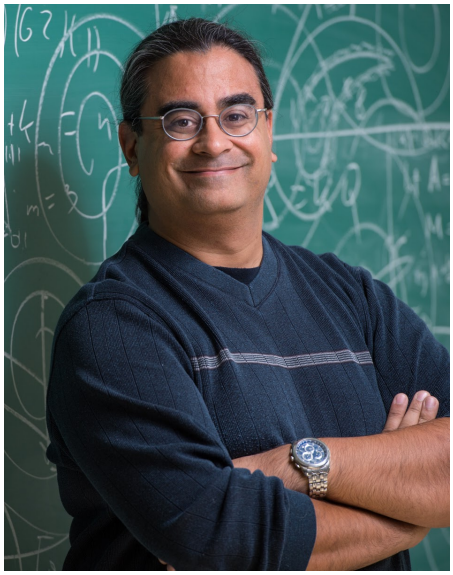
AARMS

Atlantic Association for Research in the Mathematical Sciences

2020-21 Annual Report

aarms.math.ca

1 Director's Message



Many academic and non-academic organizations have suffered extreme disruption to their operations due to the COVID-19 pandemic. AARMS is absolutely no exception to this. Most of the signature in-person events we usually organize had to be cancelled in 2020 and 2021; including the 2020 AARMS Industrial Problem Solving Workshop, the 2020 and 2021 Annual Summer Schools, and the 2020 and 2021 Girl Guides All SySTEMs Go events. In addition, almost all of the outreach initiatives, conferences, and workshops for which AARMS had committed support did not happen.

However, despite these unfortunate modifications to our normal activities, there have been many important positive developments for AARMS since the 2019 Annual Report:

- The most consequential recent development for AARMS was our successful application for Bridging funding from NSERC's new Discovery Institutes Support (DIS) program. With this award, AARMS will at long last have access to direct funding from the federal government. The grant will provide an additional ~ $280,000 to utilize in the 2021-22 fiscal year (an approximately 300% increase in federal funding). We hope NSERC's new direct funding of AARMS will be renewed with a 5-year commitment in the full DIS competition in Fall of 2021.

- The AARMS Summer School had to be cancelled in 2020 and 2021 due to the COVID-19 pandemic. To compensate, AARMS created a new Advanced Course program that allows graduate and upper year undergraduate students to participate virtually in courses offered at AARMS Member universities. The initial offering in Fall 2020 involved 10 courses, and the Winter 2021 offering had 12 courses. This program greatly enhances the access of students in the region to specialized education in cutting edge mathematical sciences topics.

- The COVID-19 pandemic has resulted in high interest from the community in online-only scientific interactions. AARMS has responded by providing essential infrastructure to our members to host several new virtual seminar series in 2020-21 such as the Atlantic Graph Theory Seminar, the Atlantic General Relativity Seminar, the AARMS COVID-19 Seminar, the Dalhousie-AARMS Analysis-Applied Math-Physics Seminar, and the AARMS Summer Math Kitchen Party series.

- The AARMS Industrial Problem Solving Workshop (IPSW) was cancelled in 2020 due to COVID, but came back in a highly successful online format in 2021. The IPSW featured four problems from companies and governments, and involved over 50 participants over

two weeks in midsummer. We fully expect the ISPW to result in multiple new funded research collaborations in Atlantic Canada.

- Largely due to the increased funding from the NSERC DIS program, AARMS will support a record number of new postdocs in the 2021-22 academic year. The research areas of these seven highly talented young researchers include mathematical physics, combinatorics, partial differential equations, algebraic geometry, number theory, and relativity and gravitation. As indicated in our DIS proposal, postdoctoral support has been increased from $17,500 to $25,000 per year.

- AARMS entered into a new collaboration with BIRS, CRM and CAIMS to hold a series of online Career and Innovation Hub workshops during the 2020-21 academic year. Each of the themed sessions focussed on a different industrial sector that employs mathematical scientists: including the pharmaceutical, clean energy, data analytics, and finance industries. The culmination of this series was a 3-day online Career Fair in March 2021 featuring a keynote address from the president of NSERC.

- Canada's four regional Mathematical Science institutes (AARMS, CRM, Fields and PIMS) have recently collaborated (with many co-applicants) on a substantial new $3M grant from NSERC to further expand emerging infectious disease research entitled "Mathematics for Public Health".

- Using increased funding from NSERC we have funded a record number of new Collaborative Research Groups from our 2021 competition:

    - **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)

- We have launched a new graduate student scholarship program and are in the process of creating a doctoral thesis award.

The pandemic has created much financial uncertainty for the institute. The cancellation of events in 2020 and 2021 and the large influx of new funds from NSERC has led to a significant budgetary surplus. On the other hand, the status of funding from universities and provincial governments for the 2021-22 fiscal year is unclear as these entities are facing their own

exceptional financial pressures. On top of all of this is our pending 5-year application to the NSERC Discovery Institute Support (DIS) program, which is due in Fall 2021. In light of all of these uncertainties, the AARMS Executive has been engaged in careful financial planning aimed at minimizing carry forwards while still allowing for funds to meet our on-going obligations in 2022-23 and beyond.

