eliminate the threat posed by an evader in the network. The rules greatly determine the difficulty of the questions posed above. For example, the evader may be visible, but the pursuers may have limited movement speed, only moving to nearby vertices adjacent to them. Such a paradigm leads to the game of Cops and Robbers and deep questions like Meyniel’s conjecture on the cop number of a graph. A central theme is the optimization of certain parameters, such as the cop number, burning number, or localization number. Finding the exact values, bounds, and algorithms to compute these graph parameters leads to fascinating topics intersecting with classical graph theory, combinatorial designs, and probabilistic methods.

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Abstracts/Résumés

ANDREA BURGESS. University of New Brunswick Saint John

[Sunday December 4 / dimanche 4 décembre, 9:00 – Wren A]

*The Deduction Game*

The deduction game is a variant of the game of cops and robbers in which cops must capture an invisible robber, but cannot communicate with cops on other vertices to co-ordinate strategy. Thus, cops must "deduce" how other cops will move and make their own moves accordingly. We discuss characterizations of the game and connections with zero-forcing. We give bounds on the number of cops required to capture the robber, and discuss the game in some classes of graphs. This talk includes joint work with Danny Dyer, Mozghan Farahani, Krishna Narayanan, Kerry Ojakian, Mingyu Xiao and Boting Yang.
Pursuit-evasion games on graphs
Jeux de poursuite-évasion sur les graphes

JESSICA ENRIGHT, University of Glasgow
[Sunday December 4 / dimanche 4 décembre, 10:00 – Wren A]

Multilayer cops-and-robbers

(joint work with Will Pettersen, John Sylvester, and Kitty Meeks)

Multilayer graphs are graphs with multiple edge sets on a single vertex set. For example, consider a graph in which towns or neighbourhoods are vertices and different edge sets are different ways of getting between them: one edge set might be links by rail or underground, another geographic adjacency, and another fast road links. We have been studying the game of cops-and-robbers on multilayer graphs. Here, we allow each cop to move on only one layer but allow the robber to freely move on edges from any layer - from our previous analogy cops are restricted to just one mode of transport each, but robbers may use any combination. We have been interested in various problems, including a multilayer version of cop-number and optimal cop allocation between layers.

After giving several motivating examples that initially confounded our intuition, I will report on hardness results for determining multilayer cop number and performing cop allocation. I will also outline a positive relating the multilayer cop number and the treewidth of the graph on which the robber moves.

CALEB JONES, Memorial University of Newfoundland
[Sunday December 4 / dimanche 4 décembre, 17:30 – Wren A]

Burning Triple Systems

We introduce a round-based model much like graph burning which applies to hypergraphs. The rules for this new model are very natural, and generalize the original model of graph burning. A second model called “lazy burning” is also introduced, along with a new parameter, the lazy burning number. We briefly discuss results and bounds for both models that apply to general hypergraphs, and then move on to the discussion of triple systems, which have a special significance in the context of burning. We focus mainly on Steiner triple systems, obtaining a lower bound on the burning number and an upper bound on the lazy burning number. Finally, we show some additional interesting results such as the fact that there are infinitely many Steiner triple systems with lazy burning number 3.

TRENT MARBACH, Toronto Metropolitan University
[Sunday December 4 / dimanche 4 décembre, 15:30 – Wren A]

Limited visibility localization

A modification to the typical Cops and Robbers game limits the cops’ knowledge by introducing a restriction known as \( k \)-visibility. This restriction is that the cops only know the robber’s location if some cop is distance at most \( k \) from the robber. Previous work has primarily focused on the case with \( k = 0 \) and \( k = 1 \), although recent work has explored the general case. We introduce the \( k \)-visibility Localization game, focusing on the case \( k = 1 \). Play in this variant naturally splits up into two phases. For a graph \( G \), we write \( \text{prox}_1(G) \) to indicate the minimum number of cops required to see the robber on \( G \) and \( \zeta_1(G) \) to indicate the minimum number of cops required to capture the robber on \( G \).

The results that we present will show connections between these new graph parameters and the previously studied graph isoperimetric parameters, which are two parameters that bound a subgraph’s boundary with respect to the number of vertices in the subgraph. In particular, we introduce a \( h \)-index for the graph isoperimetric parameter, which provides an alternate view of how ‘large’ the graph isoperimetric parameter is for a given graph. We then show how previously published results on the graph isoperimetric problem can be utilized using the \( h \)-index idea to give lower bounds on \( \zeta_1(G) \) and \( \text{prox}_1(G) \) for several graph families.
Pursuit-evasion games on graphs
Jeux de poursuite-évasion sur les graphes

JOHN MARCOUX, Toronto Metropolitan University
[Sunday December 4 / dimanche 4 décembre, 17:00 – Wren A]
Distance-Restricted Firefighting on Finite Graphs

In the classic version of the game of firefighter, on the first turn a fire breaks out on a vertex in a graph \( G \) and then \( k \) firefighters protect \( k \) vertices. On each subsequent turn, the fire spreads to the collective unburnt neighbourhood of all the burning vertices and the firefighters again protect \( k \) vertices. Once a vertex has been burnt or protected it remains that way for the rest of the game. We previously introduced the concept of distance-restricted firefighting where the firefighter’s movement is restricted so they can only move up to some fixed distance \( d \) and they may or may not be permitted to move through burning vertices.

In this talk we establish the NP-Completeness of the distance-restricted versions of the Maximum Vertices Saved problem as well as covering some interesting properties of the Expected Damage function. This is joint work with David Pike, Andrea Burgess, and Verafin Inc. as part of the Mitacs Accelerate Program.

MICHAEL MOLNAR, Toronto Metropolitan University
[Sunday December 4 / dimanche 4 décembre, 15:00 – Wren A]
Limited Visibility Localization

We explore a variation of the localization game, where a set of cops seek to identify the location of an invisible robber using distance probes. We define the parameter \( \zeta_1(G) \) to be the minimum number of cops required to win the game on a graph \( G \), with probes only revealing 0, 1, or other. We evaluate \( \zeta_1(G) \) on various graph classes, and give upper bounds for trees via their order, height, and number of leaf vertices. We show that there are trees \( T \) for which \( \zeta_1(T) \) is unbounded. This is in stark contrast to the localization game, where \( \zeta_2(T) \leq 2 \) for all trees.

TODD MULLEN, University of Prince Edward Island
[Sunday December 4 / dimanche 4 décembre, 16:30 – Wren A]
Surrounding an Active Robber

The Surrounding Cop Number is a recently introduced parameter which measures the number of Cops required not to capture the Robber, but rather to occupy all vertices adjacent to the Robber (whether or not a Cop is on the Robber’s vertex). In the Cops and Robber variant, Surrounding Cops and Robber, if a Cop ever lands on the Robber’s vertex, the Robber doesn’t lose, but rather he is simply compelled to move on his next turn to a vertex that doesn’t contain a Cop. In this talk, we introduce two similar variants to Surrounding Cops and Robber, one with an active Robber and one with a cheating Robber, that attempt to address certain peculiarities in the Cops’ and Robber’s respective strategies in Surrounding Cops and Robber. We conclude by discussing an interesting family of graphs on which the Active Number and Cheating Number differ, and speculate the size of the largest possible difference between these two parameters on a given graph.

JD NIR, Toronto Metropolitan University
[Sunday December 4 / dimanche 4 décembre, 9:30 – Wren A]
On the Best Way to Play with Fire: an Adversarial Burning Game

Graph burning is a discrete-time process that models the spread of influence in a network. Vertices are in one of two states: either burning or unburned. In each round, a burning vertex causes all of its neighbours to become burning and then a previously unburned vertex is chosen whose state is changed to burning. Previous work has focused on bounding the number of turns necessary to burn an \( n \)-vertex graph. We introduce a variation of the graph burning process that incorporates an adversarial game played on a nested, growing sequence of trees. Two players, Arsonist and Builder, play in turns: Builder adds unburned vertices to create a larger tree, then burning vertices spread fire to their neighbours, and finally Arsonist ‘lights’ a new fire on an unburned vertex. This process repeats forever. Arsonist is said to win if the limiting fraction of burned vertices tends to 1,
while the Builder is said to win if this fraction is bounded away from 1. We consider how the number of vertices granted to
Builder each turn affects the optimal strategies for each player.

BRITTANY PITTMAN, Toronto Metropolitan University

The localization game on directed graphs

In the localization game played on graphs, a set of cops uses distance probes to identify the location of an invisible robber.
This talk introduces an extension of this game and its main parameter, the localization number, to directed graphs. We present
several bounds on the localization number of a directed graphs, including a tight bound via strong components, a bound
using a linear programming problem on hypergraphs, and bounds in terms of pathwidth and DAG-width. We also consider the
localization number of random and quasi-random tournaments. This is joint work with Anthony Bonato, Ryan Cushman, and
Trent Marbach.
Quantum Information Theory
Théorie quantique de l’information

Org: Nathaniel Johnston (Mount Allison) and/et Sarah Plosker (Brandon)

With more and more mathematicians working in the field of Quantum Information Theory, and with a plenary on the topic at the meeting, it seems rather fitting to have such a session. The session will feature researchers employing tools and techniques from a wide array of fields of mathematics, including those working in matrix analysis, operator theory, and mathematical physics, and foster interaction between these researchers.

Étant donné que de plus en plus de mathématiciens travaillent dans le domaine de la théorie de l’information quantique et qu’une séance plénière sera consacrée à ce sujet lors de la réunion, il semble tout à fait approprié d’organiser une telle session. La session présentera des chercheurs utilisant des outils et des techniques issus d’un large éventail de domaines des mathématiques, y compris ceux qui travaillent dans l’analyse matricielle, la théorie des opérateurs et la physique mathématique, et favorisera l’interaction entre ces chercheurs.

Schedule/Horaire
Room/Salle: Rosetti B

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Abstracts/Résumés

XIAONING BIAN, Dalhousie University
[Sunday December 4 / dimanche 4 décembre, 9:00 – Rosetti B]

Generators and relations for 3-qubit Clifford+CS operators

This is a work in progress. We found a finite presentation of the group G of 3-qubit Clifford+CS operators in terms of generators and relations. The proof is easy — applying a known method to a known result. The calculation is non-trivial, which involves simplifying hundreds of long equations. Our main contribution is the simplification method. Its idea is factoring a group into a product of cosets, in other words, finding a "nice" tower of group extensions starting from the trivial group to the group in focus. The ongoing part is to check our result in proof assistant Agda.
Quantum Information Theory
Théorie quantique de l’information

JASON CRANN, Carleton University
[Saturday December 3 / samedi 3 décembre, 8:30 – Rosetti B]
Gaussian quantum information over general kinematical systems

Mathematically, quantum kinematical systems with finitely many degrees of freedom are described by a locally compact abelian group $G$ and a cocycle. The cocycle induces a symplectic (i.e., phase space) structure on $G \times \hat{G}$, which encodes the canonical commutation relations of the associated (projective) Weyl representation. Such abstract quantum kinematical systems have been studied from a variety of perspectives, including finite-dimensional approximations, uncertainty relations and generalized metaplectic/Clifford operators. In this work, we continue this program by developing a formalism to study Gaussian states and channels for general quantum kinematical systems.

I will quickly review the phase space formulation for bosonic/qudit systems and discuss its generalization to abstract (2-regular) Weyl systems. I will then introduce Gaussian states and channels for abstract Weyl systems and discuss some of our main results, including a complete characterization of Gaussian states for arbitrary Weyl systems, and single letter formulae for the quantum capacities and minimum output entropies for arbitrary Gaussian channels over finite Weyl systems.

ERIC CULF, University of Ottawa
[Sunday December 4 / dimanche 4 décembre, 9:30 – Rosetti B]
Rigidity for Monogamy-of-Entanglement Games

In a monogamy-of-entanglement (MoE) game, two players who do not communicate try to simultaneously guess a referee’s measurement outcome on a shared quantum state they prepared. We study the prototypical example of a game where the referee measures in either the computational or Hadamard basis and informs the players of her choice.

We show that this game satisfies a rigidity property similar to what is known for some nonlocal games. That is, in order to win optimally, the players’ strategy must be of a specific form, namely a convex combination of four unentangled optimal strategies generated by the Breidbart state. To show this, we appeal to a positivity argument via a sum-of-squares decomposition satisfied by the game polynomial. We extend this result to show that strategies that win near-optimally must also be near an optimal state of this form. We also show rigidity for multiple copies of the game played in parallel.

As an application, we show that this can be used to achieve bit commitment in a model where it is impossible classically.

FRANK FU, Dalhousie University
[Sunday December 4 / dimanche 4 décembre, 8:30 – Rosetti B]
Programming quantum circuits with Proto-Quipper

Proto-Quipper is a family of quantum programming languages that formalizes various aspects of Quipper. In this talk, I will demonstrate a prototype of Proto-Quipper that supports linear types, dependent types, circuit boxing and dynamic lifting. I will show how these features are used in programming quantum circuits.

MICHAEL KOZDRON, University of Regina
[Saturday December 3 / samedi 3 décembre, 9:30 – Rosetti B]
A Quantum Martingale Convergence Theorem

It is well-known in quantum information theory that a positive operator valued measure (POVM) is the most general kind of quantum measurement. A quantum probability is a normalised POVM, namely a function on certain subsets of a (locally compact and Hausdorff) sample space that satisfies the formal requirements for a probability and whose values are positive operators acting on a complex Hilbert space. A quantum random variable is an operator valued function which is measurable with respect to a quantum probability. In this talk, we will discuss a quantum analogue of the Lebesgue dominated convergence theorem and use it to prove a quantum martingale convergence theorem (MCT). In contrast with the classical MCT, the
Quantum Information Theory
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quantum MCT exhibits non-classical behaviour; even though the limit of the martingale exists and is unique, it is not explicitly identifiable. Fortunately, a partial classification of the limit is possible through a study of the space of all quantum random variables having quantum expectation zero. Based on joint work with Kyler Johnson.

__LARISSA KROELL__, University of Waterloo

[Sunday December 4 / dimanche 4 décembre, 8:00 – Rosetti B]

An operator system view on regular quantum graphs

Quantizing aspects of classical graphs has led to various equivalent definitions of a quantum graph. One definition comes from quantizing the edge relation, which leads to a specific operator system. Under certain circumstances, this can be viewed as a quantization of a classical confusability graph. Another approach involves quantizing the adjacency matrix, which leads to a concept called the quantum adjacency operator. We give an overview of the different notions of quantum graphs and discuss how to translate between them. Then, using the quantum adjacency operator perspective, we introduce a quantum notion of regularity. We show that this leads to a basis condition on the corresponding operator system for quantum graphs on full matrix algebras.

__DEBBIE LEUNG__, University of Waterloo

[Sunday December 4 / dimanche 4 décembre, 10:00 – Rosetti B]

The platypus of the quantum channel zoo and their generic nonadditivity

Understanding quantum channels and the strange behavior of their capacities is a key objective of quantum information theory. One approach is to develop the menagerie of the diverse and complex phenomena displayed by quantum channels. To this end, we construct several families of quantum channels with exotic quantum information-theoretic features. The simplest example of the first family is obtained by gluing together a maximally useful and a completely useless qubit channel, and the resulting channel is unlike either of the constituent channels, and unlike any other known class of channels. In particular, it has additive quantum, private and classical capacity expressions, but the private capacity is significantly larger than the quantum capacity, and the channel has superadditive quantum capacity when used jointly with many other generically chosen channels. While part of the above results rely on a convincing conjecture, we construct a second related family of channels and prove similar results unconditionally.

Joint work with Felix Leditzky, Vikesh Siddhu, Graeme Smith, John Smolin

__JEREMY LEVICK__, University of Guelph

[Saturday December 3 / samedi 3 décembre, 9:00 – Rosetti B]

Generalizing a result of Watrous on Mixed Unitarity

We show some avenues for generalizing a result of Watrous that there is a ball around the completely depolarizing channel consisting of all mixed-unitary unital channels. We also discuss some applications.

__SHIRIN MOEIN__, Mount Allison University

[Sunday December 4 / dimanche 4 décembre, 15:30 – Rosetti B]

Absolutely $k$-Incoherent Quantum States and Spectral Inequalities for Factor Width of a Matrix

Coherence quantifies the amount of superposition and quantum states, $k$-incoherence is a refinement of this property. Based on the eigenvalues, we investigate the set of quantum states that can be shown to be $k$-incoherent. The absolute separability problem asks for a characterization of which quantum states can be determined to be separable based only on their eigenvalues, we introduce the corresponding “absolute” question for the resource theory of $k$-coherence. To this end, absolutely $k$-incoherent quantum states are introduced, and several necessary and sufficient conditions for them are derived.
This is joint work with Dr. Nathaniel Johnston, Dr. Rajesh Pereira, and Dr. Sarah Plosker.

