

Atlantic Association for Research in the Mathematical Sciences

2021-22 Annual Report

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1 Director's Message

After many months, it finally seems like the chaos induced by the COVID-19 pandemic is receding and AARMS activities are starting to return to normal. We are beginning to see more in-person events being planned and are looking forward to pre-pandemic levels of scientific interaction both within our community and with external collaborators and partners.

However, we are not quite there yet. In this annual report, you will see an accounting of AARMS's activities in the 2021-22 fiscal year, when the pandemic was still the principal factor shaping how AARMS researchers pursued their scientific goals. As such, it is dominated by virtual interactions, online events, and the funding of highly qualified personnel. Many of the new programs we launched to deal with the realities of COVID-19,



such as the online AARMS Advanced Course program, have been well-received by the community. A key question moving forward is how to retain the useful innovations spurred by the pandemic while facilitating a full-fledged "return to normal".

On the funding front, the most consequential development for AARMS was our successful application to NSERC's Discovery Institute support program. This award will, for the first time, provide AARMS with stable, direct and substantial federal funding. This funding, in the amount of \$372,819 per year for five years starting in the spring of 2022, has already allowed us to support a record number of Collaborative Research Groups (CRGs) and postdoctoral fellows in 2021-22. In particular, our new CRGs are:

- Developing general dynamic modelling systems and spatiotemporal models for omics data Administered by Hong Gu, (Dalhousie)
- Graph Searching in Atlantic Canada Administered by Danielle Cox, (MSVU)
- Groups, Rings, Lie and Hopf Algebras Administered by Yorck Sommerhäuser (MUN)
- Mathematical foundations and applications of Scientific Machine Learning Administered by Alexander Bihlo (MUN)



 Numerical Solution of Geophysical Inverse Problems Administered by Peter Leliévre, (MTA)

More information about the first year activities of each of these CRGs, as well as biographies of our 2021-22 postdoctoral fellows, can be found below.

The COVID-19 pandemic caused the cancellation of the in-person AARMS Summer School in 2021-22. The Summer School was replaced by the AARMS Advanced Course program that allows graduate and upper year undergraduate students to participate virtually in courses offered at AARMS Member universities. This program greatly enhances the access of students in the region to specialized education in cutting edge mathematical sciences topics. Similarly, the 2021 in-person Industrial Problem Solving Workshop was converted to a highly successful online format, featuring four problems from companies and governments, and involved over 50 participants over two weeks in midsummer. We hope for a return to in-person versions of both these events soon.

Due to our increased funding from NSERC, we have recently launched a number of new programs including a Graduate Student Scholarship and Doctoral Thesis Award. We have also commissioned an external review of AARMS's Equity, Diversity and Inclusion practices and have begun implementing its recommendations. In the near future, we plan on launching a new program aimed at providing travel support for junior researchers.

In conclusion, I would like to express my appreciation to the AARMS Executive, AARMS Board, AARMS Scientific Review Panel, and wider Atlantic mathematical sciences community for their sustained efforts in driving all of our programs and initiatives. AARMS is grateful for the continued support of a number of organizations, including provincial governments; and all of AARMS's member universities. Special recognition is due to David Langstroth for expert administrative efforts and his chairing of AARMS's new committee on Equity, Diversity and Inclusion. I would also like to thank PIMS, Fields, CRM, BIRS and CANSSI for their ongoing and valued collaboration. Finally, I would like to thank NSERC for their strong new support for the mathematical sciences in Atlantic Canada.

Sanjeev Seahra AARMS Director October 2022



2 Report on Funding

2.1 NSERC

We are pleased to report that our application for funding from the NSERC Discovery Institutes Support Program (DIS) was successful. AARMS has received 5 years of funding at the amount of \$372,819 per year, starting in the 2022/23 year. The stability of this support will enable AARMS to make longer term plans for programs such as Collaborative Research Groups, Postdoctoral Fellowships and the Annual Summer School.

2.2 COVID Related Funding

AARMS has partnered with CRM, Fields and PIMS on two major funding applications to support mathematical sciences focussed research on the COVID-19 pandemic. The first of these (*The Mathematics of COVID-19 Task Force*) was funded by the Canadian Institutes for Health Research (CIHR) while the second (*Mathematics for Public Health*) was funded by NSERC in collaboration with the Public Health Agency of Canada (PHAC). AARMS has leveraged these pan-Canadian multi-institute awards to obtain an additional from the New Brunswick Health Research Foundation (NBHRF) to support the study of the pandemic in an Atlantic Canadian context. These initiatives have also led to several individual research grants for AARMS researchers. Currently, the Director of AARMS serves on the Steering Committee of *Mathematics for Public Health*.

CIHR and NSERC/PHAC funding has been used to support eight different trainees at the undergraduate, graduate and postdoctoral level since early 2020. The work of these highly qualified personnel in collaboration with faculty from Atlantic Canada have played an important (and sometimes central) role in the pandemic response of New Brunswick, Newfoundland and Labrador, Prince Edward Island and the Northwest Territories. More details can be found in media reports and online articles, a selection of which are:

- COVID-19 hospitalizations could double within a month, new N.B. projections show
- <u>COVID-19 modelling: the complex science of simple lines</u>
- Even without Omicron, NB cases on steep upward trend
- N.B. COVID-19 roundup: Province projects 5,500 new cases per day, 220 hospitalizations
- Omicron making life difficult for mathematicians trying to track COVID-19



3 Report on Activities

3.1 AARMS Collaborative Research Groups (CRGs) Program

AARMS supported 6 Collaborative Research Groups in the 2021/22 academic year. One of these CRGs, **Computational Aspects in Finance and Insurance** under the administration of Kai Liu at UPEI, has come to the end of its program and the final report is included below. The five other CRGs were tentatively funded for one year, while AARMS waited to see the result of our application for long term funding from the NSERC DIS program. Having been awarded five years of funding from DIS, AARMS invited each of these CRGs to apply for another year of support, and we are happy to report that they will all continue through the 2022/23 academic year. The 2021/22 reports from these groups are included below.

3.1.1 Computational Aspects of Finance and Insurance

3.1.1.1 Members

Academic Administrator: Kai Liu (University of Prince Edward Island)

Collaborators from AARMS member universities:

- Kai Liu (University of Prince Edward Island)
- Alexander Alvarez (University of Prince Edward Island)
- Shafiqul Islam (University of Prince Edward Island)
- Shaohua Chen (Cape Breton University)
- M Tariq Hasan (University of New Brunswick (Fredericton))
- Beibei Jia (University of Prince Edward Island)
- Justin Kakeu (University of Prince Edward Island)
- Frederick Kibenge (University of Prince Edward Island)
- Antonio Bolufe-Rohler (University of Prince Edward Island)
- Guohua Yan (University of New Brunswick (Fredericton))
- Qiang Ye (Dalhousie University)

Collaborators from other institutions

- A.H.M. Mahbubar Rahman (Concordia University)
- Wenging He (Western University)
- Lysa Porth (University of Guelph)
- Ken Seng Tan (Nanyang Technological University (Singapore))
- Marcos Escobar (Western University)



- Anatoliy Swishchuk (University of Calgary)
- Sebastian Ferrando (Ryerson University)
- Pablo Olivares (Ryerson University)
- Chou-Wen Wang (National Sun Yat-sen University, Taiwan)
- Haifei Liu (Nanjing University, China)

3.1.1.2 Activities

Seminars:

- J. Dong (Jilin University), "Application of Digital Twin technology in real-time signal transmission of Internet of Vehicles", Feb. 11, 2022 (Virtual)
- A. Assadi (Canadian Imperial Bank of Commerce), "Reinforcement learning in algorithm trading using python", Nov. 29, 2021 (Virtual)
- L. Doiron (University of Prince Edward Island), "The Feasibility and Costing of Guaranteed Basic Income in Canada", Nov. 10, 2021 (Virtual)
- L. Doiron (University of Prince Edward Island), "Guaranteed Basic Income Presentation", Oct. 27, 2021 (Virtual)

Conference: Computational Aspects in Finance and Actuarial Sciences

Held in Charlottetown, July 8-9, 2022, this conference brought together leaders in finance, and actuarial sciences, across disciplines, and across borders, tackling very important and timely topics in finance and actuarial sciences. Our intention for this conference was to have a broad scope in terms of applications in Finance and Actuarial Sciences but with an emphasis on numerical and computational issues (including trendy topics such as machine learning algorithms in finance and insurance, but also more traditional methods such as numerical solutions for PDEs, Monte Carlo simulations, etc). The conference included a dynamic program with high quality speakers focusing on innovative research, policy discussions, and business challenges and successes. Presentations were given by:

Jean Francois Begin (Simon Fraser University) Ciro Diaz (Toronto Metropolitan University) Guojun Gan(University of Connecticut) Frederic Godin (Concordia University) Xiyue Han (University of Waterloo) Cody Hyndman (Concordia University) Hiromichi Kato (Wilfrid Laurier University) George Lai (Wilfrid Laurier University) Shu Li (Western University)

Anne MacKay (Université de Sherbrooke) Roman Makarov (Wilfrid Laurier University) Christian Maxwell (Western University) Alexander Melnikov (University of Alberta) Yechao Meng (University of Waterloo) Pablo Olivares (Toronto Metropolitan University) Ali Raisolsadat (University of Prince Edward Island)

Alexey Rubtsov (Toronto Metropolitan University



Student Supervision:

- Ali Raisolsadat (May 2022 August 2022): NSERC Undergraduate Student Research Award & Undergraduate Research Award. Project Title: Pricing Inflation-Indexed Swaps and Swaptions with Markov Regime-Switching Jump-Diffusion Models. Supervisor: Dr. Kai Liu and Dr. Xander Wang Note: this research has been presented at AARMS CRG Conference: Computational Aspects in Finance and Actuarial Sciences (July 8-9, 2022) & The 25th International Congress on Insurance: Mathematics and Economics (July 12-15, 2022)
- Marcos Ledesma (May 2022 August 2022): TD Summer Research Award & Undergraduate Research Award. Project Title: Modelling and Pricing of Climate and Weather Derivatives.

Supervisor: Dr. Alexander Alvarez

- Ali Raisolsadat (May 2021 August 2021): Undergraduate Research Award. Project Title: Quantitative Risk Control for Climate Change, Fund Reservation and Policy Adaptation. Supervisor: Dr. Kai Liu
- Jiaying Liu (May 2021 August 2021): TD Summer Research Award & Undergraduate Research Award. Project Title: Option pricing with orthogonal polynomials. Supervisor: Dr. Alexander Alvarez
- Junshi Dong, Graduate Student, Jan 2020 August 2022
 M. Sc. Thesis project: Biogeographical Modelling of Cross-Species Coronavirus Dispersal Supervisory Committee: Dr. Kai Liu, Dr. Yingwei Wang, Dr. Shafiqul Islam, Dr. Antonio Bolufe-Rohler, Dr. Justin Kakeu, Dr. Frederic Kibenge.