The significant chaos induced by the pandemic has also provided an opportunity to modernize several of AARMS accounting practices. In particular, as described in section 4, we have changed our fiscal year to be synchronized with NSERC's and have moved to an accrual based accounting system. These changes should simplify financial management moving forward, but will make comparison to previous years somewhat more challenging.

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 the provinces of New Brunswick, Newfoundland and Labrador, Prince Edward Island; and all of AARMS's member universities. Special recognition is due to David Langstroth for expert administrative efforts. 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 2021

2 Report on Funding

2.1 NSERC

We are pleased to report that our application for one year of bridge funding from the NSERC DIS program has been successful. We requested $371,000 and were awarded $283,760, in addition to the $98,850 which we will receive through the CTRMS program. This will allow us to invest increased resources into activities such as postdoctoral fellowships, collaborative research groups and the following new programs which we will launch in 2021/22.:

- Junior Researcher Travel Support
- Graduate Student Scholarship
- Doctoral Thesis Award

2.2 COVID Related Funding

Two grants for mathematical research on the topic of the COVID 19 pandemic have been awarded and work is ongoing. The first is a multi-institute research program funded by CIHR for two years. The second consists of matching funds from the New Brunswick Health Research Foundation (NBHRF), also for two years. These funds supported the postdoctoral fellowship at UNB of Ting Hao Hsu (Sept 2020-March 2021).

AARMS, CRM, Fields, and PIMS recently collaborated (with many other researchers/co-applicants) on a successful $3M proposal to NSERC's Emerging Infectious Disease Modelling Initiative (EIDM) called "Mathematics for Public Health". The detailed disbursement of these funds is yet to be determined. The Director of AARMS serves on the Steering Committee for this initiative.

3 Report on Activities

3.1 AARMS Collaborative Research Groups (CRGs) Program

AARMS recently completed its 2021 Collaborative Research Group competition with increased funding from NSERC. This has resulted in the creation of 4 new CRGs and the renewal of one existing CRG; see section 3.1.3 below for more details.

A few words about the two AARMS CRGs that began 2 year projects in September 2019 are warranted. These CRGs are **Computational Aspects in Finance and Insurance** under the administration of Kai Liu at UPEI, and **Groups, Rings, Lie and Hopf Algebras** under the administration of Yorck Sommerhäuser at Memorial. Due to the interruption of the pandemic many activities of these CRGs have been curtailed. As a result, we offered both CRGs the option of extending their term to three years with no increase in funds, or to compete in the 2021 CRG competition for increased funding. **Computational Aspects in Finance and Insurance** elected to

not compete in 2021, while **Groups, Rings, Lie and Hopf Algebras** did participate in the competition and was successful.

3.1.1 Groups, Rings, Lie and Hopf Algebras

3.1.1.1 Members

Academic Administrator: Yorck Sommerhäuser (Memorial University)

Collaborators from AARMS member universities

- 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 (Vanderbilt University, Nashville)
- Alexander Premet (University of Manchester)
- Christoph Schweigert (University of Hamburg)
- Kirill Zainoulline (University of Ottawa

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 (Vanderbilt University, Nashville)
- Alexander Premet (University of Manchester)
- Christoph Schweigert (University of Hamburg)
- Kirill Zainoulline (University of Ottawa

3.1.1.2 Activities

The AARMS Collaborative Research Group ‘Groups, Rings, Lie and Hopf Algebras is a collaboration of twenty-four scientists, half of which are coming from universities within Atlantic Canada and the other half from different universities worldwide. It engages in research activities

on the topics that give it its name and their application to other scientific fields, such as mathematical physics.

The first activity organised in the framework of the collaborative research group was an AARMS workshop during the Science Atlantic Conference in October 2019 in Halifax, which was organised by CRG members Peter Selinger from Dalhousie and Yorck Sommerhäuser from Memorial. One purpose of the workshop was to bring the category group at Dalhousie and the Hopf algebra group at Memorial, who work in neighbouring research areas, closer together. To achieve this goal, the two organisers began by giving introductory overview talks over the two research areas, which were then followed by more specialised research talks given by Mikhail Kotchetov from Memorial, Julien Ross from Dalhousie, Mitja Mastnak from Saint Mary's, and Jonathan Gallager from Dalhousie.

The second activity of the collaborative research group took place almost directly afterwards, namely from November 4 to November 8, 2019: Paolo Bellingeri from the University of Caen in France gave a mini course with the title 'surface braid groups and mapping class groups'. It took place at Memorial University in St. John's, with a daily lecture of about one-and-a-half hours. Two additional supporting lectures were given by Lukas Woike and Yang Yang, two PhD students of CRG member Christoph Schweigert from the University of Hamburg. Another external participant was Owen Sharpe from Saint Mary's University in Halifax.

A month later, CRG member Nicolás Andruskiewitsch visited Memorial for two weeks, from December 3 to December 17, in order to collaborate in particular with the CRG members Mikhail Kotchetov and Yorck Sommerhäuser. Professor Andruskiewitsch is a researcher at the Universidad Nacional de Cordoba and one of the editors of the 'Journal of Algebra'. He is considered one of the leading researchers on Hopf algebras worldwide and has visited Atlantic Canada several times.