CARLO MARIA SCANDOLO, University of Calgary
[Sunday December 4 / dimanche 4 décembre, 16:00 – Rosetti B]
The operational foundations of PT-symmetric and quasi-Hermitian quantum theory

PT-symmetric quantum theory was originally proposed with the aim of extending standard quantum theory by relaxing the Hermiticity constraint on Hamiltonians. However, no such extension has been formulated that consistently describes states, transformations, measurements and composition, which is a requirement for any theory. We aim to answer the question of whether a consistent theory with PT-symmetric observables extends standard quantum theory. We work within the framework of general probabilistic theories, which is the most general framework for physical theories. We construct the set of states of a system with PT-symmetric observables, and show that the resulting theory allows only one trivial state. We then analyze one of the most popular fixes to the issues of PT-symmetric quantum theory, which is the requirement of quasi-Hermiticity on observables. After showing that quasi-Hermitian systems are equivalent to standard quantum systems, we prove that if PT-symmetry is added on top of quasi-Hermiticity, then the system is equivalent to a real quantum system. Thus our results show that neither PT-symmetry nor quasi-Hermiticity constraints are sufficient to extend standard quantum theory consistently.

THOMAS THEURER, University of Calgary
[Sunday December 4 / dimanche 4 décembre, 16:30 – Rosetti B]
Resource theories of operations

The question where quantum mechanics differs from classical physics is not only of interest, but has technological implications too. To address it in a systematic manner, so-called quantum resource theories were developed. These are mathematical frameworks that emerge from restrictions that are put on top of the laws of quantum mechanics and single out specific aspects of quantum theory as resources. It is then investigated how these restrictions influence our abilities to do certain tasks, how these restrictions can be overcome, and how the resulting resources can be quantified. Historically, resource theories were mainly focused on the resources present in quantum states. In this talk, I will speak about how these concepts can be extended to quantum operations. This allows us to describe quantum resources that cannot be captured in resource theories of states and leads to various interesting applications.

YUMING ZHAO, University of Waterloo
[Saturday December 3 / samedi 3 décembre, 10:00 – Rosetti B]
An operator-algebraic formulation of self-testing

We give a new definition of self-testing for quantum correlations in terms of states on $C^*$-algebras. We show that this definition is equivalent to the standard definition for any class of finite-dimensional quantum models which is closed under submodels and direct sums, provided that the correlation is extreme and has a full-rank model in the class. This last condition automatically holds for the class of POVM quantum models, but does not necessarily hold for the class of projective models by a result of Mančinska and Kaniewski. For extreme binary correlations and for extreme synchronous correlations, we show that any self-test for projective models is also a self-test for all POVM models. The question of whether there is a self-test for projective models which is not a self-test for POVM models remains open.

An advantage of our new definition is that it extends naturally to commuting operator models. We show that an extreme correlation is a self-test for finite-dimensional quantum models if and only if it is a self-test for finite-dimensional commuting operator models, and also observe that many know finite-dimensional self-tests are in fact self-tests for infinite-dimensional commuting operator models.

Joint work with Connor Paddock, William Slofstra, and Yangchen Zhou
Recent advances on nonlinear evolution equations
Développements récents dans le domaine des équations d'évolution non linéaires

Org: Fabio Pusateri (Toronto), Gigliola Staffilani (MIT) and/et Catherine Sulem (Toronto)

In this session the speakers will report on recent advances on nonlinear evolution equations and their mathematical analysis. Topics will include Fluid Dynamics, General Relativity, Dispersive Equations and Parabolic Flows.

Dans cette session, les intervenants feront état des avancées récentes sur les équations d'évolution non linéaires et leur analyse mathématique. Les sujets abordés seront la dynamique des fluides, la relativité générale, les équations dispersives et les écoulements paraboliques.

**Schedule/Horaire**

**Room/Salle: Duchesse**

**Saturday December 3**

8:30 - 9:00  Manuela Girotti (Saint Mary's University), *The dynamics soliton gasses: Fredholm determinants, asymptotics, and kinetic equations* (p. 139)

9:00 - 10:00 Slim Ibrahim (University of Victoria) (p. 140)

10:00 - 10:30 Yakov Shlapentokh-Rothman (University of Toronto), *Self-Similarity for the Einstein Vacuum Equations and Applications* (p. 141)

14:30 - 15:30 Michael Sigal (University of Toronto), *Vacuum solutions of the theory of electroweak interactions* (p. 141)

16:00 - 16:30 Olga Trichtchenko (Western University) (p. 141)

16:30 - 17:30 Catherine Sulem (University of Toronto), *A Hamiltonian approach to nonlinear modulation of surface water waves in the presence of linear shear currents.* (p. 141)

17:30 - 18:00 Manuel Palacios (University of Toronto), *Asymptotic Stability of Peakons for the Novikov equation* (p. 140)

18:00 - 18:30 Thomas Wolf (Brock University), *Exact solitary wave solutions for a coupled gKdV-NLS system* (p. 141)

**Sunday December 4**

8:30 - 9:00  Giusy Mazzone (Queen's University), *Periodic motion of a harmonic oscillator interacting with a viscous fluid* (p. 140)

9:00 - 9:30  Gael Yomgne Diebou (Fields Institute), *Remarks on the heat flow of harmonic maps: uniqueness and weak-strong theory* (p. 139)

9:30 - 10:00 Jia Shi (MIT), *On the analyticity of the Muskat equation* (p. 141)

10:00 - 10:30 Adilbek Kairzhan (University of Toronto), *Asymptotic stability near the soliton for quartic Klein-Gordon in 1D* (p. 140)

**Abstracts/Résumés**

**GAELE YOMGNE DIEBOU,** The Fields Institute for Research in Mathematical Sciences

[Sunday December 4 / dimanche 4 décembre, 9:00 – Duchesse]

*Remarks on the heat flow of harmonic maps: uniqueness and weak-strong theory*

There are essentially two research lines pertaining to the harmonic maps problem: the first is related to the theory of weak solutions whose global existence is proved for initial data in $W^{1,2}$ and the second to the theory of strong (mild) solutions which are constructed in scaling invariant spaces. The uniqueness question for both notion of solutions is largely open. In this talk, I will discuss a new uniqueness result and its consequence in bridging the gap between finite energy weak solutions and mild solutions.
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Développements récents dans le domaine des équations d’évolution non linéaires

MANUELA GIROTTI, Saint Mary’s University
Saturday December 3 / samedi 3 décembre, 8:30 – Duchesse

The dynamics soliton gasses: Fredholm determinants, asymptotics, and kinetic equations

I will describe a collection of collaborations with K. McLaughlin (Tulane U.), T. Grava (SISSA/Bristol), R. Jenkins (UCF) and A. Minakov (U. Karlova). We analyze the case of a regular, dense (modified) KdV soliton gas and its large time behaviour in the presence of a single trial soliton. We show that the solution can be decomposed as the sum of the background gas solution (a modulated elliptic wave), plus a soliton solution: the individual expressions are however quite convoluted due to the interaction dynamics. We are able to derive the local phase shift of the gas after the passage of the soliton, and we can trace the location of the soliton peak as the dynamics evolves; additionally, we show that the soliton peak, while interacting with the soliton gas, has an oscillatory velocity whose leading order average value satisfies the kinetic velocity equation analogous to the one posited by V. Zakharov and G. El.

SLIM IBRAHIM, University of Victoria
Saturday December 3 / samedi 3 décembre, 9:00 – Duchesse

ADILBEK KAIRZHAN, University of Toronto
Sunday December 4 / dimanche 4 décembre, 10:00 – Duchesse

Asymptotic stability near the soliton for quartic Klein-Gordon in 1D

In this talk we discuss the nonlinear focusing Klein-Gordon equation in $1+1$ dimensions and the global space-time dynamics of solutions near the unstable soliton. We give a proof of optimal decay, and local decay, for even perturbations of the static soliton originating from well-prepared initial data belonging to a subset of the stable manifold constructed in Bates-Jones (Dynamics reported, 1989) and Kowalczyk-Martel-Muñoz (J. Eur. Math. Soc., 2021). Our results complement those of Kowalczyk-Martel-Muñoz (J. Eur. Math. Soc., 2021) and confirm numerical results of Bizon-Chmaj-Szpak (J. Math. Phys., 2011). In particular, we provide new information both local and global in space about asymptotically stable perturbations of the soliton under localization assumptions on the data.

This is a joint work with Fabio Pusateri.

GIUSY MAZZONE, Queen’s University
Sunday December 4 / dimanche 4 décembre, 8:30 – Duchesse

Periodic motion of a harmonic oscillator interacting with a viscous fluid

We consider the motion of a harmonic oscillator immersed in a viscous incompressible fluid within an infinite pipe. The motion of the fluid is driven by a prescribed, time-periodic flow rate. As the fluid flows in the channel, it may exert a periodic force on the oscillator. In this setting, if the frequency of this force matches the natural frequency of the oscillator, then the phenomenon of resonance may occur with the mass oscillating with increasing amplitude. Because of the phenomenon of resonance, the motion of the harmonic oscillator would not be time-periodic. We will show that resonance does not occur in the class of weak solutions to the governing equations if the flow rate is "sufficiently small". In addition, we will prove that at a large distance from the oscillator- the fluid velocity converges to the time-periodic generalization of the Poiseuille flow in an infinite pipe.

MANUEL PALACIOS, University of Toronto
Saturday December 3 / samedi 3 décembre, 17:30 – Duchesse

Asymptotic Stability of Peakons for the Novikov equation

The Novikov equation is an integrable Camassa-Holm-type equation with a cubic nonlinearity. One of its most important features is the existence of peaked traveling waves. In this talk, we will prove the asymptotic stability of those peakon solutions,
Recent advances on nonlinear evolution equations
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under $H^1(\mathbb{R})$-perturbations satisfying that their associated momentum density defines a non-negative Radon measure. In order to do that, we first prove a rigidity theorem, sometimes called Liouville theorem. The main novelty in our analysis, compared to the Camassa-Holm case, comes from the fact that the momentum is not a conserved quantity anymore. To overcome this problem, we introduce a new Lyapunov functional unrelated to the (non-conserved) momentum of the equation.

JIA SHI, MIT
[Sunday December 4 / dimanche 4 décembre, 9:30 – Duchesse]
On the analyticity of the Muskat equation

The Muskat equation describes the interface of two liquids in a porous medium. We will show that if a solution to the Muskat problem in the case of same viscosity and different densities is sufficiently smooth, then it must be analytic except at the points where a turnover of the fluids happens. We will also show analyticity in a region that degenerates at the turnover points provided some additional conditions are satisfied.

YAKOV SHLAPENTOKH-ROTHMAN, University of Toronto
[Saturday December 3 / samedi 3 décembre, 10:00 – Duchesse]
Self-Similarity for the Einstein Vacuum Equations and Applications

I will discuss old and new notions of self-similarity for the Einstein Vacuum Equations and discuss applications of these such as the construction of Naked Singularities.

MICHAEL SIGAL, University of Toronto
[Saturday December 3 / samedi 3 décembre, 14:30 – Duchesse]
Vacuum solutions of the theory of electroweak interactions

In this talk I will describe the vacuum sector of the Weinberg-Salam (WS) model of electroweak forces. (In the vacuum sector the WS model yields the $U(2)$-Yang-Mills-Higgs equations.) We show that at large constant magnetic fields the translational symmetry of the equation is broken spontaneously: the solutions, with the lowest energy locally, in the plane orthogonal to the magnetic field, have the symmetry of a lattice. The stability of these solutions is an open problem.

CATHERINE SULEM, University of Toronto
[Saturday December 3 / samedi 3 décembre, 16:30 – Duchesse]
A Hamiltonian approach to nonlinear modulation of surface water waves in the presence of linear shear currents.

This is a study of the water wave problem in a two-dimensional domain in the presence of constant vorticity. The goal is to describe the effects of uniform shear flow on the modulation of weakly nonlinear quasi-monochromatic surface waves. Starting from the Hamiltonian formulation of this problem and using techniques of Hamiltonian transformation theory, we derive a Hamiltonian, high-order Nonlinear Schrödinger equation (often referred to as Dysthe equation) for the time evolution of the wave envelope. Consistent with previous studies, we observe that the uniform shear flow tends to enhance or weaken the modulational instability of Stokes waves depending on its direction and strength. This model is tested against direct numerical simulations of the full Euler equations and against a related Dysthe equation recently derived by Curtis, Carter and Kalisch (2018). This is a joint work with P. Guyenne and A. Kairzhan.

OLGA TRICHTCHENKO, Western University
[Saturday December 3 / samedi 3 décembre, 16:00 – Duchesse]
Thomas Wolf, Brock University

Exact solitary wave solutions for a coupled gKdV-NLS system

We study a coupled gKdV-NLS system

\[ u_t + \alpha u^p u_x + \beta u_{xxx} = \gamma(|\psi|^2)_x, \quad i\psi_t + \kappa \psi_{xx} = \sigma u \psi \]

with nonlinearity power \( p > 0 \), which has been introduced in the literature to model energy transport in an anharmonic crystal material [1,2]. There is a strong interest in obtaining exact solutions describing frequency-modulated solitary waves \( u = U(x - ct), \quad \psi = e^{i\omega t} \Psi(x - ct) \), with wave-speed \( c \), and modulation frequency \( \omega \). Some solutions have been found for \( p = 1 \) (KdV) in [1], while for \( p = 2 \) (mKdV), no exact solutions were found [2]. Nothing has been done for \( p \geq 3 \).

We derived exact solutions for \( p = 1, 2, 3, 4 \), starting from the travelling wave ODE-system satisfied by \( U \) and \( \Psi \). The method is new: (i) obtain first integrals by use of multi-reduction symmetry theory [3]; (ii) apply a hodograph transformation which leads to a triangular system; (iii) introduce an ansatz for polynomial solutions of the base ODE; (iv) characterize conditions under which solutions yield solitary waves; (v) solve an algebraic system for the unknown coefficients under those conditions.

The resulting solitary waves exhibit a wide range of features: bright/dark peaks; single/multi-peaked; zero/non-zero backgrounds.

References:


Sitting at the intersection of several directions of research, representation theory of algebras has been an active domain of research which receives impetus from different areas. In return, it often provides new tools to the study of some classical and modern problems in various realms of research. This session aims to bring together some researchers working on different aspects of representation theory of algebras to share their perspectives and new research. In particular, there will be talks on the combinatorial, geometric and homological aspects of representation theory, to just mention a few. This will hopefully stimulate further interaction between experts in this area, as well as with those interested in the connections between representation theory with some other domains.

Située à l’intersection de plusieurs directions de recherche, la théorie des représentations des algèbres est un domaine de recherche actif qui reçoit des impulsions de différents secteurs. En retour, elle fournit souvent de nouveaux outils pour l’étude de certains problèmes classiques et modernes dans divers domaines de recherche. Cette session vise à réunir des chercheurs travaillant sur différents aspects de la théorie des représentations des algèbres afin de partager leurs perspectives et leurs nouvelles recherches. En particulier, il y aura des exposés sur les aspects combinatoires, géométriques et homologiques de la théorie des représentations, pour n’en citer que quelques-uns. Nous espérons ainsi stimuler l’interaction entre les experts de ce domaine, ainsi qu’avec ceux qui s’intéressent aux liens entre la théorie des représentations et d’autres domaines.

Schedule/Horaire

**Saturday December 3**

8:30 - 9:00  |  **Milen Yakimov** (Northeastern University), *Poisson geometry and representation theory of root of unity quantum cluster algebras* (p. 147)

9:10 - 9:40  |  **Charles Paquette** (Royal Military College), *Biserial algebras and bricks* (p. 145)

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14:30 - 15:00 |  **Benjamin Dequêne** (Université du Québec à Montréal), *Some Jordan recoverable subcategories of modules over gentle algebras* (p. 144)

15:00 - 15:30 |  **Deepanshu Prasad** (Queen’s University), *An Extension of Sato-Kimura Theorem for Semi-invariant rings* (p. 145)

16:00 - 16:30 |  **Colin Ingalls** (Carleton University), *Sets of mutually orthogonal projective and affine planes* (p. 145)

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9:50 - 10:20 |  **Emily Barnard** (DePaul University), *Triangulations and maximal almost rigid representations* (p. 144)

15:30 - 16:00 |  **David Speyer** (University of Michigan), *Coxeter groups and torsion classes of quiver and preprojective algebras* (p. 146)

16:10 - 16:30 |  **Will Dana** (University of Michigan), *Walls of shards and filtrations of shard modules* (p. 144)

16:40 - 17:10 |  **Thomas Brüstle** (Université de Sherbrooke), *Relative torsion classes* (p. 144)

Abstracts/Résumés
EMILY BARNARD, DePaul University

Triangulations and maximal almost rigid representations

Let $kQ/I$ be a finite representation type gentle algebra. Two modules $M$ and $N$ are called almost rigid if they do not have any nonsplit extensions or if any extension between $M$ and $N$ is indecomposable. A module $T$ is maximal almost rigid (mar) if its indecomposable summands form a maximal collection of pairwise almost rigid modules. In this talk, we show each mar module $T$ has the same number of summands. We use a modified version of the surface model for the modules of $kQ/I$ developed by Coelho-Simões and Baur to show that each mar $T$ corresponds bijectively to a permissible triangulation of our surface. Finally, we show that the endomorphism algebra of a mar module over $kQ/I$ is the endomorphism algebra of a tilting module over a bigger gentle algebra. Our results generalize the hereditary type A case, where the mar modules correspond to triangulations of a polygon, and their endomorphism algebras are tilted algebras.