3.1.1.3 Publications

- T. Chen, Y. Li and K. Liu (2022). Portfolio Selection from under-diversification to concentration", *Empirical Economics*. Revised and Re-submitted.
- X. Rong, T. Zhang and K. Liu (2022). Insurance Institutional Investor and Corporation Value from Value Selection and Creation Perspective. *PLOS ONE*, 17(7):e0269520. DOI: 10.1371/journal.pone.0269520.
- C. Wang, K. Liu, B. Li and K.S. Tan (2022). Portfolio Optimization Under Multivariate Affine Generalized Hyperbolic Distributions. *International Review of Economics and Finance*, 80:49-66, DOI: 10.1016/j.iref.2022.02.053.
- A. Alvarez, A. Assadi and K. Liu (2021). Closed-form Approximated Pricing of Multivariate Derivatives Under Switching Regime Models with Multiple States of the Markov Chain. *Applied Stochastic Models in Business and Industry*, 37(6):1042-1059, DOI: 10.1002/asmb.2635.
- K. Liu and K.S. Tan (2021). Real-time Valuation of Large Variable Annuity Portfolios: A



Green Mesh Approach. *North American Actuarial Journal*, 25(3):313-333, DOI:10.1080/10920277.2019.1697707.

- X. Rong, Bingjie Song, T. Zhang, K. Liu (2021). Home Bias and Corporate Environmental Social Responsibility. *Sustainability*, 13(11), 5860, DOI: 10.3390/su13115860.
- W. Bai, H. Liu, K. Liu and A. Alvarez (2021). How to Construct a Lower Risk Fund of Funds? Financial Analysts Journal, Submitted.
- J. Liu, K. Liu and N. Saad (2021), "Some remarks on the Black-Scholes Equation", Working Paper.
- J. Zhang, A. Alvarez and K. Liu (2021). Multi-Asset Spread Option Pricing via Least Squared Polynomial Approach. Working Paper.
- J. Dong, K. Liu, Y. Wang, S. Island and A. Bolufe-Rohler (2022). Multi-level Modelling of Cross-Species Coronavirus Dispersal. In progress.

3.1.2 Developing General Dynamic Modelling Systems & Spatiotemporal Models for Omics Data

3.1.2.1 Members

Academic Administrator: Hong Gu, Mathematics & Statistics, Dalhousie University

Other Researchers from AARMS Member Universities:

- Joe Bielawski Biology, Dalhousie University
- Zoe Finkel Oceanography, Dalhousie University
- Graham Gagnon Architecture and planning, Dalhousie University
- Andrew Irwin Mathematics & Statistics, Dalhousie University
- Toby Kenney Mathematics & Statistics, Dalhousie University
- Janice Lawrence Biology, UNB
- Adrian Reyes-Prieto_Biology, UNB
- Nanwei Wang Mathematics & Statistics, UNB

Other CRG Members:

- Jesse Shapiro Microbial Evolutionary Genomics, McGill University
- David Walsh Microbial Ecology and Genomics, Concordia University
- Ximing Xu Mathematics & Statistics, Nankai University, China

3.1.2.2 Activities

During the past year, the CRG members have been focused on sub-group meetings to develop different research directions within the large theme of dynamic modelling for omics data. Our CRG members are divided into four main groups —



- Dalhousie technique group (Hong Gu, Toby Kenney, Joe Bielawski)
- Drinking Water study group in Dalhousie (Graham Gagnon, Joe Bielawski, Hong Gu)
- Lake Water study group in Quebec (Jesse Shapiro, Joe Bielawski, Hong Gu)
- Ocean study group (Andrew Irwin, Zoe Finkel)

Each of the above four groups' members are also associated with a large number of HQPs, and some of them have both wet labs and dry labs. Throughout the year, we have had regular monthly meetings between the Dalhousie technique group and the Lake Water study group in Quebec. We also held approximately monthly meetings between the Dalhousie technique group and the Drinking Water study group in Dalhousie, with HQPs co-supervised between two groups meeting more frequently (about once a week). We also had some irregular discussions between the Dalhousie technique group.

In addition, the bioinformatics (upstream) analysis of daily samples from Lake PLSF in Quebec, over an approximately two-year period has been completed thanks to the effort of multiple postdoc fellows from Dr. Jesse Shapiro's group. Many data exploratory, dimension reduction and modelling methods devleloped by Dr. Hong Gu and Dr. Toby Kenney's group have been applied to analyze these data by the postdoc fellow Dr. Wei Zhou and PhD student Paul Bjorndahl, both co-supervised by Dr. Joseph P Bielawski and Dr. Hong Gu. These analysis results have been presented and discussed in the monthly meetings. Using our variable selection methods, a number of key microbes have been identified as associated with blooms, and Dr. Jesse Shapiro's group has confirmed that most of these selected biomarkers are indeed known to be related to toxin generation. The microbial subcommunities discovered by statistical methods have also led to biological interpretations. These analysis results are currently being written up as a paper. The key microbes selected at this stage will be our focus for the dynamic modelling in the next stage of the research.

The above detailed time series data is, to the best of our knowledge, the first such data for the lake water microbiome study. Combined with the 7–8 year longitudinal data set that Dr. Jesse Shapiro's group has previously collected and processed, we have acquired an excellent lake water microbiome time series, with some of the samples also including metagenomic data and toxicity analysis. Data on environmental conditions and lake blooms have also been collected for the past 8 years. This provides very exciting oppotunities for the CRG to make large contributions both to the Mathematical and Statistical modelling aspects and more importantly on the scientific front. This collaboration has resulted in one paper(1) published in a high impact journal as listed below.

The collaboration between the Dalhousie technique group and the Drinking Water study group in



Dalhousie has also resulted in one submitted paper. A large number of new challenges and research topics have arisen in the discussion between these groups. One of the new topics is about using fluorescence spectroscopy to measure the characteristics of natural organic matter (NOM) concomitant with browning surface water supplies, and the development of the methods for analyzing these data. Fluorescence spectroscopy is a rapid, widely accessible and operationally simple technique for quantifying the characteristics of NOM most impacted by these surface water trends. Fluorescence has been shown (from the below submitted paper (2)) to provide reliable prediction and identification of correlated fluorescent constituents of NOM, algal toxins, and taste & odour compounds. Accordingly, fluorescence measurements can be useful for assessing the impact of climate pressures on surface water quality anddownstream treatment processes.

Another new research topic is to design a methodological framework for observational or experimental monitoring of wastewater treatment processes based on microbial taxonomic diversity and abundance dynamics of specific taxa of major concern. Wastewater is an exceptionally interesting source of microbiome data because of both the rich diversity of microbes present in wastewater, and the influence of wastewater on human health and the environment. Despite this, there is, to date, no detailed research on the microbial communities and their dynamic changes after each stage of the wastewater process. We have thus recruited a new PhD student, Sarah Jennifer Organ, to be co-supervised by Drs. Hong Gu, Joe Bielawski and Amina Stoddart (Department of Civil and Resource Engineering, Dalhousie University) to work on the wastewater microbiome project, starting in September 2022.

3.1.2.3 Publications

- 1. Paul Bjorndahl, Joseph P Bielawski, Lihui Liu, Wei Zhou & Hong Gu, (2022) Novel application of survival models for predicting microbial community transitions with variable selection for eDNA. Applied and Environmental Microbiology. 88(6).
- Paul Bjorndahl, Sean A. MacIsaac, Hong Gu, Crystal L. Sweeney, Lindsay E. Anderson, Isobel DeMont, Graham A. Gagnon. (2022) The identification of novel geosmin-associated fluorescence regions to inform development of monitoring strategies for T&O outbreaks in drinking water supplies impacted by climate pressures. Chemical Engineering Journal Advances (under review).
- Libai Xu, Ximing Xu, Dehan Kong, Hong Gu, Toby Kenney. Stochastic Generalized Lotka-Volterra Model with An Application to Learning Microbial Community Structures. Applied Mathematical Modelling (under review).



3.1.3 Graph Searching in Atlantic Canada

3.1.3.1 Members

Academic Administrator: Danielle Cox (Mount Saint Vincent University)

Collaborators from AARMS member universities

- Andrea Burgess : University of New Brunswick
- Nancy Clarke: Acadia University
- Danielle Cox: Mount Saint Vincent University
- Danny Dyer: Memorial University of Newfoundland
- Art Finbow: Saint Mary's University
- Stephen Finbow: St. Francis Xavier University
- Shannon Fitzpatrick (Chair of committee): University of Prince Edward Island
- Bert Hartnell: Saint Mary's University
- Jared Howell: Memorial University Of Newfoundland, Grenfell Campus
- Jeannette Janssen: Dalhousie University
- Margaret-Ellen Messinger: Mount Allison University
- Rebecca Milley: Memorial University of Newfoundland, Grenfell Campus
- Richard Nowakowski: Dalhousie University
- David Pike: Memorial University of Newfoundland

Collaborators from Other Institutions

- Anthony Bonato: X University
- Christopher Duffy: University of Melbourne, Australia
- Jessica Enright: University of Glasgow, Scotland
- Gena Hahn: Universite de Montreal
- Melissa Huggan: Vancouver Island University
- Bill Kinnersley: University of Rhode Island, USA
- Gary MacGillivray: University of Victoria
- Kerry Ojakian: The City University of New York, USA
- Pawel Pralat: X University (formerly Ryerson)
- Ben Seamone: Dawson College
- Boting Yang: University of Regina

3.1.3.2 Activities

Online Graph Searching Seminar & Coffee Klatch

Seven seminars and coffee klatches took place from October 2021 - April 2022. We invited speakers with EDIA in mind. We asked a diverse group of international early and late career researchers who represented the breadth of topics studied in the graph searching community.



- Dr. Andrea Burgess
- Dr. Ryan Cushman
- Dr. Petr Golovach
- Dr. Karen Gunderson

- Dr. Mohamed Omar
- Dr. Paweł Prałat
- Dr. Petra Wolf

Attendees were students and faculty and attendance ranged from 15-30+ attendees from across Canada and beyond. The majority of attendees were national/international collaborators and their students and postdoctoral fellows.

