AARMS

Atlantic Association for Research in the Mathematical Sciences

Annual Report 2016

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Message from the Director

This past year has been a transitional one for AARMS: Jeannette Janssen finished her very successful tenure as Director on June 30, and I began my four-year term on July 1. I am pleased to report that with the help of Jeannette, the AARMS Executive and Board, our Executive Administrator David Langstroth, and the wider Atlantic Canadian community, the changeover has been remarkably smooth. Specifically, AARMS is continuing to provide crucial support to a broad spectrum of fundamental and applied research rooted in Atlantic Canada and with a tangible global reach.

All of the Association's principal programs remain vigorous and well subscribed. The fifteenth edition of the AARMS summer school was held at Dalhousie University and featured courses touching on aspects of category theory, topology, quantum computation, and other fascinating topics. The organizers leveraged the induced concentration of expertise in Halifax to hold a week long *International Conference on Category Theory* in August, which accentuates the evolution of the Summer School into a short thematic program.

The third generation of AARMS Collaborative Research Groups (CRGs) have been actively pursuing new insights into black holes, scientific computation, chaos and fractals, and much more. They organized a diverse collection of events including regular seminar series, international workshops, and even a *Software Carpentry Bootcamp* attended by faculty, graduate students, and representatives from local industry. CRG-driven events complimented the larger menu of AARMS supported conferences and workshops, which collectively involved over 600 participants, 211 of whom were from outside Atlantic Canada.

One of the Association's core activities is the Postdoctoral Fellows program, which attracts top mathematical talent from around the world to Atlantic Canada. AARMS funded nine postdoctoral researchers in 2016, three of which were new appointments. Many alumni of the AARMS postdoctoral program have gone on to secure permanent positions that allow them to pursue their internationally recognized mathematical research.

Our outreach efforts were aimed at a wide variety of target audiences in 2016 with the goal of increasing mathematical literacy and appreciation outside of academia. We paid special attention to traditionally under-represented groups, and plans for expanding and intensifying our efforts in 2017 are well underway.

The Association's relationships with other organizations has grown and evolved. We have entered into an agreement with Mitacs that streamlines access to graduate internships for Atlantic students. We became an academic sponsor of the Mathematics Sciences Research Institute (MSRI) in

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Berkley, which furnishes mathematics departments throughout the region with access to a number of high quality programs. We continue to cooperate with Canada's other mathematical institutes on a number of fronts: PIMS, Fields, CRM, CANSSI and AARMS have signed a Memorandum of Agreement to form a national database of mathematical scientists interested in collaboration with industry. The same group worked together closely on a joint statement to the Canadian Government's Fundamental Science Review panel.

It is our sincere hope that the robust history of collaboration with the other Canadian Institutes persists as the Association enters a pivotal phase. AARMS is now a mature and independent institute. I have been deeply impressed by the breadth and quality of research being executed in the region as evidenced by the numerous impressive applications we receive for all of our programs.   Soon, NSERC will begin the exercise of allocating the next round of *Collaborative and Thematic Resources Support in Mathematics and Statistics* (CTRMS) to Canadian mathematical and statistical institutes. AARMS stands ready to utilize additional federal resources to support world-class mathematics in Atlantic Canada.

I would like to thank the provinces of New Brunswick, Newfoundland and Labrador, and Nova Scotia, our member universities and NSERC for their support; as well as PIMS, Fields, CRM, and CANSSI for their collaboration.

Sanjeev Seahra
AARMS Director
March, 2017

Collaborative Research Groups

AARMS Collaborative Research Groups consist of Atlantic Province University researchers with common research interests who wish to collaboratively develop their research programs. Members of a CRG typically organize intensive workshops, share PDF appointments, coordinate graduate training programs, propose and assist in AARMS summer school programs, jointly supervise graduate students, and carry out other activities supporting their research programs.

AARMS believes that groups of researchers with common research interests can benefit from sharing resources and coordinating activities. Furthermore, CRGs offer young researchers a larger community for growing their research program. AARMS also believes that the critical mass achieved by CRGs will help the Atlantic Provinces to recruit and retain faculty in mathematical sciences, to attract post-doctoral fellows and offer enhanced training programs attracting more graduate students.

In 2016 the third generation of AARMS CRGs completed their first year. They were: **The Atlantic Collaborative Research Group in Numerical Analysis and Scientific Computing**, **Mathematical and Physical Aspects of Black Holes**, and **Iterated Function Systems (IFS), Fractals, Invariant Measures and Applications**. We report on these below.