THOMAS BRÜSTLE, Bishop’s University and Université de Sherbrooke

Relative torsion classes

We study the notion of torsion classes relative to exact structures. This is motivated by the notion of almost rigid objects introduced by Emily Barnard, Emily Gunawan, Emily Meehan and Ralf Schiffler. More generally, the aim is to study cluster-like structures for exact categories.

WILL DANA, University of Michigan

Walls of shards and filtrations of shard modules

The representation theory of preprojective algebras is intertwined with the combinatorics of Coxeter groups. In particular, for a simply laced Dynkin diagram, the King stability domains of bricks of its preprojective algebra partition the reflecting hyperplanes of the associated Coxeter group into cones called shards, which previously arose in work of Nathan Reading on the lattice structure of the weak order. In joint work with David Speyer and Hugh Thomas, we extend this result to non-Dynkin diagrams by showing a bijection between rigid bricks with full-dimensional stability domain (which we call “shard modules”) and shards. In this talk, we’ll give an overview of this generalization, and then showcase a couple of ways in which the geometry of shards relates to properties of shard modules. We’ll generalize a result from the Dynkin case, showing that, at any wall of a shard, it’s met by two other shards such that the three corresponding shard modules fit into a nice short exact sequence. We’ll then apply this result to families of diagrams with “tails” to visualize how shard modules are related to the positions of their shards in this case.

BENJAMIN DEQUÊNE, Université du Québec à Montréal

Some Jordan recoverable subcategories of modules over gentle algebras.

Gentle algebras form a class of finite dimensional algebras introduced by Assem and Skowronski in the ’80s. Modules over such an algebra can be described by string and band combinatorics, which are some kind of walk in the associated gentle quiver, thanks to the works of Butler and Ringel. A subcategory $C$ of modules is said to be Jordan recoverable if we can recover (up to isomorphism) a representation $X$ in $C$ from the Jordan form of its generic nilpotent endomorphisms, called the generic Jordan form data of $X$.

The main aim of the talk is to explain the notion of Jordan recoverability through various examples and to highlight a combinatorial characterization of that property for some special kind of subcategories of modules over gentle algebras - a result...
which extends the work of Garver, Patrias, and Thomas done in Dynkin cases. If time allows it, we could discuss some open questions related to this result.

*This is a part of my Ph.D. work supervised by Hugh Thomas.*

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**COLIN INGALLS**, Carleton University

[Saturday December 3 / samedi 3 décembre, 16:00 – Carlyle A]

Sets of mutually orthogonal projective and affine planes

A pair of planes, both projective or both affine, of the same order and on the same pointset are orthogoval if each line of one plane intersects each line of the other plane in at most two points. In this paper we prove new constructions for sets of mutually orthogoval planes, both projective and affine, and review known results that are equivalent to sets of more than two mutually orthogoval planes. We also discuss the connection between sets of mutually orthogoval planes and covering arrays. This is joint work with Charles J. Colbourn, Jonathan Jedwab, Mark Saaltink, Ken W. Smith, and Brett Stevens.

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**SHIPING LIU**, Université de Sherbrooke

[Saturday December 3 / samedi 3 décembre, 9:50 – Carlyle A]

Module categories with a null fourth power of the radical

This is a joint work with Youqi Yin. Motivated by the well known fact that an artin algebra is semi-simple if and only if its module category has a null radical, our work aims to initiate a study of the representation theory of representation-finite artin algebras in terms of the nilpotency of the radical of their module category. In this talk, we shall give a complete list of artin algebras $A$ such that $\text{rad}^4(\text{mod } A) = 0$.

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**CHARLES PAQUETTE**, Royal Military College of Canada

[Saturday December 3 / samedi 3 décembre, 9:10 – Carlyle A]

Biserial algebras and bricks

Biserial algebras form an important class of tame algebras, which include the class of special biserial algebras. In this talk, we study the bricks over such algebras, which are the modules having a division algebra as endomorphism algebra. For a general finite dimensional algebra $A$, bricks over $A$ form an important family of indecomposable modules. They are the simple objects of the wide subcategories of the module category, they include all stable modules in the sense of King, and more recently, have shown to be deeply connected to the $\tau$-tilting theory and the so-called wall-and-chamber structure of $A$. We will show that a biserial algebra $B$ has finitely many bricks (then called brick-finite) if and only if no quotient of $B$ is gentle of infinite type. The latter can be detected by classifying the minimal brick-infinite biserial algebras, that is, the biserial algebras which are brick-infinite but such that every proper quotient is brick-finite. We also consider some infinite dimensional bricks (called generic bricks) and explain how the existence of those is equivalent to the existence of infinite families of bricks. This is joint work with Kaveh Mousavand.

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**DEEPAHSHU PRASAD**, Queen’s University

[Saturday December 3 / samedi 3 décembre, 15:00 – Carlyle A]

An Extension of Sato-Kimura Theorem for Semi-invariant rings

We give an analog of a result of Sato-Kimura in the context of a semi-invariant ring for a finite dimensional algebra over an algebraically closed field $\mathbb{K}$ of characteristics 0. Then, we examine the case of finite dimensional hereditary algebras over $\mathbb{K}$ and give another proof of a result by Paquette and Weyman. This is joint work with Charles Paquette and David Wehlau.
Spin chains as modules over the affine Temperley-Lieb algebra

Let \( V = (\mathbb{C}^2)^{\otimes N} \) be the tensor product of \( N \) copies of the two-dimensional simple \( U_q(sl_2) \)-module. It is also a \( U_q(sl_2) \)-module (through the coproduct on \( U_q(sl_2) \)). The algebra of endomorphisms \( \text{End}_{U_q(sl_2)} V \) is known to define a representation of the (original) Temperley-Lieb algebra \( \text{TL}_N \) on \( V \) (Jimbo (1985, 1986), Martin (1992)). This is known as the \((q-)\)Schur-Weyl duality. The \( \text{TL}_N \)-action on \( V \) was extended to one of the affine Temperley-Lieb algebra \( \text{aTL}_N \) by two physicists in their study of spin chains (Pasquier and Saleur (1990)). While this extended action fails to commute with that of \( U_q(sl_2) \), the interplay between both actions can be used to reveal the structure of \( V \) as a \( \text{aTL}_N \)-module.

This is joint work with Théo Pinet (arXiv:2205.02649).

Centralizers of products of \( LU_q(sl_2) \)-modules at roots of unity

Let \( V \) be the fundamental representation of the quantum group \( U_q(sl_2) \). Quantum Schur-Weyl duality says that the centralizer of the action of \( U_q(sl_2) \) on the product \( V^\otimes n \) is isomorphic to the Temperley-Lieb algebra \( \text{TL}_n(q + q^{-1}) \), even when \( q \) is a root of unity (in which case we consider the action of Lusztig’s extension \( LU_q(sl_2) \)). We explore products other than \( V^\otimes n \), namely we describe the centralizer of the action of \( LU_q(sl_2) \) on \( P \otimes V^\otimes n \), where \( P \) is a projective \( LU_q(sl_2) \)-module. We give a complete description of the algebra \( \text{End}_{LU_q(sl_2)}(P \otimes V^\otimes n) \) in both cases when \( q \) is a root of unity or not. This is joint work with Yvan Saint-Aubin.

Leclerc’s conjecture on a cluster structure for type A Richardson varieties

Leclerc constructed a conjectural cluster structure on Richardson varieties in simply laced types using cluster categories coming from preprojective algebras. We show that in type A, his conjectural cluster structure is in fact a cluster structure. We do this by comparing Leclerc’s construction with another cluster structure due to Ingermanson, which uses the combinatorics of wiring diagrams and the Deodhar stratification. Though the two cluster structures are defined very differently, we show that the quivers coincide and clusters are related by the twist map for Richardson varieties, recently defined by Galashin–Lam. This is join work with Melissa Sherman-Bennett.

Coxeter groups and torsion classes of quiver and preprojective algebras

I’ll describe the relationship between the combinatorics of Coxeter groups, and the representation theory of quiver path algebras and preprojective algebras. I’ll start back with Colin Ingalls and Hugh Thomas’s 2006 paper “Noncrossing partitions and representations of quivers”, explain how Nathan Reading and my work on Cambrian lattices fits in, and describe work in progress with Hugh Thomas and Will Dana.

Nakayama Algebras which are Defect Invariant

Nakayama Algebras which are Defect Invariant
It was very beautiful idea of Emre Sen to consider "syzygy filtrations" and create epsilon construction which he used to prove several homological statements about Nakayama algebras: about ψ-dimension, Gorenstein dimension, finitistic dimension. Now, in this joint work we consider the process of reversing epsilon construction, while preserving the defect of the algebras; we apply this to give complete classification of Nakayama algebras which are Auslander-Gorenstein and finitistic Auslander algebras.

NICHOLAS WILLIAMS, Lancaster University
[Sunday December 4 / dimanche 4 décembre, 8:30 – Carlyle A]

Cyclic polytopes and representation theory

Oppermann and Thomas show how the representation theory of Iyama’s higher Auslander algebras of type $A (A_d^n)$ is related to triangulations of even-dimensional cyclic polytopes. We show how two natural partial orders on the set of triangulations of a cyclic polytope, the higher Stasheff–Tamari orders, can be interpreted on the representation-theoretic side as well-known orders on silting complexes introduced by Aihara and Iyama. This allows one to interpret triangulations of odd-dimensional cyclic polytopes within the representation theory of $A_d^n$, namely, as equivalence classes of $d$-maximal green sequences. This allows the higher Stasheff–Tamari orders to be interpreted algebraically in odd dimensions too. Finally, we prove the 1996 conjecture of Edelman and Reiner that the two higher Stasheff–Tamari orders are equal, and thereby obtain new results on the representation theory of $A_d^n$.

MILEN YAKIMOV, Northeastern University
[Saturday December 3 / samedi 3 décembre, 8:30 – Carlyle A]

Poisson geometry and representation theory of root of unity quantum cluster algebras

We will show that all root of unity quantum cluster algebras have canonical structures of Cayley-Hamilton algebras (in the sense of Procesi) and Poisson orders (in the sense of De Concini-Kac-Procesi and Brown-Gordon). The first result allows to transfer finiteness properties between the quantum and classical situations. The second result relates the representation theory of these algebras to the Poisson geometry of the Gekhtman-Shapiro-Vainshtein brackets. We will then prove that the spectrum of each upper cluster algebra equipped with the GSV Poisson structures has an explicit Zariski open torus orbit of symplectic leaves, which is a far reaching generalization of the Richardson divisor of a Schubert cell in Lie theory. At the end we will combine the above results to describe explicitly the fully Azumaya loci of the root of unity quantum cluster algebras. This classifies their irreducible representations of maximal dimension. This is a joint work with Shengnan Huang, Thang Le, Greg Muller, Bach Nguyen and Kurt Trampel.
Set theory and its applications
Théorie des ensembles et ses applications

Org: Keegan Dasilva Barbosa (Toronto) and/et Paul Szeptycki (York)

Set theory is a branch of mathematical logic focused on studying the nature of the infinite. It is a long standing field that has found applications in topology, topological dynamics, $C^*$ algebras, theoretical computer science, and combinatorics. The goal of this session is to bring forth a wide variety of researchers to present their current results, discuss current trends, and potentially collaborate.

La théorie des ensembles est une branche de la logique mathématique axée sur l’étude de la nature de l’infini. Il s’agit d’un domaine de longue date qui a trouvé des applications en topologie, en dynamique topologique, dans les algèbres $C^*$, en informatique théorique et en combinatoire. L’objectif de cette session est d’amener une grande variété de chercheurs à présenter leurs résultats actuels, à discuter des tendances actuelles et à collaborer éventuellement.

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Abstracts/Résumés

DAVOUD ABDI, University of Calgary

[Saturday December 3 / samedi 3 décembre, 10:00 – Baker]

Counterexample to Conjectures of Bonato-Tardif, Thomassé and Tyomkyn

Two structures $R$ and $S$ are equimorphic when each embeds in the other; we may also say that one is a sibling of the other. Generally, it is not the case that equimorphic structures are necessarily isomorphic: the rational numbers, considered as a linear order, has up to isomorphism continuum many siblings. Let $\text{Sib}(R)$ be the number of isomorphism classes of siblings of $R$. Thomassé conjectured that for each countable relational structure $R$, $\text{Sib}(R) = 1$, $\aleph_0$, or $2^{\aleph_0}$. There is an alternative case of interest, whether $\text{Sib}(R) = 1$ or infinite for a relational structure $R$ of any cardinality. The alternate Thomassé conjecture is connected to the Bonato-Tardif conjecture asserting that the sibling number of a tree is one or infinite. Further, Tyomkyn conjectured that if a locally finite tree has a non-surjective self-embedding, then it has infinitely many siblings, unless the tree is a ray. All the conjectures mentioned were verified for some structures such as chains, rayless trees, rooted trees, rayless graphs, cographs, countable $NE$-free posets, etc. This talk will introduce some locally finite trees having an arbitrary finite number of siblings, which disproves all conjectures of Bonato-Tardif, Thomassé and Tyomkin.
SHAUN ALLISON, University of Toronto

Polish groups involving $S_\infty$

Say that a Polish group $G$ involves a Polish group $H$ iff there is a closed subgroup $G_0$ of $G$ and a closed normal subgroup $N$ of $G_0$ such that $G_0/N \cong H$. The group $S_\infty$ is the Polish group of (full-support) permutations of $\mathbb{N}$. We show that the non-Archimedean Polish groups involving $S_\infty$ has a deep and interesting theory, with several formulations that are equivalent. We use this theory to show that the non-Archimedean Polish groups which classify $\equiv^+$ are exactly those which involve $S_\infty$.

DANIEL CALDERON, University of Toronto

Borel's conjecture and meager-additive sets

Strong measure zero sets were introduced by Borel and have been studied since the beginning of the previous century. Borel conjectured that every strong measure zero set of real numbers must be countable. A few years later, Sierpiński proved that if the continuum hypothesis (CH) is assumed, then there exists an uncountable strong measure zero set of reals. Nevertheless, the question about the relative consistency of Borel’s conjecture remained open until 1976 when Laver, in a ground-breaking paper, constructed a model of set theory in which every strong measure zero set of reals is countable.

A result of Galvin, Mycielski, and Solovay provides a characterization of Borel’s strong nullity in terms of an algebraic (or translation-like) property for subsets of the real line. By means of this characterization, a strengthening of strong nullity, meager-additivity, appeared on the scene. Meager-additivity and other smallness notions on the real line have received considerable attention in recent years. A 1993 question due to Bartoszyński and Judah asks whether strong nullity and meager-additivity have a very rigid relationship, in the following sense:

**Question (Bartoszyński–Judah, 1993):** Suppose that every strong measure zero set of reals is meager-additive. Does Borel’s conjecture follow?

We proved that it is relatively consistent with ZFC that every strong measure zero subset of the real line is meager-additive while there are uncountable strong measure zero sets (i.e., Borel’s conjecture fails), giving a negative answer to the question above.

CESAR CORRAL, York University

Strong Fréchet properties, squares and AD families

We will deal with some questions about strengthenings of Fréchetness and the $\alpha_i$ properties introduced by Arhangel’skii. Using $\square(\kappa)$-sequences, we can build spaces which are Absolutely Fréchet and productively Fréchet but under some assumptions they may fail to be bisequential. We will also show that some of these properties can be obtained in ZFC using almost disjoint families.

TETSUYA ISHIU, Miami University

The Mardešić Conjecture for Countably Compact Spaces

We shall outline the proof that for all positive integers $d$ and $s$, if $Z_j$ is an infinite Hausdorff space for each $j < d+s$ and $\prod_{j<d+s} Z_j$ is a continuous image of a countably compact subspace of the product of $d$-many compact linearly ordered spaces, then the space $\prod_{j<d+s} Z_j$ is countably compact.
topological spaces, then there are at least $s + 1$-many indexes $j < d + s$ such that $Z_j$ is compact and metrizable. This theorem is a strengthening of the Mardešić Conjecture, which was proved by G. Martínez-Cervantes and G. Plebanek in 2019, but it was proved by a completely different method.

SUMUN IYER, Cornell University  
[Saturday December 3 / samedi 3 décembre, 15:00 – Baker]  
*Dynamics of the Knaster continuum homeomorphism group*

We use the projective Fraïssé approach and Ramsey’s theorem to show that the universal minimal flow of the homeomorphism group of the universal Knaster continuum is homeomorphic to the universal minimal flow of the free abelian group on countably many generators.

Knaster’s continuum is a compact, connected metrizable space which is indecomposable: in the sense that it is not the union of two non-trivial compact, connected, metrizable subsets. We will define a projective Fraïssé class whose limit approximates the universal Knaster continuum in such a way that the group $\text{Aut}(\mathbb{K})$ of automorphisms of the Fraïssé limit is a dense subgroup of the group, $\text{Homeo}(\mathbb{K})$, of homeomorphisms of the universal Knaster continuum. The computation of the universal minimal flow involves modifying the Fraïssé class in a natural way so that it approximates an open, normal, extremely amenable subgroup of $\text{Homeo}(\mathbb{K})$.

VINICIUS RODRIGUES, York University  
[Saturday December 3 / samedi 3 décembre, 8:30 – Baker]  
*Special sets of reals and weakenings of normality in Isbell-Mrówka spaces*

The problem of the existence of a non-metrizable separable normal Moore space is a classical problem related to uncountable normal Isbell-Mrówka spaces and with the class of $\mathcal{Q}$-sets - which are special subsets of the reals: the existence of these objects are independent of ZFC and equivalent. Using the same techniques as the ones needed to prove this equivalence, analogous relations between uncountable pseudonormal Isbell-Mrówka spaces and $\lambda$-sets were established.