Winter GSAC research meeting

This event took place on Friday, January 21, 2022 via Zoom. Our speakers were

- Dr. Stephen Finbow* (St. Francis Xavier University), who spoke on eternal domination;
- Dr. Karen Gunderson* (University of Manitoba), who spoke on graph burning;
- Dr. Jared Howell* (Memorial University Grenfell Campus), who spoke on the watchman's walk on digraphs;
- Dr. Melissa Huggan* (Mount Allison University), who spoke on the localization game;
- Dr. Öznur Yaşar Diner* (Kadir Has University, Istanbul, Turkey), who spoke on

constructive characterizations of forbidden minors in k-searchable graphs.

We had 32 attendees from across Canada and the globe. The attendees ranged from well established researchers to graduate students and post-doctoral fellows of GSAC members. The workshop consisted of five 20-minute talks highlighting open problems in different areas of graph searching. There were then breakout groups related to each topic. These breakout groups resulted in ongoing collaborations between GSAC members on eternal domination and graph burning and will result in the publication of peer-reviewed journal articles.

Canadian Mathematical Society Graph Searching Session

Danny Dyer*, Stephen Finbow* and Brittany Pittman were co-organizers of this session, held at the Summer 2022 CMS meeting in St. John's. The session had 11 speakers, of which 5 were graduate students, 1 was a post-doc, and 5 were faculty members. It was a well-attended session, with approximately 20-30 attendees. The faculty were all members of the CRG (though some national and international).

GRASCan & one day workshop

The 2022 Graph Searching in Canada workshop took place Aug 3-5 and was organized by GSAC members, Danielle Cox, Andrea Burgess and Anthony Bonato. It was virtual with over 40 international participants. A summer school with Dr. Anthony Bonato (Toronto Metropolitan University) and Dr. Shahin Kamali (York University) was held in Aug 3 with students attending from across Canada.



Introduction to Research in Graph Searching Summer School

This one-day workshop was held on August 16, 2022 at the University of Prince Edward Island. The topic of the workshop was Spreading on Dynamic Graphs and the instructor was Dr. Jessica Enright from the University of Glasgow. Four undergraduate students from Atlantic Canada attended the workshop.

East Coast Combinatorics Conference (ECCC)

ECCC was held in-person and virtually at UPEI on August 16-18. The ECCC had 23 in-person attendees and at least 15 who viewed the live-stream. Our plenary speaker wasa Dr. Jessica Enright. The travel of nine students was supported using GSAC and ECCC funds.

AARMS Advanced course

Danny Dyer taught an AARMS advanced course on graph searching, which had 6 students from Atlantic Canada; 4 graduate and 2 undergraduate.

Teaching Seminar

In May 2022 an online teaching workshop, The 3rd Annual Calculus Instruction in Atlantic Canada workshop took place online via Zoom. It is a workshop aimed at university and high school educators who teach upper level mathematics. As part of this event the GSAC ran a workshop on introducing math research in the classroom using graph searching as an accessible way to do so. The workshop was run by GSAC members Danielle Cox, Danny Dyer and Melissa Huggan and had 15 participants attend. The group consisted of university instructors and high school educators. It was well received.

Outreach

Two collaborations took place. One with NS Math Circles and another with WISE Atlantic, as Danielle Cox gave graph theory related presentations to these groups. The nature of the pandemic made this goal a bit challenging. In future years of funding we hope to elaborate on these collaborations.

Industry Collaborations

Dr. Enright has worked with the Scottish government on several agricultural projects related to graph searching/dynamic graph processes and ran a summer school for the GSAC-organized ECCC. Dr. Andrea Burgess and Dr. Danny Dyer co-supervised a Mitacs Accelerate Internship for their Masters student, Mozhgan Farahani, with Verafin, an anti-financial crime company, on a problem relating money-laundering to the firefighter problem. Dr. Andrea Burgess and Dr. David Pike co-supervised a Mitacs Accelerate Internship for their Masters student, John Marcoux, also with Verafin, examining computational aspects of the firefighting problem with a distance restriction.



3.1.3.3 Publications

The following is a list of collaborations that are currently taking place and the topics that are being investigated. We anticipate that publications will arise from each of these collaborations. In some cases, the papers are already under review.

1. Rylo Ashmore, Danny Dyer*, Trent Marbach, Rebecca Milley* - Cat herding

2. lain Beaton, Stephen Finbow^{*}, Shannon Fitzpatrick^{*}, Ben Seamone^{*} - Eternal Domination Eviction Model

3. Andrea Burgess*, Danny Dyer*, Mozghan Farahani - Deduction number (Completed Masters thesis)

4. Andrea Burgess*, Danny Dyer*, Krishna Narayanan - Deduction on strong products

5. Andrea Burgess*, Danny Dyer*, Kerry Ojakian*, Boting Yang* - Algorithmic deduction number 6. Nancy Clarke*, Danielle Cox*, Melissa Huggan*, Svenja Huntemann, Trent Marbach – Time-Delayed Cops and Robbers (Submitted for publication)

7. Nancy Clarke*, Stephen Finbow*, Todd Mullen – Surrounding an Active Robber

8. Danielle Cox*, Margaret-Ellen Messinger*, Kerry Ojakian* - Graph Burning Conjecture

9. Anders Cornect, Danny Dyer*, Jared Howell* - Watching directed circulants

10. Danny Dyer*, Juliana Cuéllar Guasca, Jared Howell* - Watching Cayley graphs on nonabelian groups

11. Danny Dyer*, Roxanne Ghorbanivashki, Rebecca Milley* - Average Watchmen

12. Danny Dyer*, Jared Howell*, Brittany Pittman - Watching digraph products

13. Danny Dyer*, Melissa Huggan*, Dylan Pearson - Slow localization

14. Danny Dyer*, Arthur McCool, David Pike* - Zombies and Survivors (Completed Masters project)

15. Karen Gunderson*, Bojan Mohar*, JD Nir, Paweł Prałat* - Graph Burning

16. Jared Howell*, Kerry Ojakian*, David Pike* - Variants of Surrounding and Containing

3.1.4 Groups, Rings, Lie and Hopf Algebras

3.1.4.1 Members

Academic Administrator: Mikhail Kotchetov

Collaborators from AARMS member universities:

- Yuri Bakhturin (Memorial University, St. John's)
- Tom Baird (Memorial University, St. John's)
- John Irving (Saint Mary's University, Halifax)
- Yorck Sommerhäuser (Memorial University, St. John's)
- Eduardo Martinez-Pedroza (Memorial University, St. John's)
- Mitja Mastnak (Saint Mary's University, Halifax)
- Braham Rangipour (University of New Brunswick, Fredericton)
- Peter Selinger (Dalhousie University, Halifax)
- Roman Smirnov (Dalhousie University, Halifax)



- Nicholas Touikan (University of New Brunswick, Fredericton)
- Yiqiang Zhou (Memorial University, St. John's)

Collaborators from other institutions:

- Nicholás Andruskiewitsch (University Nacional de Córdoba)
- Georgia Benkart (University of Wisconsin, Madison)
- Alberto Elduque (University of Zaragoza)
- Jörg Feldvoss (University of South Alabama, Mobile)
- Terry Gannon (University of Alberta, Edmonton)
- Yevgenia Kashina (DePaul University, Chicago)
- Simon Lentner (university of Hamburg)
- Susan Montgomery (University of Southern California, Los Angeles)
- Alexander Olshanskiy (Venderbilt University, Nashville)
- Alexander Premet (University of Manchester)
- Christoph Schweigert (University of Hamburg)
- Kirill Zainoulline (University of Ottawa)

3.1.4.2 Activities

The first activity organized by the CRG in this period was the mini course Introduction to Schubert Calculus via (nil-)Hecke algebras, by Kirill Zaynullin from the University of Ottawa. From September 21 to 23, 2021, Professor Zaynullin delivered 4 lectures at Memorial University, giving a self-contained exposition on the use of the techniques of nil-Hecke algebras in the equivariant Schubert calculus for cohomology of flag varieties. These lectures were attended in person by local faculty and graduate students and were also broadcast via Zoom.

Dr. Zaynullin's PhD student Cameron Ruether attended the mini course and also reported the results of his thesis: in particular, he delivered a seminar: Twisting Spin, Half-spin, and Hopf Algebras on September 22.

Unfortunately, later in 2021, the re-introduced restrictions forced us to suspend further research visits and in-person delivery of mini courses. So, the second mini course Tensor Topology, by Chris Heunen from the University of Edinburgh, UK, was delivered purely online from November 16 to 25, 2021. It started with an introduction to monoidal categories and then explored their built-in notion of space.

The third mini course Equivariant Derived Categories took place at Dalhousie from April 25 to 29, 2022, and was also broadcast over the internet. It was delivered by Geoffrey Vooys, who is an AARMS postdoctoral fellow at Dalhousie, co-supervised by Dorette Pronk (Dal) and Yorck Sommerhäuser (MUN). Geoffrey Vooys delivered 5 lectures, starting from an introduction to sheaves and schemes and then focusing on more technical aspects of equivariant cohomology.



As restrictions were eased in the spring of 2022, it became possible to hold our fourth – and biggest – activity of the academic year 2021-22, namely, the workshop Groups, Rings, Lie and Hopf Algebras. IV, from May 30 to June 2, 2022, as a satellite event of the CMS Summer Meeting in St. John's (June 3-6). The previous workshop with this title was held by the Atlantic Algebra Centre in 2012, so the goal of the current workshop was to discuss the progress made in the focus areas of the CRG in the last decade. The organizers (Yuri Bahturin, Mikhail Kochetov, and Yorck Sommerhäuser) expect that the interaction of researchers during the meeting will have a strong impact on the mutual understanding of results, techniques, and current problems. We originally planned to conduct the workshop in person, because we consider this format the best way to enable exchange of ideas and networking. However, due to the remaining travel restrictions, delays with Canadian visas, and personal reasons, eight participants were unable to come to St. John's, so we decided to switch the workshop to the hybrid format. We are grateful to Memorial University and, in particular, the Department of Mathematics and Statistics for providing the equipment that made it possible to broadcast all talks. The workshop ran for four full days (Monday – Thursday) and attracted 36 participants from 8 countries (Argentina, Brazil, Canada, Germany, Israel, Sweden, UK, and USA). There were 20 participants from Canada, 13 of which from Atlantic Canada. The total number of students and postdoctoral fellows was 9. A major purpose of the workshop was to bring together leading experts and younger researchers, hence, providing a unique opportunity for the latter to advertise their results and to learn from the experts. In total, 29 talks were presented (16 research lectures, 1 public lecture, and 12 shorter communications), six of which by students and postdoctoral fellows. Three speakers at the workshop were women, even though the organizers reached out to many more. We hope that, as travel returns to normal and planning in-person events can once again be done more in advance, the diversity of participants at our workshops will improve.