In the new year, the activities of the collaborative research group continued with a mini course on the computer algebra system GAP by Leandro Vendramin from the University of Buenos Aires. The mini course took place from January 13 to January 17 at Dalhousie and was broadcast to various places in Atlantic Canada, including Memorial. It consisted of five lectures of one-and-a-half to two hours in length.

For much of the following year activities were curtailed by the corona virus crisis. Travel was largely prohibited; interactions between the members of the research group had to be carried out online. Accordingly, the group held its events virtually: The first was a mini course on Hopf algebras, hosted by Peter Selinger at Dalhousie University and taught by Yorck Sommerhauser from Memorial University, with participants from all over Atlantic Canada. Because no travel was involved, it was possible to spread out the dates over a longer period of time: The mini course took place twice a week over a period of three weeks, from November 10 to November 26, 2020. One of the purposes of the mini course was to connect the category theorists at Dalhousie and

the Hopf algebraists at Memorial, who work in related fields, more closely, which was a primary goal of the research group in the first place.

The second mini course was organised by Yuri Bahturin from Memorial University. The speaker was Olga Kharlampovich, the Mary P. Dolciani Professor at Hunter College, a part of the City University of New York. Professor Kharlampovich's mini course consisted of three online lectures given on May 3, May 5, and May 7, 2021, respectively. She lectured on groups acting on trees. More precisely, key topics of her course were the Bass-Serre theory, amalgamated products, HNN extensions, ordered abelian groups, and structure theorems for finitely generated groups acting freely on certain types of trees.

Finally the CRG organised a special session on Hopf algebras at the summer meeting of the Canadian Mathematical Society, which had been postponed from the year before, but was still held only virtually in June 2021.

3.1.1.3 Publications

N. Andruskiewitsch, I. Angiono, J. Pevtsova, S. Witherspoon: Cohomology rings of finite-dimensional pointed Hopf algebras over abelian groups, to appear in Research in the Mathematical Sciences
Y. Bahturin, A. Elduque, M. Kotchetov: Graded-division algebras over arbitrary fields, J. Algebra Appl. 20 (2021), 2140009
Y. Bahturin, S. Montgomery: Group gradings and actions of pointed Hopf algebras, J. Algebra Appl. 20 (2021), 2140011
Y. Bahturin, S. Witherspoon: Delta sets and polynomial identities in pointed Hopf algebras, to appear in Algebras and Representation Theory
A. Elduque, M. Kotchetov, A. Rodrigo Escudero: Gradings on associative algebras with involution and real forms of classical simple Lie algebras, arXiv:2105.13666
Y. Kashina, Y. Sommerh¨auser: On cores in Yetter-Drinfeld Hopf algebras, J. Algebra 582 (2021), 89–125
Y. Kashina, Y. Sommerh¨auser: 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, Am. Math. Soc., Providence, 2021, 195–223
S. Lentner, S. Mierach, C. Schweigert, Y. Sommerh¨auser: Hochschild cohomology, modular tensor categories, and mapping class groups I, to appear in Springer Briefs in Mathematical Physics

3.1.2 Computational Aspects in Finance and Insurance

3.1.2.1 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)
- Guahua Yan (University of New Brunswick (Fredericton))
- Qiang Ye (Dalhousie University)

Collaborators from other institutions

- A.H.M. Mahbubar Rahman (Concordia University)
- Wenqing He (Western University)
- Lysa Porth (University of Guelph)
- Ken Seng Tan (University of Waterloo)
- 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)

3.1.2.2 Activities

Seminars:

- S. Yang (University of Toronto & Aon Path Wise Solutions Group), “Surrogate Model Assisted Nested Simulation for Large Variable Annuity Portfolios”, March 26, 2021 (Virtual)
- R. Tian (Western University), “Historical-time Functional Linear Model and its Inference with Cross-sectional Dependence”, Feb. 26, 2021 (Virtual)
- Y. Liu (University of Nebraska-Lincoln, “Recent Declines in Life Expectancy: Implication on Longevity Risk Hedging”, Feb. 19, 2021 (Virtual)
- J. Zhang, “Pricing of Multivariate Financial Derivatives”, Nov. 6, 2020 (Virtual).
- J. Liu, “Asymptotic Iteration Method Meets Black-Scholes”, Oct. 16, 2020 (Virtual).
- L. Doiron, “Asset Liability Management for Pension Plans”, March 13, 2020.
- K. Liu, “Real-time Valuation of Large Variable Annuity Portfolios: A Green Mesh Approach”, Feb. 28, 2020.
- A. Alvarez, “A robust approach to construct coherent risk measures”, Jan. 24, 2020.
- B. Wang, “Portfolio Selection using fundamental analysis”, Nov. 22, 2019.
- B. Jia, “What can artificial intelligence (AI) do for salmon and the ocean?”, Oct. 11, 2019.