Taking as a motivation, we will discuss the relations between some weakenings of normality in Isbell-Mróka spaces (as almost-normality and strong $\kappa_0$-separatedness) and other special subsets of the reals (such as $\sigma$-sets and a new class of subsets of the reals we are proposing, which we called weak $\lambda$-set). In particular, we prove that a branching almost disjoint family generated by a set of reals is almost-normal (strong $\kappa_0$-separated) if, and only if the set of reals is a $\sigma$-set (weak $\lambda$-set). This is a joint work with V. S. Ronchim and P. Szeptycki.

FRANKLIN TALL, University of Toronto  
[Saturday December 3 / samedi 3 décembre, 8:00 – Baker]  
*An undecidable extension of Morley’s theorem on the number of countable models*

AN UNDECIDABLE EXTENSION OF MORLEY’S THEOREM ON THE NUMBER OF COUNTABLE MODELS

Franklin D. Tall

This is joint work with Christopher J. Eagle, Clovis Hamel, and Sandra Muller. We show that Morley’s theorem on the number of countable models of a countable first-order theory becomes an undecidable statement when extended to second-order logic. More generally, we calculate the number of equivalence classes of sigma-projective equivalence relations in several models of set theory. Our methods include random and Cohen forcing, Woodin cardinals and Inner Model Theory.

JING ZHANG, University of Toronto  
[Saturday December 3 / samedi 3 décembre, 16:00 – Baker]
Stochastic Systems, Probability, and Other Mathematical Aspects of Data Science
Les systèmes stochastiques, les probabilités et d'autres aspects mathématiques de la science des données

Org: Martin Lysy (Waterloo)

Stochastic systems and probability are the fundamental components of statistical analysis and data science – both as mathematical models and for the computational algorithms which fit these models to data. The purpose of this session is to present some recent developments in statistics, machine learning, and data science to an audience of mathematicians, in the hopes of establishing an interchange of ideas between colleagues across a broad spectrum of interests in analyzing data: from those on the empirical side of things to those from diverse areas in mathematics which may or may not have an obvious connection to data analysis.

Les systèmes stochastiques et les probabilités sont les composantes fondamentales de l’analyse statistique et de la science des données - tant pour les modèles mathématiques que pour les algorithmes informatiques qui adaptent ces modèles aux données. L’objectif de cette session est de présenter à un public de mathématiciens quelques développements récents en matière de statistiques, d’apprentissage automatique et de science des données, dans l’espoir d’établir un échange d’idées entre collègues ayant un large éventail d’intérêts dans l’analyse des données : de ceux qui sont du côté empirique des choses à ceux qui viennent de divers domaines des mathématiques qui peuvent ou non avoir un lien évident avec l’analyse des données.

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MEIXI CHEN, University of Waterloo
[Monday December 5 / lundi 5 décembre, 8:30 – Rosetti C]

Decoding Neural Population Dynamics Through Latent Factor Models

The human brain contains some hundred billion nerve cells (a.k.a. neurons) which communicate through electrochemical waves called spikes. A sequence of consecutive spikes from a neuron is called a spike train, which encode information about firing rates. Over the past few decades, mathematical and statistical models for neuronal activities have played an important role in helping neuroscientists shed light on neuroscientific phenomena such as the interactions among multiple neurons over time. However, scalability and interpretability of these models are still a challenge in computational/theoretical neuroscience. We present a novel latent factor model for studying the spike train interactions of multiple neurons recorded simultaneously. In the
proposed model, the activities of the neuron population are described by correlated Wiener processes, which themselves depend on a small number of latent factors determining the neuronal clustering. We demonstrate how to tackle the computational challenges of high dimensional integration of latent variables and large matrix inversions. We show that our model is highly scalable and can accurately recover neuronal clusters when applied on simulated data. Finally, we apply our model to a set of experimental data obtained from rats’ medial prefrontal cortex.

SANJEENA DANG, Carleton University
[Monday December 5 / lundi 5 décembre, 10:00 – Rosetti C]
Clustering matrix-variate count data

Three-way data structures or matrix-variate data are frequent in biological studies. In RNA sequencing, three-way data structures are obtained when high-throughput transcriptome sequencing data are collected for n genes across p conditions at r occasions. Matrix variate distributions offer a natural way to model three-way data and mixtures of matrix variate distributions can be used to cluster three-way data. Clustering of gene expression data is carried out as means of discovering gene co-expression networks. In this work, a mixture of matrix variate Poisson-log normal distributions is proposed for clustering read counts from RNA sequencing. By considering the matrix variate structure, the number of covariance parameters to be estimated is reduced and the components of resulting covariance matrices provide a meaningful interpretation. We propose three different frameworks for parameter estimation - a Markov chain Monte Carlo based approach, a variational Gaussian approximation-based approach, and a hybrid approach. The models are applied to both real and simulated data, and we demonstrate that the proposed approaches can recover the underlying cluster structure. In simulation studies where the true model parameters are known, our proposed approach shows good parameter recovery.

OSVALDO ESPIN GARCIA, Western University
[Monday December 5 / lundi 5 décembre, 15:30 – Rosetti C]
Using genetic algorithms in the design of two-phase studies

The two-phase study is a cost-effective way to leverage available information in phase 1 of the study to strategically select a most informative subset in phase 2. Expensive information is then collected in the phase 2 subset only, reducing the overall cost. Last, information from both study phases is jointly analyzed by performing statistical inference. Two-phase studies provide a desirable trade-off by economically and strategically using limited resources such as budget without compromising statistical performance by leveraging missing-by-design data methods. A main challenge lies in identifying such an informative subset, which can rely on both outcome and (inexpensive) phase 1 covariates. Genetic algorithms (GAs) are stochastic optimization techniques that mimic nature's evolutionary process. Often used in discrete optimization, GAs offer wide flexibility and ease of implementation. However, these advantages also come with some obstacles, for instance lack of a unique solution and unclear converge criteria are two of the main critiques of these approaches. In this talk, I will present my work on using a GA to identify an informative sample for two-phase fine-mapping studies. I will discuss some of the mathematical and computational challenges found as well as potential future work.

JESSE GRONSBELL, University of Toronto
[Monday December 5 / lundi 5 décembre, 9:30 – Rosetti C]
Leveraging electronic health records for data science

The adoption of electronic health records (EHRs) has generated massive amounts of routinely collected medical data with potential to improve our understanding of healthcare delivery and disease processes. However, the analysis of EHR data remains both practically and methodologically challenging as it is recorded as a byproduct of clinical care and billing, and not for research purposes. For example, outcome information, such as presence of a disease or treatment response, is often missing or poorly annotated in patient records, which brings challenges to statistical learning and inference. In this talk, I will discuss predictive modeling in settings with an extremely limited amount of outcome information and demonstrate the advantages of semi-supervised learning methods that incorporate large volumes of unlabeled data into model estimation and evaluation.
The Angle Process in Deep Neural Networks and the Bessel Numbers of the Second Kind

A mysterious property of deep neural networks is that, on initialization, the inputs tend to get more and more correlated as the network gets deeper and deeper. In this talk, we investigate fully connected networks with the ReLU non-linearity, and we discover how the angle between any two inputs evolves as a function of network depth. The formula involves the joint moments of the ReLU function applied to Gaussian random variables. We take a combinatorial approach to explicitly solve for these joint moments and doing so reveals a surprising connection to the Bessel numbers of the second kind. We are able to accurately predict the joint distribution of each layer on initialization given only the inputs into the network. The formula becomes more exact as the width of each layer tends to infinity. Both the mathematical theory behind the formula as well as simulations to validate our results are presented.

The isotonic single index model under fixed and random designs

To quote L. Wasserman, probability theory asks "Given a data generation process, what are the properties of the outcomes?", while statistics ask "Given the outcomes, what can we say about the process that generated the data?", where the latter question can be viewed as solving an inverse problem.

In the first part of the talk I will motivate shape-constrained methods of estimation in the context of solving the inverse problem while striking a balance between robustness (bias) and efficiency (variance), the two key sources of error in statistical estimation. I will then discuss some recent results on the monotone single index model, a dimension reduction model. This is joint work with Fadoua Balabdaoui (ETHZ) and Cecile Durot (Paris X).

In the monotone single index model a real response variable $Y$ is linked to a multivariate covariate $X$ through the relationship $E[Y|X=x] = f_0(\alpha_0^T x)$ almost surely. Both the ridge function, $f_0$, and the index parameter, $\alpha_0$, are unknown and the ridge function is assumed to be monotone. Under random design, we show that the rate of convergence of the estimator of the bundled function $f_0(\alpha_0^T x)$ is $n^{-1/3}$. For the fixed design setting, we show that the rate of convergence is parametric, as expected. Throughout the talk I will illustrate the methodology on several real data sets.

Large graph limit for an epidemic evolution process in random network with heterogeneous age, variant and connectivity

We consider a stochastic epidemic model on a random network in which each node corresponds to an individual, and each individual is classed as either Susceptible, Infectious, or Recovered ("SIR"). While the nodes are fixed, the edges evolve randomly. Volz [1] used popular heuristics to derive corresponding deterministic ordinary differential equations as the population size goes to infinity, following the work of Newmann [2]. Later, Decreusefond [3] proved weak convergence to this ODE system in the large-population limit. In this talk, we will present a similar convergence result for a more general model including a “Death” state (compartment) together with some additional variables: degree, age and disease variant. Of particular interest, the continuous nature of the age and variant variables leads to a limiting system of partial differential equations (PDEs) in place of the ODEs considered by earlier authors. In order to prove weak convergence, a rescaled process is used, and the infinitesimal generator and the martingal properties are provided. Finally, we propose several numerical simulations in order to illustrate the convergence of compartment sizes for a large population, the distribution of age variable and the evolution of waves of the disease using the variant variable.
In this talk, I'll summarize recent work exploiting tools in mathematical logic to resolve longstanding open problems in statistical decision theory. I'll focus on an exact characterization of admissibility in terms of Bayes optimality in the nonstandard extension of the original decision problem, as introduced by Duanmu and Roy (Ann. Statist. 49(4): DOI:10.1214/20-AOS2026). Unlike the consideration of improper priors or other generalized notions of Bayes optimality, the nonstandard extension is distinguished, in part, by having priors that can assign "infinitesimal" mass in a sense that is made rigorous using results from nonstandard analysis. With these additional priors, we find that, informally speaking, a decision procedure $\delta_0$ is admissible in the original statistical decision problem if and only if, in the nonstandard extension, the nonstandard extension of $\delta_0$ is Bayes optimal among the extensions of standard decision procedures with respect to a nonstandard prior assigning at least infinitesimal mass to every standard parameter value. We use this theorem to give further characterizations of admissibility, one related to Blyth’s method and another related to a condition due to Stein that characterizes admissibility under regularity. Our results imply that Blyth’s method is a sound and complete method for establishing admissibility. Buoyed by this result, we revisit the univariate two-sample common-mean problem, and show that the Graybill–Deal estimator is admissible among a certain class of unbiased decision procedures.

Joint work with Haosui Duanmu and David Schrittesser.

Parameter inference for ordinary differential equations (ODEs) involves the evaluation of the likelihood function for each ODE solution. While this solution is typically approximated by deterministic algorithms, new research indicates that probabilistic solvers produce more reliable estimates by better considerations of numerical errors. A particularly effective probabilistic method, Fenrir, uses Kalman filtering in an efficient manner to obtain the ODE solution. However, it is constrained by the assumption of normally distributed observed data. We extend this method by allowing for observations not necessarily normally distributed. Several examples are used to demonstrate the effectiveness of this approach.
Student Research Talks
Session de présentations des étudiants

Org: Alexander Clow and Daniel Zackon

Presentations will be given by students at the undergraduate and graduate levels. These will introduce the student’s research to a general mathematical audience. All research areas in pure/applied math, statistics, and math education will be considered.


Schedule/Horaire

Room/Salle: Carlyle B

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Abstracts/Résumés

**Pingping Cong**, Western University
[Monday December 5 / lundi 5 décembre, 8:00 – Carlyle B]
*Dynamics of a three-species food chain model with fear effect*

In this paper a three-species food chain model is formulated to investigate the impact of fear. First, we derive the predator’s functional response by using the classical Holling’s time budget argument and formulate a three-species food chain model where the cost and benefit of anti-predator behaviours are included. Then we study the dissipativity of the system and perform analysis on the existence and stability of equilibria. At last, we use numerical simulations to more visually explore the effects of fear on three species. The results show that the predator’s fear effect can transform the system from chaotic dynamics to a stable state. Our results may provide some useful biological insights into ecosystems containing predator-prey interactions.

**Jenny Lawson**, University of Calgary
[Monday December 5 / lundi 5 décembre, 9:00 – Carlyle B]
*Optimality and Sustainability of Delayed Impulsive Harvesting*

Optimal and sustainable management of natural resources requires knowledge about the behaviour of mathematical models of harvesting under many different types of conditions. In this talk, we will be investigating the sustainability and optimality of delayed impulsive harvesting. Impulses describe an instantaneous change in a system due to some external effect (like harvesting in a fishery), which has a duration that is negligible compared to the overall time scale of the process. These impulses can then be combined with differential equations (DEs) to form impulsive DEs.

Delays within harvesting can represent a dependency on information that is out of date. Since it is likely that most data used to make harvesting decisions will be at least somewhat out of date, including delays within impulsive conditions is a topic of current interest. A close connection to the dynamics of high-order difference equations is used to conclude that while the inclusion of a delay in the impulsive condition does not impact the optimality of the yield, sustainability may be highly affected and is once again delay-dependent. Maximum and other types of yields are explored, and sharp stability tests are obtained for...
the model. It is also shown that persistence of the solution is not guaranteed for all positive initial conditions, and extinction in finite time is possible, which provides a possible explanation for observed but unforeseen population collapses. Overall, the results imply that delays within harvesting should be kept short to maintain the sustainability of resources.

SUN-KAI LEUNG, Université de Montréal
[Monday December 5 / lundi 5 décembre, 9:30 – Carlyle B]

GUSTAVO CICCHINI SANTOS, Toronto Metropolitan University
Understanding Non-Equilibrium Steady States
Physical systems are characterized by their response to perturbations. The Fluctuation Dissipation Theorem predicts the behavior of systems in equilibrium. Can an expression be derived using methods from quantum field theory to describe the vertex response to a perturbation, and is the Fluctuation Dissipation Theorem modified as a result of these perturbations. Using Berezin integration and properties of determinants we derive said expression. The derivation yields the same result as the less rigorous methods. We learn the Fluctuation Dissipation Theorem has an equilibrium-like response to a vertex perturbation making the Fluctuation Dissipation theorem a bad indicator of whether a system is in equilibrium or out of equilibrium.

SILAS VRIEND, McMaster University
[Monday December 5 / lundi 5 décembre, 10:00 – Carlyle B]
Infinite bubbles: a planar isoperimetric problem with two unbounded chambers
The dual of the classical isoperimetric problem asks which planar curve (if any) minimizes perimeter among all curves enclosing a fixed area A. The answer, perhaps unsurprisingly, is a circle. The resultant geometric figure consists of one compact chamber (the interior of the circle) and one unbounded chamber (the exterior of the circle). In this talk, we consider the generalization to more than one unbounded chamber. Furthermore, we present a classical variational solution to a simplified version of the following problem: given a fixed area A to enclose, which (if any) is the locally perimeter-minimizing configuration among all partitions of the plane into one compact chamber and two unbounded chambers?
Topics in Mathematical Biology: Theory, Applications and Future Perspectives
Thèmes en biologie mathématique : Théorie, applications et perspectives futures

Org: Kunquan Lan (TMU), Gunog Seo (Colgate University) and Gail S. K. Wolkowicz (McMaster)

Mathematical Biology is the application of mathematics to biological systems and is one of the fastest-growing interdisciplinary areas in applied mathematics. It is a qualitative and quantitative study of a mathematical model to describe many biological phenomena. This session aims to discuss recent developments and future directions in various topics of Mathematical Biology, emphasizing analytical and numerical approaches and applications.

La biologie mathématique est l’application des mathématiques aux systèmes biologiques et constitue l’un des domaines interdisciplinaires des mathématiques appliquées qui connaît la croissance la plus rapide. Il s’agit d’une étude qualitative et quantitative d’un modèle mathématique pour décrire de nombreux phénomènes biologiques. Cette session vise à discuter des développements récents et des orientations futures dans divers domaines de la biologie mathématique, en mettant l’accent sur les approches analytiques et numériques et les applications.