In autumn 2016 we put out a call for proposals for the fourth generation of AARMS CRGS. The proposals will be assessed in early 2017 in order for the successful groups to begin in autumn of 2017.

The Atlantic Collaborative Research Group in Numerical Analysis and Scientific Computing

Members:

Ronald Haynes (Memorial)	Colin Farquharson (Memorial)
Paul Muir (St. Marys)	Shaohua Chen (Cape Breton)
Hermann Brunner (Memorial)	Jahrul Alam (Memorial)
David Iron (Dalhousie)	Richard Karsten (Acadia)
Theodore Kolokolnikov (Dalhousie)	Scott MacLachlan (Memorial)
Hans de Sterck (Waterloo)	Alison Malcolm (Memorial)
Jean-Christophe Nave (McGill)	Alexander Bihlo (Memorial/UBC)
Martin Gander (Geneva)	Serpil Kocabiyik (Memorial)
Weizhang Huang (Kansas)	

The AARMS CRG in Numerical Analysis and Scientific Computing was formed in September 1, 2013 and was funded for two years by AARMS. The group was awarded funding for an additional two years, from 2015 – 2017 and this report covers the first of those two years.

Summary of Activities

The executive of the CRG (Haynes, Brunner, McLachlan, Muir) met on a regular basis to plan and carry out the activities of the CRG. The primary activity organized by the CRG was a workshop on singularly perturbed problems, held in Halifax in July of 2016. A member of the CRG was also involved with the organization of the Software Carpentry Workshop and the BIRS Parallel–In–Time Workshop at the end of 2016 (report pending). As well, the members of the CRG have been involved in a number of research projects related to the CRG and in the supervision of students working on these projects. Below we provide further details on the activities undertaken by the CRG over the last 12 months.

Workshop on Singular Perturbation Problems

The CRG hosted a Workshop on Numerical Analysis of Singularly Perturbed Differential Equations from July 25-29, 2016, at St. Marys University. Supported by an AARMS Conference Grant, as well as funding from CRM and from the NSF program for Conferences and Workshops in the Mathematical Sciences, the workshop attracted 22 participants, including 7 students and 3 postdoctoral researchers. A two-day short course was presented by Dr. Niall Madden of the National University of Ireland, Galway, with plenary lectures presented by Drs. Natalia Kopteva (University of Limerick), Torsten Lin (FernUniversitt in Hagen), and Martin Stynes (Beijing Computational Science Research Centre). The second half of the workshop focused on three applied problems, presented by Drs. Andrew Bernoff (Harvey Mudd College), Adriana Dawes (Ohio State University), and Alan Lindsay (University of Notre Dame). Lively discussion ensued on all topics, leading to new collaborative research connections both within the CRG community and with our international peers.

Organization of the 2016 BIRS PinT Workshop

One of the CRG members (Haynes) co–organized a BIRS workshop on parallel–in–time methods held at the end of 2016 in Banff. This workshop brought together scientists from the fields of parallel-in-time integration, multigrid methods, and domain decomposition to discuss similarities between their respective approaches to space/time algorithms, their applications and, ultimately, their combination. Participants included senior domain experts and young researchers to foster vigorous discussion and to advance the state-of-the-art in this exciting and emerging field. A detailed report had not been compiled at the time of writing this annual AARMS report.

Group member publications 2015{2016

Hermann Brunner:

1. (with Y.Y. Ma and Y.S. Xu) The oscillation of solutions of Volterra integral and integro-differential equations with highly oscillatory kernels, J. Integral Equations Appl., 27 (2015), 455-487.
2. (with C.H. Ou) On the asymptotic stability of Volterra functional equations with vanishing delays, Commun. Pure Appl. Anal., Commun. Pure Appl. Anal., 14 (2015), 397-406.
3. (with S. Seyed Allaei and W.Z. Yang) Existence, uniqueness and regularity of solutions for a class of third-kind integral equations, J. Integral Equations Appl., 27 (2015), 325-342.
4. (with R. Zhang and H. Liang) Analysis of collocation methods for generalized auto-convolution Volterra integral equations, SIAM J. Numer. Anal., 54 (2016), 899-920.