3.1.4.3 Publications

Published or accepted:

- 1. Andruskiewitsch, N. On pointed Hopf algebras over nilpotent groups. Israel J. Math. (to appear)
- 2. Andruskiewitsch, N.; Angiono, I.; Heckenberger, I. Corrigendum: Liftings of Jordan planes. Glasgow Math. J. (to appear)
- 3. Andruskiewitsch, N.; Angiono, I.; Pevtsova, J.; Witherspoon, S. Cohomology rings of finite-dimensional pointed Hopf algebras over abelian groups. Research in the Mathematical Sciences 9 (2022), no. 1, Paper No. 12, 132 pp.
- 4. Andruskiewitsch, N.; Angiono, I.; Rossi Bertone, F. Lie algebras arising from Nichols algebras of diagonal type. Int. Math. Res. Notices (to appear)
- 5. Andruskiewitsch, N.; Dumas, F.; Peña Pollastri, H. On the double of the Jordan plane. Ark. Mat. (to appear)
- 6. Andruskiewitsch, N.; and Peña Pollastri, H. On the double of the (restricted) super Jordan plane. New York J. Math. (to appear)
- 7. Bahturin, Yu. Identical relations in Lie algebras. Second edition. De Gruyter Expositions in Mathematics, 68. De Gruyter, Berlin, 2021. xxv+514 pp.



- 8. Bahturin, Yu. Some thoughts on the current state of the theory of identical relations in Lie algebras. Polynomial identities in algebras, 1–24, Springer INdAM Ser., 44, Springer, Cham, 2021.
- 9. Bahturin, Yu.; Shihadeh, A. Tensor products of graded-simple sl_2(C)-modules, Turkish Journal of Mathematics, 46 (2022), 1619-1643.
- Baird, T.J.; Cornwell, P.; Cox, G.; Jones, C.; Marangell, R. Generalized Maslov indices for non-Hamiltonian systems. SIAM J. Math. Anal. 54 (2022), 1623–1668.
- 11. Baird, T.J.; Heydari, N. Cohomology of quotients in real symplectic geometry. Algebraic & Geometric Topology (to appear)
- 12. Benkart, G.; Biswal, R.; Kirkman, E.; Nguyen, V.C.; Zhu, J. Tensor representations for the Drinfeld double of the Taft algebra. J. Algebra 606 (2022), 764–797.
- 13. Benkart, G.; Biswal, R.; Kirkman, E.; Nguyen, V.C.; Zhu, J. McKay matrices for finite-dimensional Hopf algebras. Canad. J. Math. 74 (2022), no. 3, 686–731.
- 14. Bergh, P.A.; Plavnik, J.Y.; Witherspoon, S. Support varieties for finite tensor categories: complexity, realization, and connectedness. J. Pure Appl. Algebra 225 (2021), no. 9, 21 pp.
- Bian, X.; Selinger, P. Generators and relations for 2-qubit Clifford+T operators. To appear in: Proceedings of the 19th International Conference on Quantum Physics and Logic (QPL 2022), Oxford, 2022.
- Bian, X.; Selinger, P. Generators and relations for U_n(Z[1/2,i]). In: Proceedings of the 18th International Conference on Quantum Physics and Logic (QPL 2021), Gdansk, Poland, Electronic Proceedings in Theoretical Computer Science 343, 145-164, 2021.
- 17. Briggs, B.; Witherspoon, S. Hochschild cohomology of twisted tensor products. Math. Z. 301 (2022), no. 2, 1237-1257.
- 18. Calugareanu, G.; Zhou, Y. Rings with fine idempotents. J. Algebra Appl. 21 (1) (2022), 2250013.
- 19. Cherevatsky, D.; Smirnov, R. G. A novel approach to sharacterizing the relationship between economic growth and energy consumption. Economy of Ukraine. 2021 (12), 57–70.
- 20. Cherevatsky, D.; Smirnov, R. G. On the correlation between GDP and energy consumption in macroeconomic development. Econ. Industry, 2021 2 (94), 58-69.
- 21. Cruttwell, G.; Gallagher, J.; Pacaud Lemay, J.-S.; Pronk, D. Monoidal reverse differential categories. Mathematical Structures in Computer Science (accepted)
- 22. Demer, E.; Selinger, P.; Wang, K. All passable games are realizable as monotone set coloring games. To appear in: Games of No Chance 6, Cambridge University Press, 2022.
- 23. Draper, C.; Elduque, A. Real simple symplectic triple systems. Anal. Math. Phys. 12 (2022), Paper No. 69, 46 pp.
- 24. Elduque, A. Non-group gradings on simple Lie algebras. Linear Algebra Appl. 640 (2022), 149-161.
- 25. Elduque, A.; Kochetov, M. Graded-division algebras and Galois extensions. J. Pure Appl. Algebra 221 (2021), 106773, 34 pp.
- 26. Elduque, A.; Kochetov, M.; Rodrigo-Escudero, A. Gradings on associative algebras with involution and real forms of classical simple Lie algebras. J. Algebra 590 (2022), 61-138.
- 27. Evans, D.E.; Gannon, T. Reconstruction and local extensions for twisted group doubles, and permutation orbifolds. Trans. Amer. Math. Soc. 375 (4) (2022), 2789–2826.
- 28. Farnsteiner, J.; Schweigert, C. Frobenius-Schur Indicators and the Mapping Class Group of the Torus. Lett. Math. Phys. 112 (2022), Paper No. 39, 30 pp.
- 29. Flandoli, I.; Lentner, S. Algebras of non-local screenings and diagonal Nichols algebras, SIGMA Symmetry Integrability Geom. Methods Appl. 18 (2022), Paper No. 018, 81 pp.



- Fu, P.; Kishida, K.; Ross, N.J.; Selinger, P. A biset-enriched categorical model for Proto-Quipper with dynamic lifting. To appear in: Proceedings of the 19th International Conference on Quantum Physics and Logic (QPL 2022), Oxford, 2022.
- 31. Fu, P.; Kishida, K.; Selinger, P. Linear dependent type theory for quantum programming languages. Logical Methods in Computer Science (to appear)
- 32. Fuchs, J.; Schaumann, G.; Schweigert, C. A modular functor from state sums for finite tensor categories and their bimodules. Theory and Applications of Categories 38 (2022) 436-594.
- Galindo, C.; Jaklitsch, D.; Schweigert, C. Equivariant Morita theory for graded tensor categories. Bull. Belgian Math. Soc. (accepted)
- 34. Gandhi, R.; Savage, A.; Zaynullin, K. Diagrammatics for F4. Bull. London Math. Soc. (to appear)
- 35. Karadag, T.; Witherspoon, S. Lie brackets on Hopf algebra cohomology. Pacific J. Math. 316 (2022), no. 2, 395-407.
- 36. Kashina, Y.; Sommerhäuser, Y. On Cores in Yetter-Drinfel'd Hopf Algebras. Journal of Algebra 583 (2021), 89-125
- Kashina, Y.; Sommerhäuser, Y. On Biproducts and Extensions. In: N. Andruskiewitsch, G. Liu, S. Montgomery, Y. Zhang (ed.): Hopf Algebras, Tensor Categories and Related Topics, Contemp. Math., Vol. 771, Amer. Math. Soc., Providence, 2021, 195-223
- 38. Klyachko, A.A.; Miroshnichenko, V.M.; Olshanskii, A.Yu. Finite and nilpotent strongly verbally closed groups. Journal of Algebra and its Applications (accepted)
- Lanini, M., Zainoulline, K. Twisted quadratic foldings of root systems. St. Petersburg Math. J. 33 (1) (2022), 65-84.
- 40. Lenart, C.; Su, C.; Zainoulline, K.; Zhong, C. Geometric properties of the Kazhdan-Lusztig Schubertbasis. Algebra and Number Theory (to appear)
- Li, S.M.; Ross, N.J.; Selinger, P. Generators and relations for the group O_n(Z[1/2]). In: Proceedings of the 18th International Conference on Quantum Physics and Logic (QPL 2021), Gdansk, Poland, Electronic Proceedings in Theoretical Computer Science 343, 210-264, 2021.
- 42. Makary, J.; Ross, N.J.; Selinger, P. Generators and relations for real stabilizer operators. In: Proceedings of the 18th International Conference on Quantum Physics and Logic (QPL 2021), Gdansk, Poland, Electronic Proceedings in Theoretical Computer Science 343, 14--36, 2021.
- 43. Martinez-Pedroza, E.; Rashid, F. A note on hyperbolically embedded subgroups. Communications in Algebra 50 (2022), 1459-1468
- 44. Martínez-Pedroza, E.; Sánchez Saldaña, L.J. Bowditch Taut Spectrum and dimensions of groups. Michigan Mathematical Journal (in press)
- Mastnak, M. Appendix A for "Dispersing representations of semi-simple subalgebras of complex matrices" by L.W. Marcoux, H. Radjavi, and Y. Zhang. Linear Algebra and Applications 642 (2022), 218-220.
- 46. Olshanskii, A.Yu.; Sapir M.V. Algorithmic problems in groups with quadratic Dehn function. Groups, Geometry, and Dynamics (accepted)
- 47. Premet, A.; Topley, L. Modular representations of Lie algebras of reductive groups and Humphreys' conjecture. Adv. Math. 392 (2021), Paper No. 108024, 40 pp.
- 48. Pronk, D.; Scull, L. Bicategories of fractions revisited: towards small homs and canonical 2-cells. Theory and Applications of Categories, Vol. 38, No. 24, 2022, pp. 913–1014.
- 49. Selinger, P. On the combinatorial value of Hex positions. Integers 22:G3, 2022.
- 50. Shepler, A.V.; Witherspoon, S. Gerstenhaber brackets for skew group algebras in positive characteristic. Transformation Groups 27 (2022), no. 1, 295-309.



- Smirnov, R.G.; Wang, K.; Wang, Z. The Cobb-Douglas production function for an exponential model. In: Terzioğlu, M.K. (ed.) Advances in Econometrics, Operational Research, Data Science and Actuarial Studies. Contributions to Economics. Springer, 1-12, 2022.
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- 53. Tang, G.; Zhou, Y. Nil G-cleanness and strongly nil G-cleanness of rings. J. Algebra Appl. 21 (4) (2022), 2250077.
- 54. Zainoulline K. The canonical dimension of a semisimple group and the unimodular degree of a root system. International Math. Research Notices (to appear)
- 55. Zainoulline, K. Localized operations on T-equivariant oriented cohomology of projective homogeneous varieties, J. Pure Appl. Algebra 226 (3) (2022), 17pp.
- 56. Zhou, Y. A multiplicative dual of nil-clean rings. Canad. Math. Bull. 65 (2022), 39-43.
- 57. Zhou, Y. Generalized fine rings. J. Algebra Appl. 21 (3) (2022), 2250060.
- 58. Zhou, Y. Left uniquely generated elements in rings. Comm. Algebra 49 (9) (2021), 3825-3836.