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2022 CMS WINTER MEETING | RÉUNION D’HIVER 2022 DE LA SMC
Abstracts/Résumés

STEPHANIE ABO, University of Waterloo
[Saturday December 3 / samedi 3 décembre, 17:30 – Churchill Ballroom]

*Can the clocks tick together despite the noise? Stochastic simulations and analysis*

The suprachiasmatic nucleus (SCN), also known as the circadian master clock, consists of a large population of oscillator neurons. Together, these neurons produce a coherent signal that drives the body’s circadian rhythms. What properties of the cell-to-cell communication allow the synchronization of these neurons, despite a wide range of environmental challenges such as fluctuations in photoperiods? To answer that question, we present a mean-field description of globally coupled neurons modeled as Goodwin oscillators with standard Gaussian noise. Provided that the initial conditions of all neurons are independent and identically distributed, any finite number of neurons becomes independent and has the same probability distribution in the mean-field limit, a phenomenon called propagation of chaos. This probability distribution is a solution to a Vlasov-Fokker-Planck type equation, which can be obtained from the stochastic particle model. We study, using the macroscopic description, how the interaction between external noise and intercellular coupling affects the dynamics of the collective rhythm, and we provide a numerical description of the bifurcations resulting from the noise-induced transitions. Our numerical simulations show a noise-induced rhythm generation at low noise intensities, while the SCN clock is arrhythmic in the high noise setting. Notably, coupling induces resonance-like behavior at low noise intensities, and varying coupling strength can cause period locking and variance dissipation even in the presence of noise.

JULIEN ARINO, University of Manitoba
[Saturday December 3 / samedi 3 décembre, 9:00 – Churchill Ballroom]

*Backward bifurcation in an SLIARS model with vaccination*

Backward bifurcations are known to occur in a variety of epidemic models when treatment or vaccination are taken into account. In a backward bifurcation situation, there can exist subthreshold endemic equilibria, leading to a bistable situation where the
behaviour of the system is initial conditions-dependent. The situation is easy to characterise in a deterministic setting, but more complicated in a stochastic one. To investigate this, we considered an endemic (i.e., including demography) SLIARS model for a disease presenting symptomatic and asymptomatic stages, to which we added vaccination. We showed that the deterministic version of the model can undergo backward bifurcations. We then studied numerically the equivalent (stochastic) continuous-time Markov chain and observed that a backward bifurcation was observable also in this context. Interestingly, a branching process approximation of the stochastic process was unable to pick up the same characteristic. This is joint work with Evan Milliken (U of Louisville).

MARYAM BASIRI, University of Ottawa

Traveling wave solutions for a free boundary problem modeling spread of ecosystem engineers

Ecosystem engineers are species that modify their environment to make it (more) suitable for them. Beavers are a well-known engineering species. We present a novel model for the spread of ecosystem engineers as a free boundary problem: ahead of the front, the habitat is unsuitable for the species, and behind the front, the habitat is suitable. The engineering action of the population moves the boundary ahead. We derive a semilinear parabolic equation from an individual random walk model. The condition for the moving boundary is a biologically derived two-sided condition that models the movement behavior of individuals at the boundary as well as the process by which the population moves the boundary to expand their territory.

We study the model with the Allee growth function and prove the existence of traveling wave solutions of different types. Then we will determine how model parameters affect the ability of an ecosystem engineer species to invade new environments and the speed at which such an invasion occurs.

ELENA BRAVERMAN, University of Calgary

On stability and asymptotics of equations and systems of population dynamics with concentrated and distributed delays

Many differential equations of mathematical biology assume delayed production process and the instantaneous mortality. It is well known that introduction of delay can destroy stability of the unique positive equilibrium and even lead to chaos. However, for some types of equations and systems, lags in the reproduction term do not change stability properties. Consideration of variable, unbounded and distributed delays emphasizes robustness of this ‘absolute stability’ property.

Some interesting phenomena are observed in equations of population dynamics when the production part includes two different delays. We also consider Hutchinson and Mackey-Glass equations a controlled with a term whose variable coefficient can change its sign.

ROBERT STEPHEN CANTRELL, University of Miami

A two-stage reaction-diffusion system

It is well known that in reaction-diffusion models for a single unstructured population in a bounded, static, heterogeneous environment, slower diffusion is advantageous. That is not necessarily the case for stage structured populations. In earlier work, Cantrell, Cosner and Martinez showed that in a stage structured model introduced by Brown and Lin, there can be situations where faster diffusion is advantageous. In this paper we extend and refine these results on persistence to more general combinations of diffusion rates and to cases where either adults or juveniles do not move. We also obtain results on the asymptotic behavior of solution as diffusion rates go to zero, and on competition between species that differ in their diffusion rates but are otherwise ecologically identical. We find that when the spatial distributions of favorable habitats for adults and juveniles are similar, slow diffusion is still generally advantageous, but if those distributions are different that may no longer be the case. This talk is based on joint work with Chris Cosner and Rachidi Salako.
Topics in Mathematical Biology: Theory, Applications and Future Perspectives
Thèmes en biologie mathématique : Théorie, applications et perspectives futures

YUMING CHEN, Wilfrid Laurier University
[Sunday December 4 / dimanche 4 décembre, 9:00 – Churchill Ballroom]
Threshold dynamics of a viral infection model with defectively infected cells

In this talk, we consider a viral infection model with defectively infected cells. We show that the basic reproduction number serves as a threshold parameter. When the basic reproduction number is less than or equal to unity, the infection-free equilibrium is globally asymptotically stable; when it is larger than unity, the infection equilibrium is globally asymptotically stable. The stability is established by Lyapunov’s direct method. Here we provide a procedure to determine whether the derivative of a given type of Lyapunov function candidate is negative (semi-)definite or not.

TIANYU CHENG, University of Western Ontario
[Sunday December 4 / dimanche 4 décembre, 18:00 – Churchill Ballroom]
A new perspective on infection forces with demonstration by a DDE infectious disease model

In this work, we revisit the notion of infection force from a new angle which can offer a new perspective to motivate and justify some infection force functions. Our approach can not only explain many existing infection force functions in the literature, it can also motivate new forms of infection force functions, particularly infection forces depending on disease surveillance of the past. As a demonstration, we propose a SIRS model with delay. We comprehensively investigate the disease dynamics represented by this model, particularly focusing on the local bifurcation caused by the delay and another parameter that reflects the weight of the past epidemics in the infection force. We confirm Hopf bifurcations both theoretically and numerically. The results show that, depending on how recent the disease surveillance data are, their assigned weight may have a different impact on disease control measures.

MONICA COJOCARU, University of Guelph
[Saturday December 3 / samedi 3 décembre, 15:00 – Churchill Ballroom]
Individual risk and discomfort perceptions, NPI policies and the evolution of the pandemic in Ontario 2020

In this work, we provide a granular view of factors affecting COVID-19 disease transmission across Ontario, Canada and the 34 public health units composing it. We estimate the perceived risk of infection and perceived personal discomfort of complying with non-pharmaceutical interventions (NPIs) in each PH region. With the use of dynamic programming and a simple NASH game model, we estimate the expected NPI adoption proportion across Ontario from March to December 2020. Finally, we use an SEIRL compartmental model for Ontario to study the interplay between the estimated NPI adoption from the game and the actual evolution of the infection. Finally, we explore the limitations of our work, discuss the success of our computations and highlight possible avenues of further refinement. This is joint work with: Sarah Smook (U. Guelph), David Lyver (U. Guelph) and Edward W. Thommes (U. Guelph)

TROY DAY, Queen’s University
[Saturday December 3 / samedi 3 décembre, 10:00 – Churchill Ballroom]
The Epidemiology and Economics of Physical Distancing during Infectious Disease Outbreaks

People’s incentives during an infectious disease outbreak influence their behaviour, and this behaviour can impact how the outbreak unfolds. Early on during an outbreak, people are at little personal risk of infection and hence may be unwilling to change their lifestyle to slow the spread of disease. As the number of cases grows people may then voluntarily take extreme measures to limit their exposure. Political leaders also respond to the welfare and changing desires of their constituents. In this talk I will use ideas from the study of differential games to model how individuals’ and politicians’ incentives change during an outbreak. Motivated by the COVID-19 pandemic, I focus on physical distancing behaviour and the imposition of stay-at-home orders. I show that the dynamic game being played in the population and its consequences are very different depending on the degree of asymptomatic transmission.
This is joint work with David McAdams, Fuqua School of Business and Economics Department, Duke University.

HERMANN EBERL, University of Guelph
[Saturday December 3 / samedi 3 décembre, 14:30 – Churchill Ballroom]
*

Chaos in the Hive and Beyond: A Multiscale Model of Nosemosis in an Apiary

Recent years have seen the emergence of many generic or specific models for the dynamics of honeybee diseases. The vast majority of these studies consider a single hive only. We present and discuss an eco-epidemiological multiscale model of the transmission of Nosemosis in an apiary. For the transmission of the disease on the apiary level, i.e. between hives, we develop a mathematical model of drifting, i.e. “the change of residence of bees from one hive to another” (as Corkins put it in 1932). For the transmission of the disease within a colony, we consider two routes, a direct and an indirect one. This extends our previous work on Nosemosis to the metapopulation setting. It leads to a system of 5N nonautonomous ODEs, where N is the number of colonies considered. We explore the model numerically. The main finding is that the apiary level dynamics of the disease can be greatly different (highly irregular chaos vs periodic), depending on which of the two within-hive transmission routes dominates. This is joint work with Nasim Muhammad.

SAMUEL MATTHIAS FISCHER, Osnabrück University & Helmholtz Centre for Environmental Research – UFZ
[Saturday December 3 / samedi 3 décembre, 16:30 – Churchill Ballroom]

KDE-likelihood: a tool for fitting stochastic dynamic models to equilibrium data

Stochastic dynamic models are a valuable tool to study the spatial distribution of species and estimate their responses to disturbances and environmental changes. However, fitting such models to observational data can be challenging, because their complexity typically hinders direct application of classical statistical tools such as the likelihood. Hence, modellers often examine the parameter space by applying sampling-based methods (e.g. approximate Bayesian computation, ABC), or they consider aggregated results whose distribution may be approximated via the central limit theorem. However, if the considered species distributions are assumed to be in equilibrium state, reaching these states in simulations requires long runs, making methods such as ABC difficult to apply. At the same time, aggregating results may lead to information loss that could result in identifiability issues corrupting the reliability of the parameter estimates. In this talk, we suggest the kernel-density-estimate-based (KDE-) likelihood as a tool circumventing these issues. The KDE-likelihood allows modellers to exploit the favourable statistical properties of the likelihood function without deriving it in closed form. We showcase the method’s advantages in real applications by modelling the distribution of trees in a temperate Chinese forest using the process-based model Formind.

FRÉDÉRIC HAMELIN, Institut Agro
[Sunday December 4 / dimanche 4 décembre, 16:00 – Churchill Ballroom]

The proportion of resistant hosts in mixtures should be biased towards the resistance with the lowest breaking cost

Current agricultural practices facilitate emergence and spread of plant diseases through the wide use of monocultures. Host mixtures are a promising alternative for sustainable plant disease control. Their effectiveness can be partly explained by priming-induced cross-protection among plants. Priming occurs when plants are challenged with non-infective pathogen genotypes, resulting in increased resistance to subsequent infections by infective pathogen genotypes. We developed an epidemiological model to explore how mixing two distinct resistant varieties can reduce disease prevalence. We considered a pathogen population composed of three genotypes infecting either one or both varieties. We found that host mixtures should not contain an equal proportion of resistant plants, but a biased ratio (80 : 20) to minimize disease prevalence. Counter-intuitively, the optimal ratio of resistant varieties should be biased against the costliest resistance for the pathogen to break. This benefit is amplified by priming. This strategy also prevents the invasion of pathogens breaking all resistances.

This is joint work with Pauline Clin, Frédéric Grognard, Didier Andrivon, and Ludovic Mailleret.
CHRISTOPHER M HEGGERUD, UC Davis
[Sunday December 4 / dimanche 4 décembre, 16:30 – Churchill Ballroom]

Mathematical comparison and empirical review of the Monod and Droop forms for resource-based population dynamics

Almost all biological models use either the Droop or Monod form to describe the resource-based growth of a living organism. Empirical evidence overwhelmingly suggests the Droop form describes data more accurately than the Monod form, however, the Monod form is more popular due to its simplicity. Focusing on phytoplankton, we illustrate the underlying logics behind these two forms via conceptual comparison, experimental data validation, transient, and asymptotic dynamics. The conceptual illustration provides the primary difference in their mechanisms via a paradox. Data validation is tested via field and laboratory experiments. The Droop and Monod forms have consistent asymptotic dynamics in the closed nutrient case, whereas the transient dynamics are significantly different when the nutrient uptake rate is small.

YU JIN, University of Nebraska-Lincoln
[Sunday December 4 / dimanche 4 décembre, 8:30 – Churchill Ballroom]

Population dynamics in a habitat with a protection zone

Protecting native species or endangered species has been an important issue in ecology. We derive a reaction-diffusion model for a population in a one-dimensional bounded habitat, where the population is subjected to a strong Allee effect in its natural domain but obeys a logistic growth in a protection zone. We establish threshold conditions for population persistence and extinction via the principal eigenvalue of an associated eigenvalue problem. We then obtain the influences of the protection zone on the long-term population dynamics under different boundary conditions and propose strategies for designing the optimal location of the protection zone in order for the population to persist in the long run.

LAURENCE KETCHEMEN, University of Ottawa
[Sunday December 4 / dimanche 4 décembre, 17:30 – Churchill Ballroom]

Populations dynamics in fragmented landscapes under monostable and bistable growth dynamics

Many biological populations reside in increasingly fragmented landscapes, where habitat quality may change abruptly in space. A reaction-diffusion model for a single species which grows and disperses in a one-dimensional heterogeneous landscape is presented. The landscape is composed of two homogeneous adjacent patches with different diffusivities and net growth functions (monostable and bistable). An interface condition connects population density and flux between the two patches. We first classify all possible positive steady states using a phase plane approach. We continue by analyzing the stability properties of certain simple possible positive steady states. We end by applying bifurcations theory. Numerical simulations reveal fold bifurcations.

RONGSONG LIU, University of Wyoming
[Saturday December 3 / samedi 3 décembre, 16:00 – Churchill Ballroom]

An Age-structured Model of Bird Migration

An approach to modelling bird migration is proposed, in which there is a region where birds do not move but spend time breeding. Birds leave this breeding region and enter a migration flyway which is effectively a one-way corridor starting and ending at the breeding location. Mathematically, the flyway is a curve parametrised by arc-length. Flight speed depends on position along the flyway, to take account of factors such as wind and the pausing of birds at various locations for wintering or stopovers. Per-capita mortality along the flyway is both position and age-dependent, allowing for increased risks at stopover locations due to predation, and increased risks to immature birds. A reaction-advection age-structured equation models population dynamics along the flyway and, using a Laplace transform technique, the model is reduced to a scalar delay differential equation for the number of adult birds at the breeding location. Extinction and persistence criteria are obtained for the bird population and the results of computer simulations are presented.
Multi-group flocking control of multi-agent systems

As a fascinating collective behavior, flocking is observed in a variety of biological species such as beasts, birds, fish, bees, and ants. In such situations, each individual acts as an autonomous agent and interacts only with its nearby neighbors, while the entire group displays coordinated behavior and can accomplish very complex tasks. Inspired by such collective intelligence of animal groups in nature, there has been an increased research interest in flocking control of multi-agent systems around the world in recent years. This talk discusses the flocking control problem of multi-agent systems with multi-group tracking various virtual leaders. Hybrid protocols are proposed to take into consideration of continuous communications among agents and intermittent information exchanges at a sequence of discrete times. It is shown, by employing results from graph theory and dynamical systems, that agents may be divided into multiple subgroups to follow different leaders while maintaining desired sub-formation configurations as well as collision-free motions.

Dynamics of Diffusive Lotka-Volterra competition systems in a shifting environment

We studied the existence, uniqueness and stability of forced traveling waves for the Lotka-Volterra competition system in a shifting habitat. Based on the asymptotic behaviors of the wave profiles and by means of upper-lower solution method coupled with sliding technique, we showed that the forced wave for the system exists and is unique, when the forced speed lies in a specific interval. Explicit expressions of the two end points of this interval were derived and our finding indicated that they are related to the Fisher-KPP-type invasion speed. Furthermore, we established a squeezing theorem to show the local stability of the forced waves. With the aid of comparison principle and Xinfu Chen’s idea (1997), we established the global stability of the forced waves when the initial data were properly assigned. Finally, a gap formation between two species were studied when forced traveling wave doesn’t exist.

Noise-induced transient dynamics

Many complex processes exhibit transient dynamics - intriguing or important dynamical behaviors over a relatively long but finite time period. A fundamental issue is to understand transient dynamics of different mechanisms. In this talk, we focus on a class of randomly perturbed processes arising in population dynamics where species only persist over finite time periods and go to extinction in the long run. To capture such transient persistent dynamics, we use quasi-stationary distributions (QSDs) and study their noise-vanishing asymptotic. Special attention will be paid to essential differences between models with and without environmental noises. The talk ends up with some discussions.