5. (with Q.M. Huang and X.X. Xu) Continuous Galerkin methods on quasi-geometric meshes for delay differential equations of pantograph type, Discrete Contin. Dyn. Syst. A, 36 (2016), 5423-5443.

6. (with H. Liang) Integral-algebraic equations: theory of collocation methods II, SIAM J. Numer. Anal., 54 (2016), 2640-2663

7. (with S. Seyed Allaei and Z.W. Yang) Numerical analysis of collocation methods for third-kind Volterra integral equations, IMA J. Numer. Anal. (published online 19 July 2016).

<u>Plenary Talks:</u>

1. Mathematical Modelling and Analysis (MMA 2016), University of Tartu (Estonia), June 1-4, 2016 (unable to attend).

2. Stability and Discretization Issues in Differential Equations (SCIDE 2016), University of Trieste (Italy), June 21-24, 2016.

3. Numerical Analysis, Approximation and Optimization (in memory of Prof. M.J.D. Powell), Academy of Ma

Ronald Haynes

1. Haynes, Ronald D. and Huang, Weizhang, Preface Adaptive Moving Mesh Methods, J. Math. Study, Vol. 48, No. 2, pp. i–iii, 2015.

2. Haynes, R.D. and Kwok, F., Discrete analysis of Domain Decomposition Algorithms for Grid Generation via the Equidistribution Principle, Submitted June 2014, Revised Spring 2015, Accepted AMS Mathematics of Computation, July 14 2015.

3. Haynes, R.D., Ladd, K., and Ong, B. W., Algorithm 965: RIDC Methods: A Family of Parallel Time Integrators, ACM Transactions on Mathematical Software (TOMS), Volume 43 Issue 1, August 2016.

4. Xiang Wang, Qihong Feng, and Ronald D. Haynes, Optimization of Well Placement and Production for Large-scale Mature Oil Fields, Accepted Journal of Engineering Science and Technology Review, Dec 19 2015.

5. Haynes, R.D. and Wang, X., A Multilevel Coordinate Search Algorithm for Well Placement, Control and Joint Optimization, Accepted Computers & Chemical Engineering, September 2016.

<u>Other Activities:</u>

1. Organization of the Singular Perturbation Problem Workshop

2. Organization of the BIRS Workshop on Parallel-in-Time Methods

David Iron

1. D. Iron, J. Rumsey, M. J. Ward, J. Wei, On accurately estimating stability thresholds for periodic spot patterns of reaction-diffusion systems in R2, EJAM, 26, pp 325-353, (2015)

2. C. Levy, D. Iron, Dynamics and stability of a three-dimensional model of cell signal transduction with delay, Nonlinearity, 28 (7), pp 2515-2553, (2015)

<u>Other Activities:</u>

1. Organization of the Singular Perturbation Problem Workshop

Scott MacLachlan

1. J. H. Adler, T. J. Atherton, D. B. Emerson, and S. P. MacLachlan. An energy-minimization finite-element approach for the Frank-Oseen model of nematic liquid crystals. SIAM J. Numer. Anal. 53(5):22262254, 2015.

2. J. H. Adler, T. J. Atherton, T. R. Benson, D. B. Emerson, and S. P. MacLachlan. Energy minimization for liquid crystal equilibrium with electric and flexoelectric effects. SIAM J. Sci. Comp. 37(5):S157S176, 2015.

3. J. H. Adler, T. R. Benson, E. C. Cyr, S. P. MacLachlan, and R. S. Tuminaro. Monolithic multigrid methods for two-dimensional resistive magnetohydrodynamics. SIAM J. Sci. Comp. 38:B1B24, 2016.

4. J. H. Adler, D. B. Emerson, S. P. MacLachlan, and T. A. Manteuffel. Constrained optimization for liquid crystal equilibria. SIAM J. Sci. Comp. 38:B50B76, 2016.

5. J. Adler, S. MacLachlan, and N. Madden. A first-order system Petrov-Galerkin discretisation for a reaction-diffusion problem on a fitted mesh. IMA J. Numer. Anal. 36(3):12811309, 2016.

6. L. Steigerwalt Lam, M. Hodes, G. Karmanis, T. Kirk, and S. MacLachlan. Effect of meniscus curvature on apparent thermal slip. Journal of Heat Transfer 138:122004, 2016.