Workshop on Financial Mathematics and Actuarial Science (August 6, 2021): This was a virtual event including the following speakers:

Matt Davison (Western University)
Louis Doiron (University of Prince Edward Island)
Sebastian Ferrando (Ryerson University)
José Garrido (Concordia University)
Antoine Kornprobst (Western University)
Kai Liu (University of Prince Edward Island)
Yang Lu (Concordia University)
Alexander Melnikov (University of Alberta)
Pablo Olivares (Ryerson University)
Luis Seco (University of Toronto)
Emiliano Valdez (University of Connecticut)
Yichen Zhu (Western University)

Student Supervision:

Ali Raisolsadat Undergraduate Research Student 2021
Project Title: Quantitative Risk Control for Climate Change, Fund Reservation and Policy Adaptation.
Supervisor: Dr. Kai Liu
Jiaying Liu Undergraduate Research Student 2021
Project Title: Option pricing with orthogonal polynomials.
Supervisor: Dr. Alexander Alvarez
Junshi Dong, Graduate Student 2020,
M. Sc. Thesis project: Biogeographical Modelling of Coronavirus Dispersal
Supervisory Committee: Dr. Kai Liu, Dr. Alexander Alvarez, Dr. Shafiqul Islam, Dr. Justin Kakeu, Dr. Frederic Kibenge.
Jiaying Liu, Undergraduate Summer Research Student 2020,
Research project: Some Remarks on the Black-Scholes Equation
Supervisors: Kai Liu and Nasser Saad
Jingfan Zhang, Undergraduate Summer Research Student 2020,
Research project: Numerical Approximations for the Pricing of Multivariate Derivatives
Supervisors: Alex Alvarez, Shafiqul Islam and Kai Liu
Ben Wang, Undergraduate Summer Research Student 2020,
Research project: Portfolio Selection using Fundamental Analysis
Supervisors: Alex Alvarez, Shafiqul Islam and Kai Liu
Ben Wang presented the talk “Portfolio Selection using fundamental analysis” at Science Atlantic at Dalhousie University in Oct. 2019.

3.1.2.3 Publications

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*, DOI: 10.1002/asmb.2635.

X. Rong, Bingjie Song, T. Zhang, K. Liu (2021). Home Bias and Corporate Environmental Social Responsibility. *Sustainability*, 13(11), 5860, DOI: 10.3390/su13115860.

C. Wang, K. Liu and B. Li (2020) "Portfolio Selection under Leptokurtic Moments", *International Review of Economics and Finance*, Revised and Resubmitted.

A. Alvarez (2020) "Financial modelling with multivariate mixed fractional Brownian motion", *Revista Investigación Operacional.* Vol 42. No 2, 2021.

W. Bai, H. Liu and K. Liu (2021). Construction of the SV-BEKK-GARCH Optimal Hedging Model and Its Empirical Evidence in Chinese Futures Markets. *Journal of Forecasting*, Submitted.

T. Chen, Y. Li and K. Liu (2021). Portfolio Selection – from under-diversification to concentration", *Finance Research Letters*. Submitted.

X. Rong, T. Zhang and K. Liu (2020). Insurance Institutional Investor and Corporation Value from Value Selection and Creation Perspective. *Pacific-Basin Finance Journal*, Submitted.

W. Bai, H. Liu, K. Liu, A. Alvarez (2020) "FOF Fund Network, Diversified Risk Parity and Dynamic Asset Allocation", Working Paper.

T. Chen, Y. Li and K. Liu (2020) "At Which Risk Level Does the Opposing Investment Philosophies Meet", The Review of Economic Studies, Working Paper.

K. Liu, K.S. Tan and C. Wang (2020) "Dimension Reduction in Portfolio Selection", Working Paper.

J. Zhang, A. Alvarez and **K. Liu** (2021). Multi-Asset Spread Option Pricing via Least Squared Polynomial Approach. Working Paper.

H. Liu, K. Liu, D. Li and Y. Li (2020), "Fund Managers' Association Networks, Information Sharing and Fund Performance", Applied Economics Letters, 27(10):841-847, DOI:10.1080/13504851.2019.1646400.

B. Porth, L. Porth, W. Zhu, M. Boyd, K.S. Tan, and K. Liu (2019), "Remote Sensing Applications for Insurance: A predictive Model for Pasture Yield in the Presence of Systemic Weather", North American Actuarial Journal,DOI:10.1080/10920277.2020.1717345.

K. Liu and K.S. Tan (2020), "Real-time Valuation of Large Variable Annuity Portfolios: A Green Mesh Approach", North American Actuarial Journal, DOI:10.1080/10920277.2019.1697707.

K. Liu and M. Feng (2020), "Path Generation Methods on Valuation of Large Variable Annuities Portfolio", Proceedings of the 2020 Winter Simulation Conference.

C. Wang, I. Liu, K. Liu, H. Huang, A. Alverez (2020) "Principal Component Analysis on Pricing High-Dimensional American Style Options with Levy Processes", International Review of Economics and Finance, Submitted.

W. Bai, H. Liu, K. Liu and J. Tu (2020), "Study on Tunneling and IPO Premiums from a Social Network Perspective", Journal of Banking and Finance, Submitted.

A. Alvarez, A. Assadi and K. Liu (2020) "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, Submitted.

J. Kakeu and K. Liu (2020), "Dimension Reduction on Topological Data Analysis Applied to Environmental Economics", Working Paper.