Submitted:

- 1. Andruskiewitsch, N.; Bagio, D.; Flôres, D.; Della Flora, S. On the Laistrygonian Nichols algebras that are domains.
- 2. Angiono, I.; Lentner, S.; Sanmarco, G. Pointed Hopf algebras over non-abelian groups with non-simple standard braidings.
- 3. Arora, S.; Martínez-Pedroza, E. Topological groups with a compact open subgroup, coherence and relative hyperbolicity.
- 4. Bahturin, Yu.; Olshanskii, A. Nilpotent algebras, implicit function theorem, and polynomial quasigroups.
- 5. Baird, T. E-polynomials of character varieties of real curves.
- 6. Bustillo Vazquez, P.; Pronk, D.; Szyld, M. The three F's for bicategories I: localization by fractions is exact.
- 7. Cruttwell, G.; Lambert, M.; Pronk, D.; Szyld, M. Double fibrations.
- 8. Daza-García, A.; Elduque, A.; Sayin, U. From octonions to composition superalgebras via tensor categories.
- 9. Faitg, M.; Gainutdinov, A.; Schweigert, C. Davydov-Yetter cohomology and relative homological algebra.
- 10. Fuchs, J.; Galindo, C.; Jaklitsch, D.; Schweigert, C. Spherical Morita contexts and relative Serre functors.
- 11. Fuchs, J.; Schweigert, C.; Yang, Y. String-net construction of RCFT correlators.
- 12. Hughes, S.; Martínez-Pedroza, E. Hyperbolically embedded subgroups and quasi-isometries of pairs.
- 13. Hughes, S.; Martínez-Pedroza, E.; Sánchez Saldaña, L.J. A survey on quasi-isometries of pairs: invariants and rigidity.
- 14. Irving, J.; Rattan, A. k-factorizations of the full cycle and generalized Mahonian statistics on k-forests.
- 15. Lee, J.; Martínez-Pedroza, E.; Rodríguez-Quinche, J.F. Coarse geometry of the Cops and robber game.
- 16. Olshanskii, A. Yu.; Shpilrain, V. Linear average-case complexity of algorithmic problems in groups.



3.1.5 Mathematical Foundations and Applications of Scientific Machine Learning

3.1.5.1 Members

Academic Administrator: Alex Bihlo

Collaborators from AARMS member universities

- Jahrul Alam (Mathematics and Statistics, Memorial University)
- Alex Bihlo (Mathematics and Statistics, Memorial University) Academic coordinator
- Stijn De Baerdemacker (Chemistry, University of New Brunswick)
- Ronald Haynes (Mathematics and Statistics, Memorial University)
- Vigar Husain (Mathematics and Statistics, University of New Brunswick)
- Theodore Kolokolnikov (Mathematics and Statistics, Dalhousie University)
- Peter Lelievre (Mathematics and Computer Science, Mount Allison University)
- JC Loredo-Osti (Mathematics and Statistics, Memorial University)
- Scott MacLachlan (Mathematics and Statistics, Memorial University)
- Dr. Alison Malcolm (Earth Sciences, Memorial University) Equity, Diversity & Inclusion coordinator
- Paul Muir (Mathematics and Computing Science, St.\ Mary's University)
- Jeffrey Picka (Mathematics and Statistics, University of New Brunswick)
- Jiju Poovvancheri (Mathematics and Computing Science, St.\ Mary's University)
- Nicholas Touikan (Mathematics and Statistics, University of New Brunswick)
- Hamid Usefi (Mathematics and Statistics, Memorial University)
- Asokan Variyath (Mathematics and Statistics, Memorial University)
- Nanwei Wang (Mathematics and Statistics, University of New Brunswick)

Collaborators from other institutions

- Leopold Haimberger (Meteorology and Geophysics, University of Vienna)
- Luke Olson (Computer Science, University of Illinois)
- Roman O. Popovych (Mathematics, University of Vienna)
- Francis Valiquette (Mathematics, Monmouth University)
- Andy Wan (Mathematics and Statistics, University of Northern British Columbia)
- Justin Wan (Computer Science, University of Waterloo)
- Matt West (Mechanical Science and Engineering, University of Illinois)



3.1.5.2 Activities

CRG workshop at Memorial University

The main event for the CRG was a 3-day hybrid workshop from June 1–3 at Memorial University of Newfoundland. More than 20 CRG members along with their students attended the meeting in person, with several more joining online. The plenary speakers for this CRG meeting were:

- 1. Yifan Sun (Stony Brook University): Continuous time trajectories of optimization methods
- 2. Simone Brugiapaglia (Concordia University): Two case studies in the mathematical foundations of deep learning: rating impossibility and practical existence theorems

A total of 19 talks were given by CRG members and their students, and the final book of abstracts can be found on the CRG website. From the feedback gathered from participants, this workshop did start several preliminary discussions about new collaborations among participants, which we hope on capitalizing in a prospective second year for this CRG.

CMS session on Scientific Machine Learning

The date for the CRG meeting was set to be just before the 2022 CMS summer meeting that took place at Memorial University of Newfoundland from June 3–6. In the course of this CMS meeting, CRG members Alex Bihlo, Simone Brugiapaglia and Hamid Usefi, together with Ben Adcock organized another session on Scientific Machine Learning. This session drew in an additional crowd of speakers, many of which also attended the CRG meeting, thus facilitating wider discussions among researchers in Scientific Machine Learning.

Seminar series on Scientific Machine Learning

This CRG organized the new online AARMS Scientific Machine Learning Seminar series. A total of 10 seminars were organized over the course of the 2021–2022 academic year. The topics covered in these seminars were intentionally broad, so as to cover both theoretical developments and practical applications of Scientific Machine Learning. Correspondingly, a variety of talks were given, ranging from fundamental questions such as the design of equivariant convolutional layers to the future of weather prediction using machine learning. As indicated in the original proposal, for the speakers that gave consent, the recorded talks for these seminars were then uploaded to YouTube (using the official AARMS YouTube channel). Top attendance for these virtual seminars were around 30 participants, hailing from all over North America and Europe.

3.1.5.3 Publications

1. R. Brecht and A. Bihlo, 2022. Computing the ensemble spread from deterministic weather predictions using conditional generative adversarial networks, arXiv:2205.09182.



- 2. R. Brecht, L. Bakels, A. Bihlo and A. Stohl, 2022. Improving trajectory calculations using deep learning inspired single image superresolution, arXiv:2206.04015.
- 3. A. Taghibakhshi, N. Nytko, T. Zaman, S. MacLachlan, L. Olson and M. West, 2022. Learning Interface Conditions in Domain Decomposition Solvers, arXiv:2205.09833.

3.1.6 Numerical Solution of Geophysical Inverse Problems

3.1.6.1 Members

Academic Administrator: Peter Lelièvre, Mount Allison University

Collaborators from AARMS Member Universities

- Karl Butler, University of New Brunswick
- Colin Farquharson, Memorial University of Newfoundland
- Ronald Haynes, Memorial University of Newfoundland
- Nathan Johnston, Mount Allison University
- Scott MacLachlan, Memorial University of Newfoundland

Collaborators from Other Universities

- Karl Fabian, Norwegian University of Science and Technology, Trondheim, Norway
- Suzanne McEnroe, Norwegian University of Science and Technology, Trondheim, Norway
- Thomas Günther, Leibniz Institute of Applied Geophysics, Hannover, Germany
- Florian Wagner, RWTH Aachen University, Aachen, Germany

3.1.6.2 Activities

AARMS Geophysical Inverse Problems Discussion Series (Summer 2022)

This discussion series met every two weeks on Zoom. In each meeting we discussed a different published paper that introduced a geophysical inverse problem that involved a more difficult numerical optimization problem to solve. This first phase of discussions helped to identify and better understand some of these types of more complicated inverse problems, from an optimization perspective. We met seven times from May through August. There were a total of 23 attendees for the entire series, with between 9 and 14 in attendance at any particular meeting, and 10 regular attendees (in attendance for half the meetings or more). These roughly hour long discussions focussed on the main topic identified in our proposal: numerical optimization for geophysical inversion. Our discussions covered all proposed subtopics, including joint and constrained inversion, unstructured parameterizations, lithological and surface geometry inversion, and derivative-free and global optimization methods. This first planned phase of the



discussion series was designed to involve more applied discussions prior to further focussed theoretical attention of the problems identified. The first phase served its purpose by:

- gathering a large and diverse group of attendees, from many different educational backgrounds, and at different stages in their careers, from various different universities;
- identifying topics in the field where knowledge was lacking, and where future collaborative research may focus;
- developing future collaborative plans between participants.

HQP Support

Several students and PDFs were co-supervised by CRG members over the first year. CRG funds were committed to their ongoing support.

3.1.6.1 Publications

Papers

- H. Jahandari, P. Lelievre and C. G. Farquharson, Forward modelling of direct-current resistivity data on unstructured grids using an adaptive mimetic finite-difference method, Geophysics, submitted July, 2022.
- Z. Pastore, P. Lelievre, S. A. McEnroe and N. S. Church, 2022, 3D joint inversion of scanning magnetic microscopy data, Geophysical Research Letters, 49, e2021GL096072.

Presentations

- X. Lu, C. Galley, P. Lelievre and C. Farquharson, 2022, Surface geometry inversion of marine CSEM data, EM Induction Workshop, C, es, mei, Turkey, September 2022.
- X. Lu, C. Farquharson and P. Lelievre, 2022, Computer modelling of electromagnetic and direct-current resistivity data for mineral exploration, GAC-NL Annual Technical Meeting, St. John's, NL, February 2022.

3.2 AARMS Postdoctoral Fellowship Program

Each year AARMS conducts a competition to award Postdoctoral Fellowships to highly qualified personnel who received their PhD within the last 4 years. AARMS provides a portion of the funding for these positions, which must be at least matched by other research funding from the host university. The program is successful in attracting highly qualified young researchers to universities in New Brunswick and the rest of the Atlantic region. AARMS also makes available a travel grant of \$1,500/year for each postdoc.

3.2.1 Postdoctoral Fellow Biographies

The following postdoctoral fellows have been supported by AARMS in the 2020/21 fiscal year:





Matthew Amy completed his doctorate in 2019 from the University of Waterloo, Canada. Matthew worked as a postdoctoral fellow at Dalhousie University with Julien Ross and Peter Selinger. His research interests include formal mathematical models of quantum computation and their application to the practical problems of quantum programming and compilation.