Other Activities:
1. Organization of the Singular Perturbation Problem Workshop

Paul Muir
1. P.H. Muir, J. Pew, An Analysis of the Reliability of Error Control B-spline Gaussian Collocation PDE Software, to appear in Mathematical and Computational Approaches in Advancing Modern Science and Engineering, eds. J. Blair, I. Frigaard, H. Kunze, R. Makarov, R. Melnik, R. Spiteri, 2016.

2. J. Pew, Z. Li, P.H. Muir, Algorithm 962: BACOLI: B-spline Adaptive Collocation Software for PDEs with Interpolation-based Spatial Error Control, ACM Trans. on Math. Softw., 42, 3, Article 25, 2016.

3. P.H. Muir and J. Pew, Recent Advances in Error Control B-spline Gaussian Collocation Software for PDEs, Interdisciplinary Topics in Applied Mathematics, Modeling and Computational Science, Springer Proceedings in Mathematics & Statistics, 117, Cojocaru, M., Kotsireas, I.S., Makarov, R., Melnik, R., Shodiev, H. (Eds.), Springer, 2015, pp. 329-334.

Other Activities:
1. Organization of the Singular Perturbation Problem Workshop
2. Software Carpentry Workshop

Mathematical and Physical Aspects of Black Holes

Members:

Ivan Booth (Memorial)	Bernard Carr (Queen Mary)
Alan Coley (Dalhousie)	David Kubiznak (Waterloo)
Jack Gegenberg (UNB)	Jorma Louko (Nottingham)
Viqar Husain (UNB)	James Lucietti (Edinburgh)
Hari Kunduri (Memorial)	Jorge Zanelli (Chile)
Robert Milson (Dalhousie)	Saugata Chatterjee (Memorial)
Sanjeev Seahra (UNB)	Jonathan Ziprick (UNB)

Over the last year the main funded activity for the CRG was organizing a five-day workshop (June 18-22) that was held just before the annual Atlantic Canada General Relativity Meeting (June 23-24). The workshop provided a focal point for members of the CRG to gather, share ideas and collaborate. CRG funds were used to pay travel and accommodation expenses for invited speakers at the workshop as well as to subsidize attendance costs for CRG members and students. For a collaboration sparked by that workshop, CRG funds paid the airfare for a post-doc research visit from Memorial to Dalhousie.

Other CRG Member Activities

There were also numerous activities encouraged by the existence of the CRG though not directly funded. The year was very research active for members with over 40 papers published. Two of these can be directly attributed to the CRG as they involved inter-university collaborations between group members. We expect this number to significantly increase over the coming year as projects initiated this year bear fruit.

Details - Workshop

The five-day workshop was collaboratively organized by Alan Coley (Dal), Robert van den Hoogen (StFX) and Sanjeev Seahra (UNB). The workshop consisted of two preliminary days (June 18 and 19) during which postdocs from our groups gave introductory lectures to our graduate (and some undergraduate) students. The postdocs were David McNutt (Dalhousie), Daniele Gregoris (Dalhousie), Jon Ziprick (UNB) and Andrey Shoom (MUN) and their lectures covered fundamentals of differential geometry, general relativity, quantum gravity and quantum field theory. Later in the workshop, Alan Coley also gave an introductory lecture to cosmology. The goal of all of these was to provide starting graduate students with more context for the upcoming lectures by the invited speakers as well as to encourage interactions between the post-docs and students from our groups.

The main part of the workshop took place from June 20-22 with six 90-minute lectures. The lectures were given by two external members of the collaboration: James Lucietti (Edinburgh) and Jorge Zanelli (Universidad de Chile) as well as Jose Geraldo Pereira (Universidade Estadual Paulista, Brazil). James spoke on the geometry of extremal black holes and their horizons, Jose gave an introduction to the mathematics of teleparallel theories of gravity and Jorge discussed Lovelock and Chern-Simons theories of gravity. These were all pitched at a grad student/summer school level and so were quite accessible to the students.

The schedule was set so that there was one lecture each morning from 9:30-11:00 and then one in the afternoon from 2:30-4:00pm. This left plenty of time for research discussions about the lectures as well as other areas of research. Collaborations initiated during these discussion will be mentioned in the following sections.

Attendance for the workshop was excellent. The official registration was 40 people but we estimate that 50 people attended at least part of the workshop or subsequent Atlantic GR meeting. Average attendance during the workshop was 30 per day. Of the registered participants, 29 were from Atlantic Canadian universities: seven professors, four post-docs and the rest students.