J. Liu, K. Liu and N. Saad, "Some remarks on the Black-Scholes Equation", Working Paper.

3.1.3 New Collaborative Research Groups

In early 2021 AARMS Initiated a new CRG funding competition, Five new Groups have been funded to begin in September 2021. The award of funding to Groups, Rings, Lie and Hopf Algebras is an enhancement and replacement for their previously awarded funding for 2021-2022):

- **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)

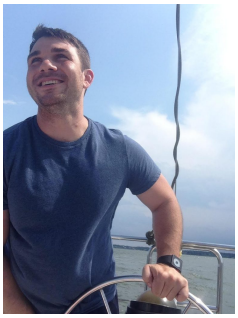
3.2 AARMS Postdoctoral Fellowship Program

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. Beginning in November 2019 he will be working 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.

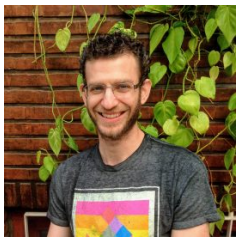


Jonathan Gallagher finished his PhD from the University of Calgary in 2018, and is now working as a postdoc with Geoff Cruttwell and Dorette Pronk at Dalhousie University. The project they are pursuing is to use recent developments in category theory to advance the use of differential geometry in diverse settings: from machine learning and deep learning to orbifolds.

Ting Hao Hsu worked at the University of New Brunswick (Fredericton) on COVID-19 related research under the supervision of James Watmough and Lin Wang from Sept 2020-March 2021.

Qingzhong Huang received his PhD from Shanghai University in 2014. He was a postdoctoral fellow at Memorial University under the supervision of Professor Deping Ye. His research interests include convex geometry, geometric analysis, and geometric functional analysis

Suzanne Lanéry received her PhD in 2015 from the University of Erlangen–Nuremberg, Germany, and is currently a postdoctoral fellow at the University of New Brunswick. Her research interests lie in the mathematical foundations of Quantum Field Theory, especially the topics of coarse-graining, refinement and renormalization, as well as their applications to quantum gravity.



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. Starting in February 2020 he will be at Dalhousie University working with Dorette Pronk. His main research interests are in topos theory and in higher category theory.

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 will be working with Peter Selinger at Dalhousie University from September 2020 onwards.

3.2.2 Incoming Postdoctoral Fellows

We held our annual postdoctoral fellowship competition in the autumn of 2020. Six new postdoctoral fellows were appointed to start in the autumn of 2021: **Pranabesh Das**, who will work at Dalhousie under the supervision of Karl Dilcher; **Melissa Huggan**, who will work at Mount Allison under the supervision of Margaret-Ellen Messinger; **Blake Keeler**, who will work at Dalhousie under the supervision of Suresh Eswaranathan; **Juan Margalef,** who will work at Memorial under the supervision of Ivan Booth; **Geoffrey Vooys**, who will work at Dalhousie under the supervision of Dorette Pronk; and **Shuwen Xue**, who will work at Memorial under the supervision of Xiaoqiang Zhao. In addition, AARMS appointed a new “AARMS Director’s Postdoc” this year: **Nomaan X**, relativity and gravitation, under the joint supervision of Viqar Husain, and Sanjeev Seahra at the University of New Brunswick (Fredericton).

All of these postdoctoral fellowships starting in the autumn of 2021 will be funded by AARMS at the enhanced 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 2020 and 2021 it was impossible to hold the school, due to the COVID-19 pandemic. In lieu of the Summer School AARMS offered a series of Online Advanced Courses.

3.4 AARMS Industrial Problem Solving Workshop

The AARMS Industrial Problem Solving Workshop (IPSW) was cancelled in 2020 due to COVID, but came back in a highly successful online format in 2021. The IPSW 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

In Fall 2020, in lieu of our annual Summer School, ten courses from Dalhousie, Memorial, or the University of New Brunswick were offered in an exclusively online format. Thirty-nine graduate students from AARMS Universities enrolled and were given credit. The courses were:

Advanced Algebra
Computational Statistics
Elementary Algebraic Topology
Introduction to Combinatorial and Geometric Group Theory
Introduction to Differential Geometry
Measure Theory
Numerical Solution of Differential Equations
Quantum Information and Computing
Stochastic Processes
Survival Analysis
Computational Statistics

These were remarkably successful and a set of new courses were offered for the winter term, starting in January 2021. Twenty-five students were enrolled.

Topics in Logic and Computation
Homological Algebra
Deep learning and deep reinforcement learning
Differential Equations and Dynamical Systems
Graph Theory
Multivariable Methods for Statistical Learning
General Relativity
Module Theory
Harmonic Analysis
Topics in PDE's and dynamical systems

The program was offered again in Fall 2021, but with far fewer courses due to the return to in-person teaching at many Atlantic universities. Nevertheless, the program attracted eleven students in two courses.

Computational Statistics
Graph Theory

3.6 Workshops and Conferences

3.6.1 Complete Listing

Due to pandemic restrictions there have been no in-person workshops or conferences. AARMS has provided access to a ZOOM license to enable researchers in our community to move their collaborative activities online. The following seminar series have been facilitated in this way.