Imperfect and Bogdanov-Takens Bifurcations in Biological Models: From Harvesting of Species to Removal of Infectives

The bifurcation induced by small perturbations of a system (on already existed bifurcations) that leads to more complex bifurcations simplifying into separate saddle and node equilibrium points is called an imperfect (perturbed) bifurcation. In this paper, we examine two types of biological models that Fred Brauer made pioneer contributions: predator-prey models with stocking/harvesting and epidemic models with immigration/isolation. First we consider a predator-prey model with Holling type II functional response whose dynamics and bifurcation are well-understood. We will show that introducing constant
stocking/harvesting of predators induces imperfect bifurcation: For the case with stocking, the model has one positive equilibrium and one negative equilibrium when stocking constant increases from zero. For the case of harvesting, the model has none, one, or two positive equilibria when harvesting constant varies; then we explain that the unique positive equilibrium is a cusp of codimension 2 and the model undergoes Bogdanov-Takens bifurcation. We also consider an epidemic model with constant importation/isolation of infective individuals and observe similar imperfect and Bogdanov-Takens bifurcations when the constant perturbation rate varies. (Based on a joint work with Dongmei Xiao).

ZHONGWEI SHEN, University of Alberta
[Monday December 5 / lundi 5 décembre, 10:00 – Churchill Ballroom]
Coexistence in random environments

We study the evolution of a community modelled by systems of stochastic differential equations with demographic noises, which exhibit coexistence dynamics only over finite periods. To capture such coexistence dynamics, we study the solution process before one species goes extinct and use quasi-stationary distributions (QSDs) to capture dynamical states governing the coexistence. In this talk, I will report some ideas and recent progress about dynamical properties of QSDs.

SABRINA H. STREIPERT, University of Pittsburgh
[Saturday December 3 / samedi 3 décembre, 8:30 – Churchill Ballroom]
Introduction and Application of the Augmented Phase Portrait

We introduce the next-iterate operators and corresponding next-iterate root-sets and root-curves associated with the nullclines of discrete planar systems. The signs of these next-iterate operators are used to augment the standard phase portrait that
includes the direction field and the nullclines, to determine whether a point is mapped above or below the corresponding nullcline. This method identifies positively invariant regions and regions that can give rise to periodic solutions. The construction of the augmented phase portrait is demonstrated using an example of a rational planar map that arises in population modeling. We show that the augmented phase portrait can provide an elementary, alternative approach for determining the global dynamics of this model. The potential and limitations of the augmented phase portrait are explored using several examples that have applications in population dynamics, epidemiology, and delay difference equations.

Hao Wang, University of Alberta
[Monday December 5 / lundi 5 décembre, 8:30 – Churchill Ballroom]
Cognitive Animal Movement Modelling

Based on our recent efforts in spatial memory modelling and analysis for cognitive animal movement, I will briefly review this topic and mention challenges in modelling and rigorous analysis. Some showcases will be given as idea illustrations.

Xiaoqiang Zhao, Memorial University of Newfoundland
[Sunday December 4 / dimanche 4 décembre, 10:00 – Churchill Ballroom]
Spatial Dynamics of Species with Annually Synchronized Emergence of Adults

In this talk, I will report our recent research on the spatial dynamics of species growth with annually synchronous emergence of adults by formulating an impulsive reaction-diffusion model. With the aid of the discrete-time semiflow generated by the one-year solution map, we establish the existence of the spreading speed and traveling waves for the model on an unbounded spatial domain. It turns out that the spreading speed coincides with the minimal speed of traveling waves, regardless of the monotonicity of the birth rate function. We also investigate the model on a bounded domain with a lethal exterior to determine the critical domain size to reserve species persistence. Numerical simulations are illustrated to confirm the analytical results and to explore the effects of the emergence maturation delay on the spatial dynamics of the population distribution. In particular, the relationship between the spreading speed and the emergence maturation delay is found to be counterintuitively variable.

HuaiPing Zhu, York University
[Monday December 5 / lundi 5 décembre, 8:00 – Churchill Ballroom]
Topological Methods in Model Theory  
Méthodes topologiques en théorie des modèles

Org: Chris Eagle (University of Victoria) and/et Franklin Tall (Toronto)

From its inception model theory has had interesting interactions with general topology, and some of the most striking results in model theory have deep ties to topology. In recent years there has been a great deal of progress in using more sophisticated tools from topology in model theory and the scope of application has broadened from first-order logic to include many other parts of model theory. This session will bring together researchers working in areas of where interactions between model theory and topology play a significant role.

Depuis ses débuts, la théorie des modèles a eu des interactions intéressantes avec la topologie générale, et certains des résultats les plus frappants de la théorie des modèles sont profondément liés à la topologie. Ces dernières années, de nombreux progrès ont été réalisés dans l’utilisation d’outils plus sophistiqués de la topologie dans la théorie des modèles et le champ d’application s’est élargi de la logique du premier ordre pour inclure de nombreuses autres parties de la théorie des modèles. Cette session réunira des chercheurs travaillant dans des domaines où les interactions entre la théorie des modèles et la topologie jouent un rôle important.

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Abstracts/Résumés

LEONARDO COREGLIANO, Institute for Advanced Study
[Sunday December 4 / dimanche 4 décembre, 16:30 – Wren B]

Continuous combinatorics and natural quasirandomness

The theory of graph quasirandomness studies graphs that "look like" samples of the Erdős–Rényi random graph $G_{n,p}$. More formally, a sequence $(G_n)_n$ is said to be quasirandom if for every finite graph $F$, the densities of $F$ in $G_n$ and in $G_{n,p}$, respectively, converge to the same number (with probability 1). This notion of similarity naturally gives rise to a topology, called density topology, on the space of graphs and is the starting point of the theory of graph limits, graphons.

In turn, the theory of graphons is the starting point of continuous combinatorics, which studies limits of arbitrary combinatorial objects (formally, models of some universal first-order theory in a finite relational language) in the analogous density topology. Thus, it is natural to ask if a theory of quasirandomness can be developed in the same level of generality.

In this talk, I will introduce the theory of natural quasirandomness, which provides such generalization. Although the theory heavily uses the language of continuous combinatorics, no familiarity with the topic is required as I will also briefly introduce its basic concepts.

This talk is based on joint work with Alexander A. Razborov.
EDUARDO DUENEZ, University of Texas at San Antonio

[Sunday December 4 / dimanche 4 décembre, 9:30 – Wren B]

Structures of random variables and stability of Orlicz spaces

Describing spaces of random variables on a probability space \((\Omega, \mathbb{P})\) as first-order real-valued structures is customarily done imposing an \textit{a priori} restriction to bounded variables in \([0, 1]\) (say) or else by generally treating any such space as an \(\mathbb{R}\)-valued first-order structure (in the language of nonstandard analysis). We introduce classes of \textit{real}-valued structures that faithfully capture the essence of the classical function spaces \(L^p(\Omega)\) and the Orlicz spaces \(L^\phi(\Omega)\) (with values in \(\mathbb{R}\) or in some Banach space \((X, \|\cdot\|)\)). This perspective casts new light on some foundation aspects of measure theory (e.g., Radon-Nykodim decompositions and the Riesz Representation Theorem) and allows for simple proofs of classical results, including the stability of \(L^p\) and of \(L^\phi\) (when \(\phi\) satisfies a \("\Delta_2\)-condition" and the Banach space \(X\) is itself stable).

ISAAC GOLDBRING, University of California, Irvine

[Sunday December 4 / dimanche 4 décembre, 15:30 – Wren B]

An application of infinitely generic structures to von Neumann algebras

Inspired by Cohen’s advent of forcing in set theory, Robinson defined two kinds of model-theoretic forcing, so-called finite forcing and infinite forcing. While intensely studied in the 1970s, the study of the structures arising from these forcing constructions has since become largely ignored. In this talk, I will talk about a recent application of infinite forcing (adapted to the setting of continuous model theory), making progress on a conjecture of Popa in the field of von Neumann algebras. Time permitting, I will talk about extensions of this result to Chifan, Drimbe, and Ioana and also due to myself with Jekel, Kunnawalkam Elayavalli, and Pi.

NICOLAS CHAVARRIA GOMEZ, University of Notre Dame

[Sunday December 4 / dimanche 4 décembre, 16:00 – Wren B]

Pontryagin duality and continuous logic

I will present the Bohr compactification of a topological abelian group as a type space in the sense of continuous model theory. I first show that this type space is the Pontryagin dual of a certain group. In this manner, Pontryagin duality comes into the picture. This can then be extended to more general topological structures.

CLOVIS HAMEL, University of Toronto

[Sunday December 4 / dimanche 4 décembre, 10:00 – Wren B]

Topological Function Spaces, Double Ultralimits and Definability

We explore applications of \(C_p\)-theory, Grothendieck spaces and countable tightness in Model Theory and Analysis. In particular, we will discuss Gowers’ problem, which asks if the Tsirelson space or, more generally, if Banach spaces not including isomorphic copies of \(l^p\) or \(c_0\) are definable. Casazza, Dueñez and Iovino’s work negatively answers Gowers’ problem in first-order (in fact, continuous) logic. However, one could argue that this logic lacks enough expressive power for the analyst’s \(\varepsilon\)-play. We use techniques from \(C_p\)-theory and work with conditions concerning the interchangeability of double (ultra)limits in order to generalize the aforementioned undefinability results far beyond first-order logic, for example to infinitary logics such as countable fragments of continuous \(L_{\omega_1,\omega}\), which have non-compact spaces associated to them.

JOSE IOVINO, The University of Texas at San Antonio

[Sunday December 4 / dimanche 4 décembre, 9:00 – Wren B]

The undefinability of Tsirelson’s space
The Tsirelson space has been called "the first truly nonclassical Banach space". Immediately after space was introduced, the question arose of whether this space is "finitely definable". I will present a survey of recent results. This talk may serve as a preamble to the talk given by Eduardo Dueñez, where further refinements will be mentioned.

MIGUEL MORENO, University of Vienna

Finding the main gap in the generalised descriptive set theory

Shelah's main gap theorem gives us a notion of complexity, a theory is more complex when this one has more non-isomorphic models. In generalised descriptive set theory (GDST) the complexity of a theory is given by the complexity of the isomorphism relation. One of the most important questions in GDST is whether the complexity notion from GDST is a refinement of the model theory complexity notion. In this talk we will review the progress made in this question. We will see how Shelah's division lines (classifiable shallow, classifiable, unstable, stable unsuperstable, superstable with DOP, superstable with DOP) are related to different notions in GDST such as Borel set, analytical co-analitical sets, Borel* sets, complete analytical sets, Borel reducibility.

ANAND PILLAY, University of Notre Dame

Topological dynamics and model theory

I will discuss some use of topological dynamical methods in model theory, as well as applications to the structure of approximate subgroups.
"Asymptotic behavior has been the longstanding focus in population dynamics. However, understanding the long-term dynamics alone is not sufficient because many ecological processes run on shorter timescale. For example, a catastrophic event such as a flooding or hurricane can be viewed as a perturbation of an otherwise stable ecosystem. The recovery of the ecosystem to its original state runs on a transient time scale. In human society, an emerging infectious disease usually persists over a short period compared to the time scale of vital dynamics. Therefore, studying the transient behaviors in population dynamics has important implications for ecosystem management and the implementation of disease intervention strategies. The study of mathematical aspects of transient dynamics has been growing in recent years. The results include characterization of an ecosystem’s response to a perturbation under different norms, identification of the underlying mechanisms of long transients, and transient behaviors in various models that are subject to spatial-temporal heterogeneity. This session aims to bring researchers who have experience working on transient dynamics together to communicate and advocate future endeavors in investigating the transients. Also, such a session may hopefully stimulate and initiate possible collaborations on the theme and related topics."

"Le comportement asymptotique est depuis longtemps le point de mire de la dynamique des populations. Cependant, la compréhension de la dynamique à long terme ne suffit pas car de nombreux processus écologiques se déroulent sur des échelles de temps plus courtes. Par exemple, un événement catastrophique tel qu’une inondation ou un ouragan peut être considéré comme une perturbation d’un écosystème autrement stable. Le rétablissement de l’écosystème dans son état initial s’effectue sur une échelle de temps transitoire. Dans la société humaine, une maladie infectieuse émergente persiste généralement sur une courte période en comparaison avec à l’échelle de temps de la dynamique vitale. Par conséquent, l’étude des comportements transitoires dans la dynamique des populations a des implications importantes pour la gestion des écosystèmes et la mise en œuvre de stratégies d’intervention contre les maladies. L’étude des aspects mathématiques de la dynamique transitoire s’est développée ces dernières années. Les résultats incluent la caractérisation de la réponse d’un écosystème à une perturbation sous différentes normes, l’identification des mécanismes sous-jacents des longs transitoires, et les comportements transitoires dans divers modèles soumis à l’hétérogénéité spatio-temporelle. Cette session vise à rassembler les chercheurs qui ont l’expérience du travail sur les dynamiques transitoires afin de communiquer et de préconiser des efforts futurs dans l’étude des transitoires. En outre, une telle session peut, nous l’espérons, stimuler et initier d’éventuelles collaborations sur ce thème et sur des sujets connexes."

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**Rooms/Salles: Duchesse, Gerrard**

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**Org: Felicia Magpantay (Queen’s), Xiaoying Wang (Trent) and Xingfu Zou (Western)**
Abstracts/Résumés

JACQUES BELAIR, Université de Montréal
[Sunday December 4 / dimanche 4 décembre, 17:00 – Duchesse]
Modelling the use of Fangcang shelter hospitals in Wuhan

Motivated by China’s experience of using Fangcang shelter hospitals (FSHs) to successfully combat the epidemic in its initial stages, we present a two-stage, functional differential delay model considering the average waiting time of patients’ admission to study the impact of hospital beds and centralized quarantine on mitigating and control of the outbreak. We compute the basic reproduction number in terms of the hospital resources, and perform a sensitivity analysis of the average waiting times of patients before admission to the hospitals. We discuss the rôle played by FSHs in mitigating and eventually curbing the epidemic.

SUE ANN CAMPBELL, University of Waterloo
[Sunday December 4 / dimanche 4 décembre, 16:00 – Duchesse]
Dynamics of a Diffusive Nutrient-Phytoplankton-Zooplankton Model with Spatio-Temporal Delay

We study a diffusive nutrient-phytoplankton-zooplankton (NPZ) model with spatio-temporal delay. The closed nature of the system allows the formulation of a conservation law of biomass that governs the ecosystem. We formulate stability conditions for the equilibria for a general distribution of delays and analyze the Hopf bifurcations for a specific delay kernel. We show that diffusion predominantly has a stabilizing effect. If sufficient nutrient is present, however, complex spatio-temporal dynamics, both transient and stable, may occur. This is joint work with Francis Poulin (University of Waterloo) and Yiwen Tao (Zhengzhou University).

DAVID EARN, McMaster University
[Duchesse]

AO LI, York University
[Sunday December 4 / dimanche 4 décembre, 17:30 – Duchesse]
Transient disease dynamics of some SIR models over patchy environments

This paper deals with the short-term or transient dynamics of some SIR infectious disease models over patchy environments. Employing the measurements of reactivity of equilibrium and amplification rates used in ecology to study the responses of an ecological system to perturbations to an equilibrium, we analyze the impact of dispersals/travels between patches, spatial heterogeneity and other disease-related parameters on the short-term dynamics of these spatial disease models. This is in contrast to most existing works on modelling the dynamics of infectious disease which are only interested in long-term disease dynamics in terms of the basic reproduction number.
 transient oscillations that are robust in a model for immune responses to viral infections

Oscillations are abundant in immune response dynamics. These oscillations are typically short-lived (transient) and reproducible upon repeated antigenic challenges (robust). Using a simple differential equations model for T cell responses to viral infections, I show how transient oscillations can be created as orbits near a normally hyperbolic periodic orbit. The normal hyperbolicity of the periodic orbit ensures the robustness of the observed transient oscillations.

properties of long transient dynamic and its applications

There has been growing interest in non-asymptotic behaviors of solutions that last for a very long time. Here we present a framework for the systematic mathematical treatment of long transient behaviors. We focus on transient centers, points near which long transient dynamics of arbitrary slowness and arbitrary duration arise. We continue the work by deriving further properties of transient centers. We expand upon some existing results on transient centers and its reachability. We demonstrate the application of the results on complicated systems such as Predator-prey models, SIR models and so on.

multiple dose pharmacokinetic models predict bioavailability of toxins in vertebrate herbivores

A compartmental pharmacokinetic model is built to predict the concentration of toxic phytochemical in the gastrointestinal tract and blood following orally intake by an individual vertebrate herbivore. The existing single and multiple dose pharmacokinetic models are extended to incorporate the physiological factor that toxins can be excreted unchanged in feces due to gastrointestinal motility by impulsive differential equations. An index is defined to be the fraction of the toxin in the blood (i.e., bioavailability) attributed to the excretion effect. Sensitivity analysis is conducted and it is found that for any toxin, the coefficient of bioavailability which is attributed to the elimination effect of gastrointestinal motility depends mostly on absorption rate of toxin from GIT into the blood, frequency of elimination due to gastrointestinal motility, and the frequency of toxin intake.

impact of noise on the regulation of intracellular transport of intermediate filaments

Noise affects all biological processes from molecules to cells, organisms and populations. Although the effect of noise on these processes is highly variable, evidence is accumulating which shows natural stochastic fluctuations (noise) can facilitate biological functions. Herein, we investigate the effect of noise on the transport of intermediate filaments in cells by comparing the stochastic and deterministic formalizations of the bidirectional transport of intermediate filaments, long elastic polymers transported along microtubules by antagonistic motor proteins. By numerically exploring discrepancies in timescales and attractors between both formalizations, we characterize the impact of stochastic fluctuations on the individual and ensemble transport. We find that noise promotes the collective movement of intermediate filaments by reducing the impact of initial distributions of motor proteins in cells and increases the efficiency of the transport regulation by the biochemical properties of motor-cargo interactions.

multi-scale and qualitative analysis of a stoichiometric algae model

HAO WANG, University of Alberta

[Monday December 5 / lundi 5 décembre, 15:00 – Duchesse]
Algal blooms are becoming a global concern due to the increasing prevalence of eutrophication. Here we analyze a stoichiometric model for algal dynamics with rich transient behaviour, and the driving biological mechanisms are studied and understood via a multiple time-scale analysis. We further perform global qualitative analysis. Finally, I will briefly mention our recent effort in predicting imminent algal blooms in lakes using incomplete timely data.