Details – Other Activities

During the workshop there was significant discussion of research between members. Some specific examples are:

1. A collaboration was initiated to study the characterization of horizons by geometric invariants. This follows on from previous work by Andrey Shoom (post-doc, MUN) along with insights on the invariants from Alan Coley (Dal) and David McNutt (post-doc, Dal). As this work has progressed since the conference Andrey has visited Dalhousie to continue this work and Ivan Booth and Hari Kunduri (both MUN) have been consulted in this work for their expertise on horizons.
2. Jorge Zanelli (external collaborator, Universidad de Chile) and Jack Gegenberg (UNB) continued their collaboration studying the dynamics of fields and Chern-Simons forms.
3. James Lucietti (external collaborator, Edinburgh) and Hari Kunduri (MUN) continued work on their ongoing project investigating new black hole horizons and non-uniqueness.
4. Andrey Shoom (post-doc, MUN) and Jon Ziprick (post-doc, UNB) initiated a collaboration on quantum gravity. This has been subsequently supported by visits by Jon to Dal (where Andrey was visiting as mentioned above) and a subsequent visit by Andrey to UNB.

Publications

Collectively members of the collaboration have published over 40 papers in the last year with just over 20 of them coming from Atlantic Canadian members. Here we just list inter-university collaborations which can be directly attributed to the CRG. These are:
1. "Low Energy Lorentz Violation from Modified Dispersion at High Energies" by Viqar Husain and Jorma Louko. Physical Review Letters 116, 061301 (2016).
2. "Black Lenses in String Theory" by Hari K. Kunduri and James Lucietti. Physical Review D94, 0604007 (2016).

Organizational Changes

The original application for the CRG was organized by Sanjeev Seahra (UNB) and he was academic coordinator for most of the first year. However following his appointment as Director of AARMS on July 1, 2016 the role of academic coordinator was passed to Ivan Booth (MUN). Robert van den Hoogen (StFX) joined the group over the summer. The post-doc members are now Daniele Gregoris (Dal), David McNutt (Dal), Andrey

Shoom (Memorial) and Jonathan Ziprick (UNB) and there has also been some turnover in the graduate student members.

Iterated Function Systems (IFS), Fractals, Invariant Measures and Applications

Members:

Shafiqul Islam (UPEI)
Franklin Mendivil (Acadia)
Tara Taylor (STFX)
Dorette Pronk (Dal)
Eva Curry (Acadia)
Robert Dawson (SMU)
Edward Vrscay(Waterloo)
Pawel Gora (Concordia)

Mehran Ebrahimi (UOIT)
Herb Kunze (Guelph)
Abraham Boyarsky (Concordia)
Eric Bollt (Clarkson)
Orjan Stenlo (Uppsala)

During this first year, the CRG met and collaborated on some joint projects, had a Seminar series, held a Workshop/minicourse at the Science Atlantic Conference, held a Conference in June, and are supervising one MSc student and one undergraduate student . There is an additional undergraduate student being supervised in the subject area but with outside funding.

Seminar Series
The location of the seminar rotated between StFX, Acadia and UPEI and was broadcast to the other locations via Skype. Tara Taylor gave the first presentation, followed by Franklin Mendivil and Shafiqul Islam. The seminar was generally well attended at the three locations. Faculty members, graduate students and undergraduate students at Acadia, UPEI and StFX attended these seminar seminars. The CRG plans on continuing and expanding this series in the second year.

> Speaker: Tara Taylor (StFX)
> Seminar title: Multinacci Numbers, Golden Gaskets and Fractal Trees
> Date:November 9, 2015

> Speaker: Franklin Mendivil (Acadia)
> Seminar title: Sets of Sums and sums of sets
> Date: February 26, 2016

> Speaker: Shafiqul Islam (UPEI)
> Seminar title: Entropy, Maximum Entropy and Invariant Measures
> Date: March 30, 2016

Seminar Series
Since the Science Atlantic Mathematics, Statistics, and Computer Science Conference was held at Acadia this past year, it was natural for the CRG to organize a minicourse aimed at introducing students to our research areas. We gave three workshop-style presentations: "How can a set have dimension 1.58?", "Sierpiński Relatives", and

"Invariant measures of dynamical systems". We had 36 pre-registered participants, which was incredible for an early Sunday morning workshop!