Atlantic GR Seminar: Dr Robie Hennigar (MUN)
Zoom seminar
March 31, 2021 @ 1:00 pm – 2:00 pm

Dalhousie-AARMS AAMP Seminar: Jared Wunsch (Northwestern University)
Zoom seminar
March 26, 2021 @ 4:00 pm – 5:00 pm

Atlantic Graph Theory Seminar: Dr Danielle Cox, Mount Saint Vincent University
Zoom seminar
March 24, 2021 @ 3:30 pm – 4:30 pm

Dalhousie-AARMS AAMP Seminar: Marco Merkli (MUN)
Zoom seminar
March 19, 2021 @ 4:00 pm – 5:00 pm

Atlantic Graph Theory Seminar: Dr Peter Danziger, Ryerson University

Zoom seminar
March 17, 2021 @ 3:30 pm – 4:30 pm

AARMS COVID-19 Seminar: Ting-Hao Hsu (UNB)
Zoom seminar
March 17, 2021 @ 10:30 am – 11:30 am

Dalhousie-AARMS AAMP Seminar: François Monard (U. California, Santa Cruz)
Zoom seminar
March 12, 2021 @ 4:00 pm – 5:00 pm

Atlantic Graph Theory Seminar: Dr Nancy Clarke, Acadia University
Zoom seminar
March 10, 2021 @ 3:30 pm – 4:30 pm

Dalhousie-AARMS AAMP Seminar: Steven Lester (King's College London)
Zoom seminar
March 5, 2021 @ 4:00 pm – 5:00 pm

AARMS COVID-19 Seminar: James Watmough (UNB)
Zoom seminar
March 3, 2021 @ 10:30 am – 11:30 am

Atlantic Graph Theory Seminar: Dr Jeannette Janssen, Dalhousie University
Zoom seminar
March 3, 2021 @ 3:30 pm – 4:30 pm

Atlantic Graph Theory Seminar: Dr. Gary Gordon, Lafayette College
Zoom seminar
February 24, 2021 @ 3:30 pm – 4:30 pm

Atlantic GR Seminar: Sarah Muth (MUN)
Zoom seminar
February 24, 2021 @ 1:00 pm – 2:00 pm

AARMS COVID-19 Seminar: JC Loredo-Osti (Memorial)
Zoom seminar
February 17, 2021 @ 10:30 am – 11:30 am

Atlantic Graph Theory Seminar: Dr Anthony Bonato, Ryerson University
Zoom seminar
February 10, 2021 @ 3:30 pm – 4:30 pm

AARMS COVID-19 Seminar: Sanjeev Seahra (UNB)
Zoom seminar
February 3, 2021 @ 10:30 am – 11:30 am

Dalhousie-AARMS AAMP Seminar: Alan Lindsay (Notre Dame)

Zoom seminar
January 29, 2021 @ 4:00 pm – 5:00 pm

Atlantic Graph Theory Seminar: Jordan Barrett, PhD Candidate, McGill University
Zoom seminar
January 27, 2021 @ 3:30 pm – 4:30 pm

Dalhousie-AARMS AAMP Seminar: Allan Greenleaf (Rochester)
Zoom seminar
January 22, 2021 @ 4:00 pm – 5:00 pm

Atlantic Graph Theory Seminar: Dr. Hugh Thomas, UQAM
Zoom seminar
January 20, 2021 @ 3:30 pm – 4:30 pm

Atlantic Graph Theory Seminar: Dr Stephen Finbow, Saint Francis Xavier University
Zoom seminar
January 13, 2021 @ 3:30 pm – 4:30 pm

AARMS COVID-19 Seminar: Ali Gharouni (McMaster)
Zoom seminar
December 16, 2020 @ 3:00 pm – 4:30 pm

Atlantic Graph Theory Seminar: Dr Erin Meger (Université du Québec à Montréal)
Zoom seminar
December 9, 2020 @ 3:30 pm – 4:30 pm

Dalhousie-AARMS AAMP Seminar: Peter Hintz (MIT)
Zoom seminar
December 4, 2020 @ 4:00 pm – 5:00 pm

Atlantic Graph Theory Seminar: Dr Melissa Huggan (Ryerson University)
Zoom seminar
December 2, 2020 @ 3:30 pm – 4:30 pm

Dalhousie-AARMS AAMP Seminar: Graham Cox (Memorial University)
Zoom seminar
November 27, 2020 @ 4:00 pm – 5:00 pm

Atlantic Graph Theory Seminar: Dr Jared Howell (Memorial University of Newfoundland, Grenfell Campus)
Zoom seminar
November 25, 2020 @ 3:30 pm – 4:30 pm

Atlantic GR Seminar: Jinzhao Wang (ETH Zurich) and Saikat Mondal (MUN)
Zoom seminar
November 25, 2020 @ 1:00 pm – 2:00 pm

Atlantic Graph Theory Seminar: Kyle MacKeigan (PhD Candidate, Dalhousie University)
Zoom seminar
November 18, 2020 @ 3:30 pm – 4:30 pm

AARMS COVID-19 Seminar: Shannon LeBlanc (Dept of Health NB)
Zoom seminar
November 18, 2020 @ 3:00 pm – 4:30 pm

Atlantic Graph Theory Seminar: Dr Andrea Burgess (University of New Brunswick, Saint John)
Zoom seminar
November 4, 2020 @ 3:30 pm – 4:30 pm

AARMS COVID-19 Seminar: Ali Gharouni (McMaster)
Zoom seminar
December 16, 2020 @ 3:00 pm - 4:30 pm