LIN WANG, University of New Brunswick

GAIL WOLKOWICZ, McMaster University

Transient oscillations induced by delayed growth response in the chemostat

In order to try to account for the transient oscillations observed in chemostat experiments, we consider a model of single species growth in a chemostat that involves delayed growth response. The time delay models the lag involved in the nutrient conversion process.

By applying local and global Hopf bifurcation theorems, we prove that the model has unstable periodic solutions that bifurcate from unstable nonnegative equilibria as the parameter measuring the delay passes through certain critical values and that these local periodic solutions can persist, even if the delay parameter moves far from the critical (local) bifurcation values. When there are two positive equilibria, then positive periodic solutions can exist. When there is a unique positive equilibrium, the model does not have positive periodic oscillations and the unique positive equilibrium is globally asymptotically stable. However, the model can have periodic solutions that change sign. Although these solutions are not biologically meaningful, they may still help to account for the transient oscillations that have been frequently observed in chemostat experiments provided the initial data, though positive, starts close enough to the unstable manifold of one of these periodic solutions. Numerical simulations are provided to illustrate that the model has varying degrees of transient oscillatory behavior that can be controlled by the choice of the initial data.

This is joint work with Huaxing Xia and Lin Wang.

PEI YU, Western University

Complex Bifurcations of a Predator-Prey System with Allee Effect

In this talk, we present a study on a predator-prey system with strong Allee effect in the prey growth. The stability analysis of the model is carried out, and a comprehensive bifurcation analysis is presented. By a hierarchical parametric analysis, explicit stability conditions are obtained in terms of the system parameters. In particular, it is proved that this model can exhibit codimension-5 Hopf bifurcation and codimension-4 Bogdanov-Takens bifurcation, showing much more complex dynamical behaviours compared to the system without the Allee effect.

HUAIPING ZHU, York University

Dynamics of the asymptomatic infection in the spread of SARS-CoV-2

The COVID-19 pandemic continues with multiple waves of outbreaks, Omicron changed the game one year ago and still dominates. Among many of the factors including emerging VOCs, vaccine and reinfection, nonpharmaceutical interventions, behavior and adherence of individuals, asymptomatic infection plays a special role responsible for the repeated outbreaks and therefore exit strategy. In this talk, I will present models emphasizing the role of asymptomatic infections. For a more general form of the incidence function for the asymptomatic cases, the complex dynamics are found to be associated with the Bogdanov-Takens bifurcation of codimension 2, I will explain the threshold conditions for the transient and asymptotic
Transient Behaviors in Population Dynamics
Comportements transitoires dans la dynamique des populations

dynamics of the transmission. The existence of a nilpotent singularity and unstable Bogdanov-Takens bifurcations partially explains the reason and mechanisms of the repeated multiple-waves epidemics. The models were validated using data from a recent omicron wave in areas where partial test or citywide test-trace-isolate Zero-COVID policy were implemented.
Variational Analysis: Applications and Theory
Analyse variationnelle : Applications et théorie

Org: Walaa Moursi and/et Henry Wolkowicz (Waterloo)

This session provides an excellent opportunity for connecting researchers from different areas of optimization to interact, share recent research progress and discuss possible directions of future collaboration. Areas of interest range from theoretical results to applications in statistics and computer science.

Cette session offre une excellente occasion de mettre en relation des chercheurs de différents domaines de l’optimisation pour interagir, partager les progrès récents de la recherche et discuter des orientations possibles d’une collaboration future. Les domaines d’intérêt vont des résultats théoriques aux applications en statistique et en informatique.

Schedule/Horaire
Room/Salle: Austen

Friday December 2

11:00 - 11:30  Henry Wolkowicz (Waterloo), Regularized Nonsmooth Newton Algorithms for Best Approximation, with Applications (p. 176)

11:30 - 12:00  Andersen Ang (Waterloo), Multigrid proximal gradient method for convex optimization (p. 174)

13:00 - 13:30  Hristo Sendov (Western), Polar convexity and a refinement of the Gauss-Lucas theorem (p. 176)

13:30 - 14:00  Walaa Mousi (Waterloo), How to project onto the intersection of a closed affine subspace and a hyperplane (p. 175)

14:00 - 14:30  Kennedy Idu (Toronto), On Approximating Zeros of Monotone Operators in Banach Spaces (p. 175)

14:30 - 15:00  Phillip Braun (Western), On the Hadamard-Fischer’s Inequality, the Inclusion-Exclusion Formula, and Bipartite Graphs (p. 174)

15:00 - 15:30  Haesol Im (Waterloo), Revisiting Degeneracy, Strict Feasibility, Stability in Linear Programming (p. 175)

15:30 - 16:00  Fei Wang (Waterloo), Singularity degree for non-facially exposed faces (p. 176)

Abstracts/Résumés

ANDERSEN ANG, University of Waterloo
[Friday December 2 / vendredi 2 décembre, 11:30 – Austen]

Multigrid proximal gradient method for convex optimization

We present a recent result on accelerating a 1st-order method for solving convex (possibly non-smooth) composite optimization problem of the form \( f(x) + g(x) \), where \( f \) is convex and differentiable and \( g \) is convex and possibly non-differentiable. We propose a multigrid (MG) based convergence acceleration method for the proximal gradient method. Coming from the domain of PDEs and scientific computing, the idea of multigrid assumes that the optimization problem has a hierarchical structure that can be exploited. By utilizing such hierarchy, acceleration can be achieved by a multi-level process.

We provide several theoretical results for the proposed method. We show a fixed-point property of the sequence generated by the method, and we provide a simple convergence analysis, based on a recent result on the Polyak-Lojasiewicz inequality, to show that the proposed method achieves a linear convergence rate on strongly convex problems.

Finally, we illustrate that the proposed MG-accelerated proximal gradient outperforms the proximal gradient method with Nesterov’s acceleration, especially for large-sized problems in certain problem classes, such as a class of PDEs with a free boundary condition known as the elastic obstacle problem. If time permits, we will discuss briefly on the grid-independence convergence rate and also the on using MGProx for imaging application such as deblurring.
PHILLIP BRAUN, University of Western Ontario
[Friday December 2 / vendredi 2 décembre, 14:30 – Austen]

On the Hadamard-Fischer’s Inequality, the Inclusion-Exclusion Formula, and Bipartite Graphs

The classical Hadamard-Fischer-Koteljanskii inequality is an inequality between principal minors of positive definite matrices. In this work, we present an extension of the Hadamard-Fischer-Koteljanskii inequality, that is inspired by the inclusion-exclusion formula for sets. We formulate necessary and sufficient conditions for the inequality to hold. We describe general structures of the collection of index sets involved. In analyzing these structures, a graph-theoretical property that applies to bipartite graphs is found. We establish that if the vertices of a bipartite graph satisfy simple conditions, then the bipartite graph contains a vertex subgraph which is a cycle or a complete subgraph missing a matching. This is joint work with Hristo Sendov.

KENNEDY IDU, University of Toronto
[Friday December 2 / vendredi 2 décembre, 14:00 – Austen]

On Approximating Zeros of Monotone Operators in Banach Spaces

The problem of finding and approximating zeros of monotone operators is well studied in Hilbert spaces motivated by its root in nonlinear problems of mathematical analysis and applications. Progress has been due to the nice geometry and identities of the space and its isomorphism to the dual. These readily lend problem to the powerful machinery of fixed point theory via transformation to the problem of finding fixed points of pseudocontractions. In general Banach spaces, where the notion of fixed points does not make sense for such operators, it is not immediately clear how to tow this path.

In this talk, we introduce a recent fixed point notion which presents a framework for the zero-problem in the sense of fixed point theory. Using this, we construct an approximation scheme which converges strongly to a solution of the zero-problem in Banach spaces. This is a joint work with Charles Chidume.

HAESOL IM, University of Waterloo
[Friday December 2 / vendredi 2 décembre, 15:00 – Austen]

Revisiting Degeneracy, Strict Feasibility, Stability in Linear Programming

Currently, the simplex method and the interior point method are indisputably the most popular algorithms for solving linear programs. Unlike general conic programs, linear programs, LPs, with a finite optimal value do not require strict feasibility in order to establish strong duality. Hence strict feasibility is seldom a concern, even though strict feasibility is equivalent to stability and a compact dual optimal set. This lack of concern is also true for other types of degeneracy of basic feasible solutions in LP. In this note we discuss that the specific degeneracy that arises from lack of strict feasibility necessarily causes difficulties in both simplex and interior point methods. In particular, we show that the lack of strict feasibility implies that every basic feasible solution, BFS, is degenerate; thus conversely, the existence of a nondegenerate BFS implies that strict feasibility (regularity) holds. We prove the results using facial reduction and simple linear algebra. In particular, the facially reduced system reveals the implicit non-surjectivity of the linear map of the equality constraint system. As a consequence, we emphasize that facial reduction involves two steps where, the first guarantees strict feasibility, and the second recovers full row rank of the constraint matrix. This illustrates the implicit singularity of problems where strict feasibility fails, and also helps in obtaining new efficient techniques for preprocessing. We include an efficient preprocessing method that can be performed as an extension of phase-I of the two-phase simplex method.

WALAA MOUSI, University of Waterloo
[Friday December 2 / vendredi 2 décembre, 13:30 – Austen]

How to project onto the intersection of a closed affine subspace and a hyperplane

Let A be a closed affine subspace and let B be a hyperplane in a Hilbert space. Suppose we are given their associated nearest point mappings. We present a formula for the projection onto their intersection. As a special case, we derive a formula for
the projection onto the intersection of two hyperplanes. These formulas provide useful information even if the intersection is empty. Examples and numerical experiments are also provided.

Hristo Sendov, The University of Western Ontario  
[Friday December 2 / vendredi 2 décembre, 13:00 – Austen]  
Polar convexity and a refinement of the Gauss-Lucas theorem

We will introduce the notion of polar convexity, which extends the usual notion of convexity. We will give examples, explain its basic properties, and show how it arises in various situations. Then, we will use it to give a new refinement of the classical Gauss-Lucas theorem for complex polynomials. The Gauss-Lucas theorem states that the critical points of a polynomial are in the convex hull of its zeros.

Fei Wang, Fields Institute and University of Waterloo  
[Friday December 2 / vendredi 2 décembre, 15:30 – Austen]  
Singularity degree for non-facially exposed faces

We define the singularity degree of a face which is not necessarily facially exposed. We show that the singularity degree of a linear conic optimization problem is equal to the singularity degree of the minimal face on the linear image of the convex cone. As an application, we give a bound of the singularity degree for generic frameworks and tensegrities underlying a Laman plus d graph (Laman graph plus d edges). This is joint work with Henry Wolkowicz.

Henry Wolkowicz, University of Waterloo  
[Friday December 2 / vendredi 2 décembre, 11:00 – Austen]  
Regularized Nonsmooth Newton Algorithms for Best Approximation, with Applications

We consider nonsmooth algorithms for the best approximation problem from polyhedral sets. This classical problem has many varied approaches and many applications. In particular, we study a regularized semismooth method where the Jacobian is singular, and compare the computational performance to that of classical projection methods, e.g., the recently studied HLWB projection method.

We observe empirically that the regularized semismooth method significantly outperforms the HLWB approach. However, the HLWB has a convergence guarantee while the semismooth method does not due to singularity of the generalized Jacobian.

We provide several applications including solving large scale linear programs, triangles from branch and bound methods, and generalized constrained linear least squares. We include scaling methods that improve the efficiency and robustness.

work with Yair Censor, Walaa Moursi, Tyler Weames
Where are we on the mathematics and statistics education hype curve?
Où en sommes-nous sur la courbe d’hype de l’enseignement des mathématiques et des statistiques?

Org: Andie Burazin (University of Toronto Mississauga) and Diana Skrzydlo (University of Waterloo)


Miroslav Lovric (McMaster) gave a fantastic 2022 CMS Summer Meeting Education Plenary in which he made the audience think about where we, teaching practitioners, are on the mathematics and statistics education “Gartner hype cycle”, a curve which represents the maturity of emerging trends. Are we following new trends because they are talked about the most? There are a lot of fun and innovative educational approaches being used in the design of mathematics and statistics courses and its assessments. But, how good are these approaches when it comes to teaching and learning in mathematics and statistics? How can the success of these approaches be measured and validated? In this session, presenters will share educational research results and the methods to validate educational approaches. As well, the participants will be asked to engage in a tasteful and informal discussion to conclude the session.

Schedule/Horaire

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Abstracts/Résumés

SAMANTHA-JO CAETANO, University of Toronto

[Saturday December 3 / samedi 3 décembre, 10:00 – Whistler]

Using student feedback to tailor your teaching.

In recent years, there has been a large development of new and exciting tools to implement in our math and statistics classrooms. Implementation of these tools are not always smooth and so it might be good to have measures in place to ensure that the tool is working well for both student engagement and learning. In this talk I will chat about different ways to collect student feedback and how to use that feedback to tailor your teaching.
feedback and use it to implement, pivot and navigate your courses in order to check that new features to your course are working as intended.

**JULIE JENKINS**, McMaster University
[Saturday December 3 / samedi 3 décembre, 9:30 – Whistler]

**DIANA SKRZYDLO**, University of Waterloo
[Whistler]

*Discussion and Next Steps*

We'll have time for a lively discussion about what we've seen and heard, and think about what we can look into in the future.

**AMANDA HARSY, MARIE MEYER, MICHAEL SMITH, CARA SULYOK**, Lewis University
[Saturday December 3 / samedi 3 décembre, 8:30 – Whistler]

*Grading with a Growth Mindset*

Instructors can support student development by encouraging and recognizing students for their growth in learning and by using assessment practices that support the idea that through practice and effort concepts can be understood. Growth grading systems, often referred to as mastery grading, are alternative assessment techniques that professors have implemented to support a growth mindset of learning. This talk will provide an overview of growth-based grading systems such as mastery grading, standards-based grading, and specifications grading, as well as results from a multi-institutional study analyzing the impacts of this growth grading system. Throughout our collaboration, we have been surveying students at the beginning and end of the semester regarding their attitudes about mathematics and learning as well as test anxiety and growth mindset. We will discuss this study along with other noteworthy research results related to using these alternate assessment methods.

**PETER TAYLOR**, Queen’s
[Saturday December 3 / samedi 3 décembre, 8:00 – Whistler]

*How are we doing?*

The question I want to ask first is what am I teaching and why am I teaching it. And only then am I ready to ask how I am teaching it and how well is it working. And I guess my experience of moving from the “what” to the “how” is somewhat organic, in that I can only think about the how in the context of the what, though of course that still leaves lots of room for imagination. And how well is it working? Well I guess I ask my students, and then also myself! I’ll give some examples.

**DAN WOLCZUK**, University of Waterloo
[Saturday December 3 / samedi 3 décembre, 9:00 – Whistler]

*Fact, Fiction, or Fad?*

As we seek to improve teaching and learning in mathematics and statistics, we encounter a constant stream of innovative ideas. For any of these ideas, it is generally easy to find some sources that support them and some other sources that refute them. Thus, evaluating whether these methods will be effective for our students is a challenging endeavor.

In this presentation, I will discuss a strategy for determining if an educational approach is fact, fiction, or fad. I will also share what I’ve learned after having applied this strategy over the last 7 years.
STÉPHANIE ABO, University of Waterloo

Can the clocks tick together despite the noise? Stochastic simulations and analysis of the mean-field limit

The suprachiasmatic nucleus (SCN), also known as the circadian master clock, consists of a large population of oscillator neurons. Together, these neurons produce a coherent signal that drives the body’s circadian rhythms. What properties of the cell-to-cell communication allow the synchronization of these neurons, despite a wide range of environmental challenges such as fluctuations in photoperiods? To answer that question, we present a mean-field description of globally coupled neurons modeled as Goodwin oscillators with standard Gaussian noise. Provided that the initial conditions of all neurons are independent and identically distributed, any finite number of neurons becomes independent and has the same probability distribution in the mean-field limit, a phenomenon called propagation of chaos. This probability distribution is a solution to a Vlasov-Fokker-Planck type equation, which can be obtained from the stochastic particle model. We study, using the macroscopic description, how the interaction between external noise and intercellular coupling affects the dynamics of the collective rhythm, and we provide a numerical description of the bifurcations resulting from the noise-induced transitions. Our numerical simulations show a noise-induced rhythm generation at low noise intensities, while the SCN clock is arrhythmic in the high noise setting. Notably, coupling induces resonance-like behavior at low noise intensities, and varying coupling strength can cause period locking and variance dissipation even in the presence of noise.