Pranabesh Das received his Ph.D. from the Indian Statistical Institute in 2018. After completing his doctorate degree, he joined the University of Waterloo, Canada as a postdoctoral fellow with Cam Stewart where he stayed for the next three years. In July 2021 he joined Dalhousie University as a postdoc working with Karl Dilcher. His research interests lie in number theory, more specifically in Diophantine equations, Diophantine approximations, number sequences, and transcendence.



Melissa Huggan completed her PhD in 2019 at Dalhousie University. She then joined Ryerson University as an NSERC postdoctoral fellow working under the supervision of Anthony Bonato. She has been working as an AARMS postdoctoral fellow under the supervision of Margaret-Ellen Messinger at Mount Allison University. Melissa's research interests are in combinatorial game theory, graph theory, and pursuit-evasion games.



Blake Keeler completed his Ph.D. in 2021 at the University of North Carolina at Chapel Hill under the supervision of Yaiza Canzani. His thesis work was on the subject of high-frequency spectral asymptotics on Riemannian manifolds. His other research interests include energy decay for the damped wave equation and dispersive estimates for operators on manifolds with conic singularities. Blake is currently dividing his time between McGill University as a CRM-ISM postdoctoral fellow and Dalhousie University as an AARMS postdoctoral fellow. His current research goals are centered around applying techniques



from microlocal analysis and Riemannian geometry to understand Laplace eigenfunctions in a variety of geometric settings.



Juan Margalef completed his Ph.D. in mathematical physics in 2018 under the supervision of Fernando Barbero and Eduardo Villaseñor. He did his first postdoc at Penn State University with Abhay Ashtekar. Currently, he is a postdoc at MUN with Ivan Booth and Hari Kunduri. His work revolves around the mathematical aspects of General Relativity and Field Theories. His main achievement is the development of the relative bicomplex framework, an essential generalization of the standard covariant phase space in the presence of boundaries, which has been used by him and his collaborators to solve several long-lasting problems. His goal now is to apply these techniques to some horizons problems in which the group of MUN is a world-leading expert. Juan Margalef is also passionate about science communication and outreach.



Martin Szyld completed his PhD in 2015 from the University of Buenos Aires, Argentina, where he also worked as a postdoctoral fellow with Eduardo Dubuc. He has been working at Dalhousie University with Dorette Pronk. His main research interests are in topos theory and in higher category theory.



Geoffrey Vooys completed his PhD at the University of Calgary in Summer 2021 specializing in arithmetic geometry and category theory. He was working as a postdoctoral fellow under the supervision of Dorette Pronk at Dalhousie. Geoff's main research interests primarily include equivariant geometry, arithmetic geometry, (higher) category theory, descent theory, and applications of geometry and category theory to the Langlands Programme for p-adic groups.





Abraham Westerbaan obtained his doctorate in 2019 from the Radboud University. His research revolves around the use of von Neumann algebras to make (categorical) models for quantum programming languages. In his spare time he enjoys rock climbing. He was working with Peter Selinger at Dalhousie University from September 2020.



Nomaan X completed his PhD at the Raman research institute in April 2021 working on various aspects of quantum field theory on causal sets. He is going to join the gravity group at the University of New Brunswick. Nomaan's research interests include causal sets, discrete geometry and more broadly, computational methods in quantum gravity. He is also interested in classical and semi-classical general relativity.



Shuwen Xue completed her Phd in August 2021 at Auburn University under the supervision of Dr. Wenxian Shen. She was working as an AARMS postdoctoral fellow at Memorial University of Newfoundland with Dr. Xiaoqiang Zhao. Her research interests are in partial differential equations, dynamical systems and mathematical biology. More specifically, she works on population dynamics under the influence of chemotaxis and/or climate change.

3.2.2 Incoming Postdoctoral Fellows

We held our annual postdoctoral fellowship competition in the autumn of 2021. Six new postdoctoral fellows were appointed to start in the autumn of 2022: **Dipanjan Dey**, who will work at Dalhousie under the supervision of Alan Coley; **Luca Marchetti**, who will work at the University of New Brunswick under the supervision of Vigar Husain, Sanjeev Seahra and Edward



Wilson-Ewing; **Alexandre Landry**, who will work at Dalhousie under the supervision of Alan Coley; and **Fanheng Xu**, who will work at Memorial under the supervision of Jie Xiao;

All of these postdoctoral fellowships starting in the autumn of 2022 will be funded by AARMS at the level of \$25,000/year. Matching funds are provided by their supervisor and host university. AARMS also makes available a travel fund of \$1500/year for each postdoc.

3.3 AARMS Summer School

During a four week period every summer AARMS invites highly regarded faculty from around the world to deliver graduate courses in the mathematical sciences and their applications. In 2021 and 2022 the lingering pandemic made it too risky to plan for an in-person Summer School. In lieu of this program, AARMS continued to offer a series of Online Advanced Courses.

3.4 AARMS Industrial Problem Solving Workshop

The AARMS Industrial Problem Solving Workshop (IPSW) was held online between July 26 and August 6. The workshop featured four problems from companies and governments, which are described in detail below:

- The Black Arcs (TBA) builds agent-based microsimulations to explore how changes impact a community. These microsimulations use a synthetic population layered on top of real geospatial data and simulate travel activities using an implementation of Miller and Roorda's Travel Activity Scheduler for Household Agents (TASHA). One emergent property that can come from these microsimulations is a synthetic contact matrix generated from the activity of the agents over a period of time. Contact matrices have proven to be a valuable tool for predicting the spread of infectious diseases, with COVID-19 being a recent example. Specifically, these contact matrices can directly inform parameters in ordinary differential or network based models of disease spread. This challenge looks to investigate how this type of disease modelling can be applied to synthetic contact networks generated in TBA's microsimulations in order to explore a variety of infection scenarios.
- The City of Fredericton operates a parking garage that can be accessed on a pay-as-you-go (hourly) basis or using monthly/daily parking permits. The City wants to ensure there is always some space available for hourly parking to support downtown businesses while keeping the garage as full as possible with monthly permit holders to ensure efficient use; i.e., if too many parking permits are sold, then there will not be enough spaces for pay-as-you-go users. In order to find the optimal number of permits sold, students will have access to a dataset generated by automated cameras operated by Hotspot Parking. These have recorded a large sample of the license plates of cars



using the parking garage over a 6+ month period, which can be cross-referenced with a database of permit holders and hence used to model the permit holder demand for parking spaces as a function of the time of day.

- CFM (a JDI subsidiary) uses drones to inspect critical infrastructure in various industry sectors. Multiple flights of the same structures are flown over time to determine whether changes (corrosion, structural damage, etc.) have taken place. Currently, the process is manually-driven and does not offer automated change detection for the large and often complex structures we inspect. This process is cumbersome and offers little value to the end-user. An automated means of detecting change using background information from CFM's inspection group and drone imagery may offer significant cost savings and value to our many customers. The goal of this problem is to create an automated workflow where drone imagery from multiple campaigns is overlaid and compared for any visible change using relevant inspection criteria and analytics. The preferable outcome is a user-friendly visual tool that displays any areas where change has been automatically detected between campaigns. Visualization tools are currently available in the market place, however the change detection algorithm needs to be developed.
- The New Brunswick Department of Natural Resources and Energy Development requires the development of a deer population estimation model. The Fish and Wildlife Branch currently uses a population dynamics model which accounts for annual population change (births and deaths) that provides information on trends but not abundance. A model is required that will produce reliable abundance estimates at a Wildlife Management Zone level and predict future populations under various harvest and climatic scenarios. Existing digital data that may be used for statistical analysis includes harvest data (sex/age), vehicle collision data (age/sex, female productivity), and summer/winter survival rates.

The IPSW involved over 50 participants over two weeks in midsummer. We fully expect multiple new funded research collaborations to arise from the 2021 IPSW, and will report on this in the future.

This year's IPSW was sponsored by Acadian, CANSSI, NBIF, Springboard Atlantic, and UNB.

3.5 AARMS Online Advanced Courses

We continued to offer Online Advanced Courses in lieu of our annual Summer School, although with a gradual return to in-person instruction there was a declining appetite for purely online instruction. The courses in Fall 2021 which were attended by 11 students were:

Computational Statistics, taught by Armin Hatefi (Memorial)

We will cover some fundamental numerical techniques for statistical inference such as Maximum Likelihood method, Bayesian method, Method of Moments, Optimization and Integration, EM



algorithms, Markov Chain and Monte Carlo and other related topics. Some theoretical properties of the methods will also be discussed. We will extensively use R statistical software which is freely available for Linux, Macintosh and Windows OS. Students should have already taken undergraduate Probability/Mathematical Statistics courses equivalent to STAT 3411 offered at Memorial University and previous exposure to R programming.

Graph Theory, taught by David Pike (Memorial)

The course will focus on concepts and proof techniques pertaining to Graph Theory. Three areas will be covered: matchings (including covers, the Konig-Egervary theorem, Hall's theorem, Tutte's 1-factor theorem), connectivity (including edge-connectivity, Menger's theorem, Dirac's fan lemma, the Chvatal-Erdos theorem), and network flows (including cuts, the Ford-Fulkerson algorithm, Menger's theorem). Previous exposure to basic concepts in Graph Theory, such as from an undergraduate course in the subject, is expected.

The courses offered in Winter 2022, which were attended by 18 students, were:

Deep Learning and Deep Reinforcement Learning, taught by Alex Bihlo (Memorial) This course will provide a short overview of classical methods of machine learning before providing an introduction to the areas of deep learning, reinforcement learning, and deep reinforcement learning. An introduction to TensorFlow and Keras will be provided.

Discrete Random Structures, taught by Jeannette Janssen, (Dalhousie)

This course will cover basics of probability and stochastic processes, and then focus on areas where probability and combinatorics interact. Topics include: probabilistic method, stochastic graph models for complex networks, probabilistic algorithms. Probabilistic techniques include: expectation and concentration of random variables, stochastic processes, conditional expectation, Markov chains, martingales, branching processes.

Hopf Algebras, taught by Yorck Sommerhäuser (Memorial)

Hopf algebras are algebras for which it is possible to form the tensor product of two representations. A typical example is the group algebra of a group. Hopf algebras play a role in remarkably many areas of mathematics, such as algebraic topology, Lie theory, or category theory, and also in physics, for example in the theory of exactly solvable models in statistical mechanics, conformal field theory, and the theory of renormalization. The course will provide an introduction to the basics of Hopf algebra theory. Emphasis will be on results that generalize classical theorems from group theory, like Lagrange's theorem, Cauchy's theorem, and Maschke's theorem.

Numerical Methods for Solving Differential Equations, taught by Sanjeev Seahra (UNB)

The principal goal of this course is to give students "hands-on" experience in solving ordinary and partial differential equations (ODEs and PDEs) using (primarily) finite difference methods. The emphasis will be on practical scientific computing; i.e., the construction of numerical algorithms to deal with actual problems in the physical, biological or engineering sciences.