Atlantic Graph Theory Seminar: Dr Erin Meger (Université du Québec à Montréal)
Zoom seminar
December 9, 2020 @ 3:30 pm - 4:30 pm

Dalhousie-AARMS AAMP Seminar: Peter Hintz (MIT)
Zoom seminar
December 4, 2020 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: Dr Melissa Huggan (Ryerson University)
Zoom seminar
December 2, 2020 @ 3:30 pm - 4:30 pm

Dalhousie-AARMS AAMP Seminar: Graham Cox (Memorial University)
Zoom seminar
November 27, 2020 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: Dr Jared Howell (Memorial University of Newfoundland, Grenfell Campus)
Zoom seminar
November 25, 2020 @ 3:30 pm - 4:30 pm

Atlantic GR Seminar: Jinzhao Wang (ETH Zurich) and Saikat Mondal (MUN)
Zoom seminar
November 25, 2020 @ 1:00 pm - 2:00 pm

Atlantic Graph Theory Seminar: Kyle MacKeigan (PhD Candidate, Dalhousie University)
Zoom seminar
November 18, 2020 @ 3:30 pm - 4:30 pm

AARMS COVID-19 Seminar: Shannon LeBlanc (Dept of Health NB)
Zoom seminar
November 18, 2020 @ 3:00 pm - 4:30 pm

Dalhousie-AARMS AAMP Seminar: Reem Yassawi (Open University, London)
Zoom seminar
November 6, 2020 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: Dr Andrea Burgess (University of New Brunswick, Saint John)
Zoom seminar
November 4, 2020 @ 3:30 pm - 4:30 pm

Dalhousie-AARMS AAMP Seminar: Jean-Pierre Garbardo (McMaster University)
Zoom seminar
October 30, 2020 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: Iain Beaton (PhD Candidate, Dalhousie University)
Zoom seminar
October 28, 2020 @ 3:30 pm - 4:30 pm

Atlantic GR Seminar: Turkuler Durgut (MUN)
Zoom seminar
October 28, 2020 @ 1:00 pm - 2:00 pm

Dalhousie-AARMS AAMP Seminar: Hari Kunduri (Memorial University)
Zoom seminar
October 23, 2020 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: Dr. Ben Cameron (University of Guelph)
Zoom seminar
October 21, 2020 @ 3:30 pm - 4:30 pm

Dalhousie-AARMS AAMP Seminar: Julie Rowlett (Chalmers, Sweden)
Zoom seminar
October 16, 2020 @ 4:00 pm - 5:00 pm

Atlantic Graph Theory Seminar: David Pike (Memorial)
Zoom seminar
October 14, 2020 @ 3:30 pm - 4:30 pm

Dalhousie-AARMS AAMP Seminar: John Toth (McGill University)
Zoom seminar
October 2, 2020 @ 4:00 pm - 5:00 pm

AARMS COVID-19 Seminar: Karen Phillips (Dept of Health and Wellness, PEI) and Javier Sanchez (Atlantic Veterinary College, UPEI)
Zoom seminar
September 30, 2020 @ 3:00 pm - 4:30 pm

Atlantic GR Seminar: Kam To Billy Chan (MUN)
Zoom seminar

September 30, 2020 @ 1:00 pm - 2:00 pm

Dalhousie-AARMS AAMP Seminar: Michael Ward (UBC)
Zoom seminar
September 25, 2020 @ 4:00 pm - 5:00 pm

AARMS COVID-19 Seminar: Amy Hurford (MUN)
Zoom seminar
August 26, 2020 @ 3:00 pm - 4:30 pm

Atlantic GR Seminar: Nicholas Layden (Dalhousie) and Sharmin Akhter (MUN)
Zoom seminar
August 26, 2020 @ 1:00 pm - 2:00 pm

AARMS COVID-19 Seminar: Acadia Covid Modelling Group
Zoom seminar
August 12, 2020 @ 3:00 pm - 4:30 pm

3.7 Outreach

Pandemic restrictions during 2020-2021 also meant that most of our outreach programs did not take place. The one exception to this was "**Middle School Outreach in Kings County**" run by Acadia University. This consisted of a virtual collection of 1-hour activities available on a shared Google Drive for 2 participating schools (Wolfville and Kentville). The activities consisted of a video and printable worksheet for the teachers to discuss with their class one or two times per month during the school year.

Six virtual activities were created for approximately 32 participants from the 2 participating schools. Topics covered included the following:

1. Prisoner Hat Riddle (logic and reasoning)
2. The Antidote and the Frog (probability)
3. Zombie Bridge Riddle (optimization)
4. Around the World (geometry)
5. Dark Coin (algebra)
6. Seven Planets (logic and reasoning)

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 will 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. Special attention will be given to diversity among the award winners, with an emphasis on gender parity. We have tentatively awarded the first two $5000 scholarships in autumn 2021, but have not formally announced the winners at the time of writing.

3.8.3 Doctoral Thesis Award

In Autumn 2021, 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 2021.

3.8.4 EDI Consultancy

As indicated in our application for NSERC Discovery Institute Support Bridging funding, we have engaged an outside expert to perform an assessment of AARMS's policies and practices in the area of Equality, Diversity and Inclusion. The associated report is in the final stages of preparation and we look forward to acting on its recommendations.