MARYAM ALHAWAJ, University of Toronto

Generalized pseudo-Anosov Maps and Hubbard Trees

The Nielsen-Thurston classification of the mapping classes proved that every orientation preserving homeomorphism of a closed surface, up to isotopy is either periodic, reducible, or pseudo-Anosov. Pseudo-Anosov maps have particularly nice structure because they expand along one foliation by a factor of $\lambda > 1$ and contract along a transversal foliation by a factor of $\frac{1}{\lambda}$. The number $\lambda$ is called the dilatation of the pseudo-Anosov. Thurston showed that every dilatation $\lambda$ of a pseudo-Anosov map is an algebraic unit, and conjectured that every algebraic unit $\lambda$ whose Galois conjugates lie in the annulus $A_{\lambda} = \{ z : \frac{1}{\lambda} < |z| < \lambda \}$ is a dilatation of some pseudo-Anosov on some surface $S$.

Pseudo-Anosovs have a huge role in Teichmuller theory and geometric topology. The relation between these and complex dynamics has been well studied inspired by Thurston.

In this project, I develop a new connection between the dynamics of quadratic polynomials on the complex plane and the dynamics of homeomorphisms of surfaces. In particular, given a quadratic polynomial, we show that one can construct an extension of it which is generalized pseudo-Anosov homeomorphism. Generalized pseudo-Anosov means the foliations have infinite singularities that accumulate on finitely many points. We determine for which quadratic polynomials such an extension exists. My construction is related to the dynamics on the Hubbard tree which is a forward invariant subset of the Julia set that contains the critical orbit.

CINDY CHEN, University of Saskatchewan

SIR Infectious Disease Modelling with Vaccination

The new coronavirus attacked the world in 2019, causing harm to people’s lives and society in multiple aspects. It is therefore of high importance to develop reliable mathematical models that would be able to predict the development of similar pandemics under different scenarios, including vaccination strategies, to help inform governments and health care systems and facilitate optimal policy making.

In this work, we study an SIR (“Susceptible-Infected-Recovered”) epidemic model that considers the time evolution of the three respective groups of population. Transitions between Susceptible, Infected, and Recovered groups are usually defined by constant coefficients, such as infection and recovery rates. The novel aspect of our model is making the coefficients time-dependent.
This allows a significantly larger freedom in building the models and predicting the outcomes under different scenarios. As an example we choose the model coefficients to reflect a situation when, at a certain time, a vaccine is introduced. In this situation, it is shown that under the same parameters, vaccination leads to a significantly faster transition to a recovered population.

**K. BHASKARA, A. COOK**, McMaster University

*Hadamard Product and Binomials Ideals*

We study the Hadamard product of two varieties $V$ and $W$, with particular attention to the situation when one or both of $V$ and $W$ is a binomial variety. The main result of this paper shows that when $V$ and $W$ are both binomial varieties, and the binomials that define $V$ and $W$ have the same binomial exponents, then the defining equations of $V \times W$ can be computed explicitly and directly from the defining equations of $V$ and $W$. This result recovers known results about Hadamard products of binomial hypersurfaces and toric varieties. Moreover, as an application of our main result, we describe a relationship between the Hadamard product of the toric ideal $I_G$ of a graph $G$ and the toric ideal $I_H$ of a subgraph $H$ of $G$. We also derive results about algebraic invariants of Hadamard products: assuming $V$ and $W$ are binomial with the same exponents, we show that $\deg(V \times W) = \deg(V) = \deg(W)$ and $\dim(V \times W) = \dim(V) = \dim(W)$. Finally, given any (not necessarily binomial) projective variety $V$ and a point $p \in \mathbb{P}^n \setminus V(x_0 x_1 \cdots x_n)$, subject to some additional minor hypotheses, we find an explicit binomial variety that describes all the points $q$ that satisfy $p \ast V = q \ast V$.

**JENNY LAWSON**, University of Calgary

*Optimality and Sustainability of Delayed Impulsive Harvesting*

Optimal and sustainable management of natural resources requires knowledge about the behaviour of mathematical models of harvesting under many different types of conditions. In this talk, we will be investigating the sustainability and optimality of delayed impulsive harvesting. Impulses describe an instantaneous change in a system due to some external effect (like harvesting in a fishery), which has a duration that is negligible compared to the overall time scale of the process. These impulses can then be combined with differential equations (DEs) to form impulsive DEs.

Delays within harvesting can represent a dependency on information that is out of date. Since it is likely that most data used to make harvesting decisions will be at least somewhat out of date, including delays within impulsive conditions is a topic of current interest. A close connection to the dynamics of high-order difference equations is used to conclude that while the inclusion of a delay in the impulsive condition does not impact the optimality of the yield, sustainability may be highly affected and is once again delay-dependent. Maximum and other types of yields are explored, and sharp stability tests are obtained for the model. It is also shown that persistence of the solution is not guaranteed for all positive initial conditions, and extinction in finite time is possible, which provides a possible explanation for observed but unforeseen population collapses. Overall, the results imply that delays within harvesting should be kept short to maintain the sustainability of resources.

**LAILA MAHRAT**, Lewis University

*An Agent-Based Model of Environmental Transmission of Clostridioides difficile in Healthcare Settings*

Clostridioides difficile (*C. difficile*) is one of the most frequently identified healthcare-acquired infections in United States hospitals. Colonized patients, both symptomatic and asymptomatic, shed *C. difficile* endospores that can survive for long periods on surfaces outside the host and are resistant to many commonly-used disinfectants. Transmission pathways can include contact with both endospores on fomites, objects likely to carry infection, and endospore-carrying individuals. Our agent-based model simulates the spread of *C. difficile* within a hospital ward, focusing on transmission originating from environmental pathways and healthcare workers. Simulations can help determine effective control strategies to mitigate the spread of *C. difficile* in healthcare settings.

**ANA MUCALICA**, McMaster University

*Solitons on the rarefaction wave background via the Darboux transformation*
Rarefaction waves and dispersive shock waves are generated from the step-like initial data in many nonlinear evolution equations including the classical example of the Korteweg-de Vries (KdV) equation. When a solitary wave is injected on the step-like initial data, it is either transmitted over or trapped inside the rarefaction wave background. We show that the transmitted soliton can be obtained by using the Darboux transformation for the KdV equation. On the other hand, we show with the help of numerical simulations that the trapped soliton disappears in the long-time dynamics of the rarefaction wave.

GAVIN OROK, University of Waterloo

*Determining where Monte Carlo Outperforms Quasi-Monte Carlo for Functions Monotone in Each Coordinate in Dimensions 3 and Above*

The Quasi-Monte Carlo methods are one way to estimate the integrals of functions over high-dimensional cubes. They are a variation of standard Monte Carlo methods; instead of choosing random points inside the cube to calculate an estimate of the result, Quasi-Monte Carlo scrambles a deterministic set of points that are sufficiently uniform inside of the cube. This is often desirable as it limits gaps and clusters of points that can harm the quality of the estimate.

One problem of interest to researchers of Quasi-Monte Carlo is to determine cases where these methods will outperform standard Monte Carlo methods, by having a lower theoretical variance in the final result. Previous work by Lemieux and Wiart showed that for two-dimensional functions monotone in each coordinate, Quasi-Monte Carlo will always outperform Monte Carlo in this way.

In this presentation, we will consider the extension of this problem to functions monotone in each coordinate in dimensions three and above. First, using computer searches we will find cases in higher dimensions where Monte Carlo has a lower theoretical variance than Quasi-Monte Carlo. Then, we will extend these cases to higher dimensions and determine relationships between them using equivalence classes and translations defined on sets of vectors called antichains.

KEVIN MIN SEONG PARK, University of Toronto

*Deep Reinforcement Learning for Viscous Incompressible Flow*

Numerical methods for approximating the solution to the incompressible Navier-Stokes equations typically solve discretized equations on a finite mesh of the domain, a computationally expensive process. We present a mesh-free method which can be easily scaled to irregular 3D geometries as we encode the domain and boundary through signed distance functions. The numerical solution is provided by a deep neural network trained on an objective that is derived from the expectation of a martingale stochastic process of the viscous Burgers equation, similar to Monte Carlo methods through the Feynman-Kac formula. We adopt a reinforcement learning paradigm of iterating the optimization step at every simulated increment of the Itô process. The vector potential is encoded into the neural network architecture, thereby automatically satisfying the incompressibility condition without requiring the pressure term. Simulation of the Itô process requires the true velocity, which we replace with the current approximation during the training procedure and we prove that this process is a fixed-point iteration in a simplified setting. This method is capable of numerically solving solutions to elliptic and parabolic partial differential equations. Deep learning is parallelizable and hyperparameters can be incorporated to solve a family of problems. We provide an example of flow past disk with a range of input flow speeds and viscosities, all provided by a single neural network, to highlight these advantages.

KALEB D. RUSCITTI, McGill University

*The Verlinde formula for flat SU(2) connections using a toric degeneration*

The moduli space $M$ of flat SU(2) connections has a prequantum line bundle $L$ and a polarization, the data required for geometric quantization. Jeffrey and Weitsman have shown the moduli space $M$ of flat SU(2) connections has Hamiltonian functions which almost exhibit $M$ as a toric variety. If it were toric, the theory of toric varieties tells us that the space of global sections of $L$, which is the quantum data, has dimension computed by the Verlinde formula. Hurtubise and Jeffrey have constructed a “master space” $P$ with both a symplectic and a holomorphic description, which is toric and should contain all the information of $M$. Holomorphically, $P$ is a space of framed parabolic sheaves over a punctured Riemann surface, and by degenerating the original Riemann surface to the punctured one, the moduli space $M$ degenerates to the master space $P$. The
aim now is to see how the recent work of Harada, Kaveh and Khovansky makes rigorous the justification of the Verlinde formula obtained by point counting by Jeffrey and Weitsman, hence giving a new proof of the formula.

**KATARINA SACKA**, McMaster University

*Applications of Next-Iterate Operators to Discrete Planar Maps.*

Two applications of next-iterate operators for discrete planar maps defined in the work by S.H. Streipert and G.S.K. Wolkowicz are explored. The time-delay equation

\[ x_{n+1} = \frac{\alpha + x_n - 1}{A + x_n} \]

for \( n \in \mathbb{N}, \alpha \geq 0, A \in [0, 1), x_0 > 0, \) and \( x_1 > 0 \) has a unique positive equilibrium which is a saddle point. Applying the change of variables, \( y_n = x_{n-1} \), we write this equation as the planar system,

\[ x_{n+1} = \frac{\alpha + y_n}{A + x_n}, \quad y_{n+1} = x_n. \]

We show that there exists a nontrivial positive solution which decreases monotonically to the equilibrium, proving Conjecture 5.4.6 from M. Kulenovic and G. Ladas. By using the augmented phase plane with nullclines and their associated root-curves, we can show the general behaviour of solutions in the plane. Using the tangent vector to the stable manifold at the equilibrium, we can show that solutions in a particular region defined by the nullclines and their associated root-curves, will decreases monotonically to the equilibrium along the tangent vector to the stable manifold. While Conjecture 5.4.6 has been previously proven, our proof provides a more elementary solution.

The second application of next-iterate operators regards the time delay equation,

\[ x_{n+1} = \frac{\alpha + x_n + x_{n-1}}{A + x_n + x_{n-1}} \]

for \( n \in \mathbb{N}, A > \alpha > 0, x_0 > 0, \) and \( x_1 > 0 \). This equation has a unique positive equilibrium which is locally stable. Using the same change of variables as before, \( y_n = x_{n-1} \), we write this equation as the planar system,

\[ x_{n+1} = \frac{\alpha + x_n + y_n}{A + x_n + y_n}, \quad y_{n+1} = x_n. \]

By applying the augmented phase portrait, in addition to two new next-iterate operators defined in this work, we can expand this result to prove global stability.

**DAYANNA SANCHEZ**, Lewis University

*Analyzing the Impact of Alternative Assessments and Growth Mindset*

Alternate assessment techniques such as mastery grading, specifications grading, and standards-based grading are assessment techniques professors are implementing in order to support a growth mindset of learning. This proposal will support a multi-institutional collaboration that studies the impact of mastery grading assessment techniques on the growth mindset of students in a variety of mathematics classes. By analyzing pre- and post-surveys with questions adapted from Dweck’s Mindset survey, we will explore whether there is a difference in the growth mindset between various cross-sections of student populations between classes (mastery and non-mastery, specific courses, universities, etc.) and whether the growth mindset of students changed by the end of the semester. This research will explore whether there is a difference in students’ mindset of learning mathematics between various cross-sections of student populations between classes (mastery and non-mastery, specific courses, universities, etc.) and whether the growth mindset of students changed by the end of the semester.

**GUSTAVO CICCHINI SANTOS**, Toronto Metropolitan University

*UNDERSTANDING NON-EQUILIBRIUM STEADY STATES*
Physical systems are characterized by their response to perturbations. The Fluctuation Dissipation Theorem predicts the behavior of systems in equilibrium. Can an expression be derived using methods from quantum field theory to describe the vertex response to a perturbation, and is the Fluctuation Dissipation Theorem modified as a result of these perturbations. Using Berezin integration and properties of determinants we derive said expression. The derivation yields the same result as the less rigorous methods. We learn the Fluctuation Dissipation Theorem has an equilibrium-like response to a vertex perturbation making the Fluctuation Dissipation theorem a bad indicator of whether a system is in equilibrium or out of equilibrium. We then apply our result to a biochemical problem.

MELISSA MARIA STADT, University of Waterloo

Impact of feedforward and feedback controls on potassium homeostasis: Mathematical modelling and analysis

Dysregulation of potassium is a common and dangerous side effect of many pathologies and medications. Potassium homeostasis is primarily mediated by (i) uptake of potassium into the cells via the sodium-potassium pump and (ii) renal regulation of urinary potassium excretion. Due to the importance of potassium in cellular function and the daily challenge of undergoing variations in potassium intake, mammals have evolved several regulatory mechanisms to ensure proper potassium balance between the extra- and intracellular fluids. The multitude of physiological processes involved in potassium regulation makes its study well suited for investigation with mathematical modelling. In this project, we developed a compartmental model of extra- and intracellular potassium regulation. We included a detailed kidney compartment with the effects of aldosterone and potassium intake on renal potassium handling as well as intracellular potassium uptake stimulation by both insulin and aldosterone. Model simulations were conducted and analyzed to quantify the impact of individual regulatory mechanisms on whole-body potassium regulation. Additionally, we used this model to simulate and give evidence for a newly hypothesized signal, muscle-kidney cross talk, on potassium loading and depletion.

YUN-CHI TANG, University of Toronto

On Knots That Divide Ribbon Knotted Surfaces

We define a knot to be half ribbon if it is the cross-section of a ribbon 2-knot, and observe that ribbon implies half ribbon implies slice. We introduce the half ribbon genus of a knot $K$, the minimum genus of a ribbon knotted surface of which $K$ is a cross-section. We compute this genus for all prime knots up to 12 crossings, and many 13-crossing knots. The same approach yields new computations of the doubly slice genus. We also introduce the half fusion number of a knot $K$, that measures the complexity of ribbon 2-knots of which $K$ is a cross-section. We show that it is bounded from below by the Levine-Tristram signatures, and differs from the standard fusion number by an arbitrarily large amount.

WILLIAM VERREAULT, Université Laval

Series expansion via unwinding

We present a general unwinding scheme for analytic functions as well as convergence theorems for the unwinding series expansion, extending results on the Blaschke unwinding series, a nonlinear analogue of Fourier series with a wide range of practical applications.

YUMING ZHAO, University of Waterloo

There is no sum-of-squares certificate for positivity in tensor product of free algebras

In quantum information, the algebra $\mathbb{CZ}_n^* \otimes \mathbb{CZ}_m^*$ models a physical system with two spatially separated subsystems, where in each subsystem we can make $n$ different measurements, each with $m$ outcomes. The recent MIP* = RE result shows that it is undecidable to determine whether an element of $\mathbb{CZ}_n^* \otimes \mathbb{CZ}_m^*$ (for varying $n$ and $m$) is positive in all finite-dimensional representations. In this poster, I will present joint work with Arthur Mehta and William Slofstra, in which we show that it is undecidable to determine whether an element of $\mathbb{CZ}_2^* \otimes \mathbb{CZ}_2^*$ (for some sufficiently large $n$) is positive in all representations. As a consequence, there is no sum-of-squares certificate for positivity in tensor product of free algebras.
EUGENE ZIVKOV, Toronto Metropolitan University

Thin liquid film stability in the presence of bottom topography and surfactant

We consider the stability of gravity-driven fluid flow down a wavy inclined surface in the presence of surfactant. The periodicity of the bottom topography allows us to leverage Floquet theory to determine the correct form for the solution to the linearized governing partial differential equations. The result is that perturbations from steady state are wavelike, and a dispersion relation is identified which relates the wavenumber of an initial perturbation, $k$, to its complex frequency, $\omega$. The real part of $\omega$ ultimately determines the stability of the flow. We observe that the addition of surfactant generally has a stabilizing effect on the flow, but has a destabilizing effect for small wavenumbers. These results are compared and validated against nonlinear results, which are obtained by numerically solving the governing equations directly. The linear and nonlinear analyses show good agreement, except at small wavenumbers, where the linear results could not be replicated.
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