Pursuit-evasion Problems, taught by Danny Dyer (Memorial)

This course will introduce the concepts of the cop and robber model in graph theory; characterize those graphs that are k-cop-win; examine Meyniel's conjecture, and families of graphs for which Meyniel's conjecture are met; consider the cop-number of various graph products; consider the cop number of graphs embeddable in different surfaces; and consider variants of the classic model in which cops and/or robbers have asymmetric movements and information.

In Winter 2022, AARMS also offered two courses in collaboration with the NSERC funded network Mathematics for Public Health (MfPH). Registration was through the Fields Institute:

- Infectious disease modelling: theory and methods, taught by Seyed Moghadas (York University)
- Machine learning statistical methods for disease transmission modelling, taught by Nathaniel Osgood (University of Saskatchewan)

3.6 Workshops and Conferences

Due to pandemic restrictions the great majority of workshops or conferences have been held online. To facilitate these needs, AARMS provided access to a ZOOM license which could be scaled up for very large meetings. There were a few in-person events. They are all listed below.

AARMS Scientific Machine Learning Seminar: Scott MacLachlan (Memorial) WebEx seminar March 29, 2022 @ 11:00 am - 12:00 pm

Dalhousie-AARMS AAMP Seminar: Manuela Girotti (Saint Mary's Uni.) Zoom seminar March 25, 2022 @ 4:00 pm - 5:00 pm

Atlantic Canada Actuarial Student Conference University of Prince Edward Island March 25, 2022 - March 26, 2022

Atlantic Graph Theory Seminar: Theodore Kolokolnikov (Dalhousie) Online via Zoom March 16, 2022 @ 3:30 pm - 4:30 pm

Dalhousie-AARMS AAMP Seminar: Justin Tzou (Macquarie U.) Zoom seminar March 11, 2022 @ 4:00 pm - 5:00 pm



Atlantic Graph Theory Seminar: Pjotr Buys (University of Amdsterdam) Online via Zoom March 9, 2022 @ 3:30 pm - 4:30 pm

AARMS Scientific Machine Learning Seminar: Simone Brugiapaglia (Concordia University) WebEx seminar March 8, 2022 @ 11:00 am - 12:00 pm

AARMS Scientific Machine Learning Seminar: Stijn De Baerdemacker (UNB) WebEx seminar March 1, 2022 @ 11:00 am - 12:00 pm

AARMS Scientific Machine Learning Seminar: Alison Malcom (Memorial University) WebEx seminar February 22, 2022 @ 11:00 am - 12:00 pm

Dalhousie-AARMS AAMP Seminar: Micah Milinovich (U. Mississippi) Zoom seminar February 18, 2022 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: Ferenc Bencs (University of Amsterdam) Zoom seminar February 16, 2022 @ 3:30 pm - 4:30 pm

Dalhousie-AARMS AAMP Seminar: Cyril Letrouit (École Normale Supérieure) Zoom seminar February 11, 2022 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: Margaret-Ellen Messinger (Mount Allison University) Zoom seminar February 9, 2022 @ 3:30 pm - 4:30 pm

Atlantic Graph Theory Seminar: Melissa Huggan (Mount Allison) Zoom seminar February 2, 2022 @ 3:30 pm - 4:30 pm

Atlantic Graph Theory Seminar: Andrea Burgess (UNB) Zoom seminar January 26, 2022 @ 3:30 pm - 4:30 pm

Atlantic Graph Theory Seminar: Robert Kooij (Delft University of Technology) Zoom seminar January 19, 2022 @ 3:30 pm - 4:30 pm



Atlantic Graph Theory Seminar: Iain Moffat (Royal Holloway, University of London) Zoom seminar January 12, 2022 @ 3:30 pm - 4:30 pm

Atlantic Graph Theory Seminar: Sandra Kingan (Brooklyn College and Graduate Center, CUNY) Zoom seminar December 8, 2021 @ 3:30 pm - 4:30 pm

AARMS Scientific Machine Learning Seminar: Peter Dueben (ECMWF) WebEx seminar December 7, 2021 @ 11:00 am - 12:00 pm

Dalhousie-AARMS AAMP Seminar: Jesse Gell-Redman (University of Melbourne) Zoom seminar December 3, 2021 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: James Preen (Cape Breton University) Zoom seminar December 1, 2021 @ 3:30 pm - 4:30 pm

AARMS Scientific Machine Learning Seminar: Ben Adcock (Simon Fraser University) WebEx seminar November 23, 2021 @ 11:00 am - 12:00 pm

Dalhousie-AARMS AAMP Seminar: Amanda Young (Technical University of Munich) Zoom seminar November 19, 2021 @ 4:00 pm - 5:00 pm

University of New Brunswick Data Challenge University of New Brunswick (Fredericton Campus) November 19, 2021

Atlantic Graph Theory Seminar: Pavol Hell (SFU) Zoom seminar November 17, 2021 @ 3:30 pm - 4:30 pm

AARMS Scientific Machine Learning Seminar: Hamid Usefi (MUN) WebEx seminar November 9, 2021 @ 11:00 am - 12:00 pm

Dalhousie-AARMS AAMP Seminar: Nina Holden (ETH Zürich and the Courant Institute) Zoom seminar November 5, 2021 @ 4:00 pm - 5:00 pm



Atlantic Graph Theory Seminar: Jo Ellis-Monaghan (University of Amsterdam) Zoom seminar November 3, 2021 @ 3:30 pm - 4:30 pm

Dalhousie-AARMS AAMP Seminar: Perry Kleinhenz (Michigan State University) Zoom seminar October 29, 2021 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: Guss Regts (University of Amsterdam) Zoom seminar October 27, 2021 @ 3:30 pm - 4:30 pm

Formulating Success: Industry Research Connector 2021 Zoom seminar October 27, 2021 @ 1:00 pm - 3:00 pm

AARMS Scientific Machine Learning Seminar: Nicholas Touikan (University of New Brunswick) WebEx seminar October 26, 2021 @ 11:00 am - 12:00 pm

Atlantic Graph Theory Seminar: Viresh Patel (University of Amsterdam) Zoom seminar October 20, 2021 @ 3:30 pm - 4:30 pm

Dalhousie-AARMS AAMP Seminar: Ben Landon (University of Toronto) Zoom seminar October 15, 2021 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: Danny Dyer (Memorial University) Zoom seminar October 13, 2021 @ 3:30 pm - 4:30 pm

Atlantic Graph Theory Seminar: Anthony Bonato (Ryerson University) Zoom seminar October 6, 2021 @ 3:30 pm - 4:30 pm

Atlantic Algebra Centre Minicourse: Introduction to Schubert calculus via (nil-)Hecke algebras Zoom seminar September 21, 2021 - September 23, 2021

AARMS COVID-19 Seminar: Theodore Kolokolnikov (Dalhousie) Zoom seminar September 20, 2021 @ 3:00 pm - 4:30 pm



AARMS COVID-19 Seminar: Jane Heffernan (York) Zoom seminar August 23, 2021 @ 3:00 pm - 4:30 pm

17th Algorithms and Data Structures Symposium & 33rd Canadian Conference on Computational Geometry Dalhousie University August 9, 2021 - August 12, 2021

AARMS CRG Online Workshop on Financial Mathematics and Actuarial Science Online via Zoom August 6, 2021

AARMS COVID-19 Seminar: Lam Ho (Dalhousie) Zoom seminar July 26, 2021 @ 3:00 pm - 4:30 pm

AARMS Industrial Problem Solving Workshop 2021 July 26, 2021 - August 6, 2021

AARMS COVID-19 Seminar: Cindy Feng (Dalhousie) Zoom seminar July 12, 2021 @ 3:00 pm - 4:30 pm

Aiden Bruen 80th Birthday Geometry Conference Fields Institute June 13, 2021 - June 18, 2021

Session on Designs and Codes at the CMS 75+1 Anniversary Summer Meeting Online via Zoom June 7, 2021 - June 11, 2021

Connecting Women in Mathematics Across Canada (CWiMAC) Online via Zoom June 2, 2021 - June 3, 2021

AARMS COVID-19 Seminar: Tom Hurd (McMaster) Zoom seminar May 31, 2021 @ 3:00 pm - 4:30 pm

AARMS COVID-19 Seminar: Madeleine Gorman-Asal (University of New Brunswick Fredericton) Zoom seminar May 17, 2021 @ 3:00 pm - 4:30 pm



Canadian Student and Postdoc Conference on Gravity Online via Zoom May 4, 2021 - May 6, 2021

Microlocal Analysis: Theory and Applications Online Seminar Series May 3, 2021 - August 13, 2021

Groups acting on Trees: minicourse by Olga Kharlampovich Online via Zoom May 3, 2021 - May 7, 2021

AARMS COVID-19 Seminar: Ahmed Saif (Dalhousie) Zoom seminar April 21, 2021 @ 10:30 am - 11:30 am

Dalhousie-AARMS AAMP Seminar: Chunyi Gai (Dalhousie University) Zoom seminar April 9, 2021 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: Dr Jason Brown & Dr Corey DeGagne, Dalhousie University Zoom seminar April 7, 2021 @ 3:30 pm - 4:30 pm

3.7 Outreach

Pandemic restrictions during 2020-2021 also meant that many of our usual outreach programs did not take place. The exceptions are listed below.

Jr. Math and Computer Science Camp, run by researchers at Acadia University. July 5-9, 2021 The Junior Math and Computer Science Camp is an outreach initiative for students entering grades 5 and 6 in the Annapolis Valley region. Our aim is to create a high-quality academic camp that stimulates an interest and enjoyment of mathematics and computer science. This camp was cancelled in 2020 due to the Covid-19 pandemic. We opened registration on May 1st, two days into the second lockdown in Nova Scotia during the third wave of the pandemic. The participants in the camp were registered by their parents on a first-come, first-served basis with 8 spots reserved for males, 8 for females and 4 for non-binary participants. Given the challenging climate during the registration period, we extended our registration deadline until the end of June and received 16 participants (5 females, 10 males, and 1 non-binary). One of the participants received a bursary for their registration fee. The camp was 5 days in length, with three in-person days at Acadia University from 9am – 4:30pm and two virtual days from 10am – 3pm on Google Meet.