4 Administrative Changes

4.1 New Fiscal Year

AARMS has moved to a fiscal year of April 1 - March 31 with the first new year starting April 1, 2021. This replaces the calendar year which we have used in the past. This change will bring AARMS into line with the fiscal year of many of our stakeholders, including universities, governments, and major funding organizations.

This change will have the following direct consequences;

- The last fiscal year before making the change will be 15 months in duration: January 1, 2020 to March 31, 2021. Although this creates an anomalous “year” for the purposes of year-to-year comparisons, COVID 19 has already created such a large anomaly that it provides the ideal opportunity to make a change.
- The AARMS Annual Report will be completed in spring/summer and presented at the autumn Board Meeting.

4.2 Changes to Accounting

As well as adopting the new fiscal year, AARMS accounts, starting April 1, 2021, will employ the accrual method rather than the cash flow method of accounting. This change will remove the confusion that is caused when events which occur in one year are not accounted for until the following year when the money finally flows. It will make tracking of performance more transparent and budgeting easier. Any events or transactions that are committed in a given year will be accounted for in that year.

5 Accounts

Income and Expenditure Account
January 1, 2020 - March 31, 2021
(Cash Flow Account)

Income		2019
	$	$
Carried forward from previous year	41,683	254,533
Mathematical Institutes	115,325	115,325
Universities	129,500	81,000
Provinces	120,000	30,000
NSERC other grants	210,000	35,000
Other Revenue	15,589	43,985
Total Income	**632,097**	**559,843**
Expenditure		
Summer School	0	66,970
Workshops and Events (2)	38,124	90,829
Outreach (3)	18,140	116,107
PDF Program (4)	142,098	89,637
Collaborative Research Groups (5)	10,000	116,000
Administrator Salary	41,496	33,039
AARMS Online system (6)	8,451	5,372
Travel (AIMS)	2,187	2,998
Office Expenses	203	2,188
Dalhousie Overheads	13,000	13,000
Other (7)	5,692	0
Total Expenditure	**279,391**	**536,142**
Surplus: (Cash Flow)	**352,706**	**23,701**

Translation to Accrual Method

Plus Accounts Receivable	**36,000**
Minus Accounts Payable	**108,380**
Surplus (Accrued)	**280,326**

Annual Accounts 2020 / 21

Appendix 1

Revenue Breakdown

Provinces		
New Brunswick*	90,000	
Newfoundland	0	
Nova Scotia LAE	30,000	
		120,000
NSERC via Mathematical Institutes		
CRM	32,950	
Fields	32,950	
PIMS	49,425	
		115,325
Other grants		
PromoScience	30,000	
CIHR	90,000	
NBHRF	90,000	
		210,000
Universities		
Acadia*	10,000	
Cape Breton	0	
Dalhousie	30,000	
Memorial**	30,000	
Moncton	1,000	
Mount Allison*	2,000	
Mount Saint Vincent	1,000	
Saint Francis Xavier*	2,000	
Saint Mary's*	2,000	
UNB Fredericton*	45,000	
UNB Saint John	1,500	
UPEI	5,000	
		129,500
Other Revenue		
AMS book royalties	90	
IPSW support	5,000	
NSERC COVID supplement	10,499	
		15,589
	total:	**590,414**

* payments for both 2019 and 2020

** payment for 2019

Annual Accounts 2020 / 21

Appendix 2

Workshops and Scientific Events

2016 Numerical Analysis of Singularly Perturbed Diff. Eq.	5,552
2019 Agent Based Models	1,000
2019 Nonassociative Algebras and Geometry	10,600
2019 Canadian Math Education Study Group	3,000
2019 STFX Integration Challenge	500
2019 CMS Poster Sessions	3,000
2020 Combinatorial Algebra Meets Algebraic Combinatorics	7,500
2020 MSRI membership	6,972
total	**38,124**

Outreach

2019 Acadia Middle School outreach	586
2019 Math Challenge Club	1,760
2019 Acadia Fundy Math League	175
2019 Acadia Math Buffet	618
2019 Outreach Coordinator	15,000
	18,140

Annual Accounts 2020 / 21

Appendix 3

Postdoctoral Fellowships

Martin Szyld	17,500
Martin Szyld hardware (in lieu of travel)	1,953
Jonathan Gallagher	8,750
Jonathan Gallagher - COVID support	10,500
Daniele Turchetti	14,110
Suzanne Lanery	17,500
Matthew Amy	17,500
Marco de Cesare	17,500
Ting-Hao Hsu	36,785
total	**142,098**

Appendix 4

Collaborative Research Groups

2020 Computational Aspects in Finance and Insurance	10,000
2020 Groups, Rings, Lie and Hopf Algebras	0
total	**10,000**

Annual Accounts
2020 / 21

Appendix 5

Online System Expenditures

MathJobs Fee		1,152
Wizehive annual fee		5,905
Zoom License		1,302
MailChimp License		52
Website security certificate		40
	total	**8,451**

Appendix 6

Other Expenditures

HST undercharged on past USD expenditures		2,049
Grad student support on CIHR project		3,643
	total	**5,692**