Connecting Math to Our Lives and Communities, run by researchers at St Francis Xavier University. May-June, 2021. Connecting Math to Our Lives and Communities held a five-week math camp reaching 37 students in grades P-8, all from visible minorities and living in remote areas. The camp took place at St. Francis Xavier University campus as well as within local



Mi'kmaw and African Nova Scotian communities. In order to ensure that the programming was accessible to all students, there were no fees or costs for any participants. Connecting Math to Our Lives and Communities (CMTOLC) programming aims to teach math and build interest in the subject by demonstrating the real-world connections and applications of math. CMTOLC takes a specific focus on connections between math and Mi'kmaq and African Nova Scotian culture, and



draws on the knowledge of elders and community members to create program materials and inform activity planning.

The CMTOLC 2021 camp focused on five different topics over the five weeks. The topics were Gardening, Math in Nature, Mazes and Labyrinths, Wayfinding and Navigation, and Food Sovereignty. Over the summer, the camp had a virtual kick-off and wrap-up each week and one in-person day per week for each community. Camp facilitators, all St.FX education and undergraduate students, travelled into communities and ran math-related activities. Examples of the activities done in-person include gardening and creating a garden journal, investigating symmetry with birch bark biting and tie-dye, solving and building mazes, and more. In addition, at the start of camp, all participants received kits with all the supplies they would need and binders containing instructions and information about cultural connections or real life applications for each activity. All participants could do some of the activities for each week at home, and share an image of their activity for a chance to win a math-related game at the end of each week. Examples of these activities included making watering cans, constructing a hummingbird feeder, drawing maps, basic knot tying, and more! These activities demonstrated the uses of many math skills including measurement, rate of flow, ratios, counting, etc. A note we received from one family said "We are so grateful for this camp experience. May we continue to decolonize education!"

Blundon Seminar

The Blundon Seminar is an annual (since 1982) three-day math camp for senior high school students from Newfoundland who are interested in mathematics and demonstrate consistently good performance in mathematics competitions. Participation in the math camp is by invitation only based on the results of preceding Blundon, COMC, Euclid, Fermat, and Cayley contests. During the seminar the students attend two one-hour talks given by professors from MUN on various mathematical topics and applications in science and engineering. There are several problem solving sessions as well as other activities such as Mathletics and Papers Chase.

Fundy Math League

This team-based math contest is for high school students (grade 9 - 12) in the surrounding area. Acadia faculty lead the events, with assistance from Acadia students and local teachers. Students across the province attend three team competitions during the year and the top teams compete at the provincial finals in Halifax

Math Buffet

Acadia University's Math Buffets take place over the school year and are a chance for students in grades 9-12 in Hants, Kings and Annapolis counties to explore new and interactive topics in mathematics.



Concours du Groupe d'action pour les mathematiques

This is a friendly competition that takes place every Fall open to all students (K-12) in the New-Brunswick's francophone school system. The purpose of the contest is not to assess students' procedural or problem-solving skills, but rather to have them see and talk about mathematics in a different way. Thus, this contest is accessible to all students, because everyone can participate at his or her own level.

AV Middle School Outreach

Acadia faculty and students offer math outreach activities to grades 7 and 8 at schools in the area. The format is hour-long sessions every 2 weeks.

3.8 New Programs

3.8.1 Junior Researcher Travel Support

We plan to allow graduate students and postdocs to apply for funds to attend national and international conferences and workshops. As travel from Atlantic Canada is generally more expensive, this will be of great service to junior mathematicians and their supervisors, helping HQP meet peers and find opportunities for collaboration and professional networking. Details yet to be determined.

3.8.2 Graduate Student Scholarship

In summer 2021, we launched a new graduate student scholarship program. These scholarships aim to provide extra incentive to attract excellent students to Atlantic Canada, and will contribute to a healthy exchange of students and ideas between universities across Canada. The first two scholarship winners, with prizes of \$5,000 each are:



Shivam Arora, PhD student at Memorial University supervised by Eduardo Martinez-Pedroza. Shivam Arora's area of specialization is in geometric group theory. Most of his work at Memorial has been on generalizing results from discrete groups to the larger class of totally disconnected locally compact groups. More specifically, he studies topological groups that admit nice actions on non-positively curved spaces, and uses geometric and cohomological techniques to understand their subgroups. His results have been published in top journals, and he has been an active participant in local

and international research conferences and workshops where he has contributed a number of short talks. Shivam also has a good record of assisting in outreach activities promoting science in



St. John's. His other interests include mathematical foundations of Neural networks, and he is a co-founder and machine learning engineer for a local start-up called Inverte in St. John's.



Deni Salj, Masters student at Dalhousie, supervised by Dorette Pronk. Deni started his research career at the University of Calgary where he studied topological data analysis (TDA) under the supervision of Dr. Kristine Bauer. He was initially interested in how geometry and topology, and general abstract theories of shapes and spaces, could be applied to solve real world problems such as analayzing highly dimensional data sets. More recently Deni has been studying category theory and in his undergraduate research with Dr. Bauer, he used a categorical notion of finite-difference operators called 'change-action

derivatives' to describe the so-called persistence diagrams of a tool called persistent homology under the TDA umbrella.

3.8.3 Doctoral Thesis Award

This program was intended to be launched in 2021, but was deferred for a year. We plan to offer thesis awards to graduating students in our region. These awards will allow the Atlantic mathematical community to celebrate together the achievements of our students, and will also serve as a bridge between our research communities by promoting Atlantic Canadian research. Special attention will be given to diversity in the award winners. We are currently planning on offering two awards at \$2500 each. The inaugural competition will commence in October 2022.

3.8.4 Equity, Diversity and Inclusion

In the fall of 2021 AARMS received a report which we had commissioned from EDI expert Reid Lodge on the structures, practices and policies of the organizations. The report laid out a roadmap for a continuous process of change. AARMS has adopted this process which contains the following steps:

- 1. Internal review, for gaps and shortcomings.
- 2. Creation of an EDI Action Plan
- 3. 12 month period of implementing change

The process started in Spring 2022 with the formation of a committee to assess gaps and shortcomings. This has led to an EDI action plan for the 2022/23 academic year. One of the steps already implemented is the formation of a permanent EDI committee. In spring of 2023 the cycle will begin again.



4 Governance and Administration

There were no significant changes in governance and administration in 2021/22.

5 Accounts

See following pages.



Income and Expenditure Account April 1, 2021 - March 31, 2022

	accruals basis	cash flow basis wit	h adjustments
<u>Income</u>	¢	<u>2020-2021</u>	
Corriad forward from provinue year	⊅ 200.226	D	
	200,320	41,083	
Commitments written off	69,700	0	
NSERC DIS	283,760	0	
Mathematical Institutes	98,850	115,325	
Universities	91,500	129,500	
Provinces	35,000	120,000	
NSERC other grants	0	210,000	
Other Revenue	5,410	15,589	
Total Income	864,546	632,097	
<u>Expenditure</u>			
Bad Debts	6,000	0	
Summer School	0	0	
Workshops and Events (2)	114,500	38,124	
Outreach (3)	30,556	18,140	
PDF Program (4) Collaborative Research Groups (5)	253,813	142,098	
IPSW	13 878	10,000	
Graduate Scholarships	10.000	0	
EDI Consultant	5,000	0	
Administrator Salary	35,500	41,496	
Online systems and licenses (6)	9,332	8,451	
Travel (AIMS)	0	2,187	
Office Expenses	203	203	
Dalhousie Overheads	13,000	13,000	
Other (7)	0	5,692	
Total Expenditure	694,282	279,391	
		36,000 108,380	accounts receivable accounts payable
Surplus:	170,264	280,326	



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Appendix 1 Revenue Breakdown

NSERC DISBF		283,760
NSERC via Mathematical Institutes		
CRM	32,950	
Fields	32,950	
PIMS	32,950	
		98,850
Provinces		
New Brunswick	0	
Newfoundland	0	
Nova Scotia EECD	35,000	
		35,000
Other grants		
PromoScience	0	
CIHR	0	
NBHRF	0	
Universities		U
Acadia	5,000	
Cape Breton	0	
Dalhousie	18,000	
Memorial	30,000	
Moncton	1,000	
Mount Allison	1,000	
Mount Saint Vincent	1,000	
Saint Francis Xavier	2,000	
Saint Mary's*	2,000	
UNB Fredericton*	30,000	
UNB Saint John	1,500	
UPEI	0	-
Other Revenue		91,500
AMS book royalties	231	
Sringboard Atlantic IPSW support	4,216	
UNB support for IPSW grad prizes	963	
		5,410
tota	l:	514.520



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Appendix 2

Workshops and Scientific Events

total	114,500
MSRI Membership	6,303
Cdn Student and PDF Gravity conference	400
Designs and Codes	922
University of New Brunswick Data Challenge	1,000
CMS Poster Session and Prize	2,000
Stinson66 session at CMS 75th anniversary online	1,000
WADS 2021 & CCCG 2021	2,887
Aiden Bruen 80th Geometry Conf	3,000
COVID 19 research projects	94,989
Microlocal Analysis	2,000

114,500

Outreach

	30,556
AV Middle School Outreach	350
Acadia Jr. Math and CS Camp	4,741
Connecting Math to Our Lives and Communities	20,000
Concours du Groupe d'action pour les mathematiques	1,000
Math Buffet	1,000
Fundy Math League	465
Blundon Seminar	3,000



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Appendix 3

Postdoctoral Fellowships

Szyld		17,500
Huggan		25,000
Margalef		25,000
Keeler		25,000
Xue		25,000
Vooys		25,000
Das		25,000
Amy		8,750
Turchetti		1,692
NBHRF Postdoc		45,000
Directors postdoc		25,000
Postdoc Travel Grants		5,870
	total	253,813

Appendix 4

Collaborative Research Groups

202,500	total
50,000	cientific Machine Learning
37,500	eophysical Inverse Problems
37,500	araph Searching
37,500	lynamic Modelling Systems
30,000	roups, Rings Lie and Hopf Algebras
10,000	inance and Insurance



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Appendix 5

Online System Expenditures

MathJobs Fee		567
Wizehive annual fee		5,558
Zoom License		2,978
MailChimp License		228
	total	9,332

Appendix 6

Other Expenditures

total

0 **0**

Appendix 7

Write-Offs: Cancelled Obligations

	69,700
2021 NBHRF Postdoc	20,000
2020 PDFAbraham Westerbaan	17,500
2020 Connecting Math to Our Lives and Communities	10,000
2020 Bridges Conference - logo design contest	500
2019 PDF Qingzhong Huang	3,500
2019 Blundon Seminar Math Camp	3,000
2019 Data Visualization Competition	500
2019 ECCC	5,000
2019 Assessment in Math Ed Session	2,500
2019 Categorical Approaches to Geometry and Topology	3,000
2019 Borders in public health and mathematical epidemiology	4,200



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Appendix 8

Bad Debts

UPEI (2020/21) CBU (2020/21) 5,000 1,000 total 6,000