Conference
The CRG held its first conference June 10-12, 2016 at Dalhousie University. There were approximately 20 participants at this first meeting, including a few students and postdocs. There were two excellent plenary talks. The first one, on Saturday, was given by Dr. Michael Barnsley who spoken on IFS Theory: inside out and inverse limits. Dr. Barnsley was his usual enthusiastic self and inspired all with an overview of iterated function systems (IFS) and their connections with planar tilings. Dr. Barnsley is one of the "fathers" of IFS theory and its applications, notably to image compression and processing (he founded a very successful company in this area). The second plenary talk, on Sunday, was given by Dr. Robert Devaney who spoke on Cantor and Sierpinski, Julia and Fatou: Crazy Fractal topology in Complex Dynamics. Dr. Devaney gave a striking birds-eye view of complex analytic dynamics, showing both the depth of the mathematics as well as the beauty of the resulting images. Dr. Devaney is one of the best known researchers in dynamical systems and his book on this topic is one of the standard textbooks.

In addition, there were 9 contributed talks and an "open problems/brainstorming" session. The contributed talks ranged from image compression using fractal methods, dimension theory of fractals, invariant measures of dynamical systems, fractals arising from the classification of tricycloids, multidimensional radix representations, and the connections between Martin boundary theory and multidimensional wavelets. The brainstorming session was led by Dr. Barnsley and featured a lively discussion of a selection of problems and directions for further research. The conference also inspired new connections and allowed researchers with existing collaborations to work together.

Supervision of Graduate and Undergraduate Students
- Hayden VanIderstine (M.Sc.)
- Sean Rowley (full time undergraduate summer research student)
- Erica Cains (full time undergraduate summer research student)

Publications
1. D. La Torre, F. Mendivil, "Portfolio Optimization under Partial Uncertainty and Incomplete Information: A Probability Multimeasure-based Approach," to appear in Ann. Oper. Res..
2. I. Garcia, K. Hare, F. Mendivil, "Assouad Dimensions of Complementary Sets," to appear in Proc. Roy. Soc. Edinburgh Sect. A.
3. F. Mendivil, "Computing the Monge-Kantorovich Distance," to appear in Comp. Appl. Math (2016) doi:10.1007/s40314-015-0303-7.
4. D. La Torre, F. Mendivil, O. Michailovich, E.R. Vrscay, "Total variation minimization for measure-valued images with diffusion spectrum imaging as motivation," ICIAR 2016, pp. 131-137.
5. D. La Torre, F. Mendivil, E.R. Vrscay, "Iterated function systems on functions of bounded variation," Fractals 24, no 2 (2016) pp. 1650019.
6. Islam, M. S., "An alternative elementary method for approximation of invariant measures for random maps," submitted to Neural, parallel and scientific computations

7. Islam, M. S., "A Piecewise Quadratic Maximum Entropy Method for Invariant Measures of Position Dependent Random Maps," submitted to Dynamical Systems

8. VanIderstine, H., Islam, M. S., Mendivil, F and Taylor, T. "Stochastic perturbations and invariant measures of deterministic and random dynamical systems vis Chebyshev approximation ," in progress.

9. Islam, M. S. and VanIderstine, H., "A family of random maps which posses absolutely continuous infinite invariant measures ," in progress.

10. K. E. Hare, F. Mendivil, L Zubermann, "Packing and Hausdorff measures of Cantor sets associated with series," to appear in Real Anal. Exchange.

11. D. La Torre, S. Marsiglio, F. Mendivil, F. Privileggi, "Self-similar measures in multi-sector endogenous growth models," Chaos Solitons Fractals 79 (2015) pp 40-56.

12. D. La Torre, F. Mendivil, "Arclength as the invariant measure for an IFS with probabilities," Fractals 23, no 4 (2015) pp. 1550046.

AARMS Summer School

The fifteenth AARMS Summer School took place at Dalhousie University from July 11 – Aug 5, 2016 under the direction of Dorette Pronk and Geoffrey Crutwell. As usual, four courses at the beginning graduate level were offered; in 2016 the theme was Applications of Category Theory, Combinatorics and Number Theory:

- **Higher Category Theory and Categorical Logic**
      Dr. Michael Shulman, San Diego and Dr. Peter Lumsdaine, Stockholm
- **Categories, Quantum Computation and Topology**
      Dr. Jamie Vicary , Oxford
- **Stable Polynomials: with applications to graphs, matrices, and probability**
         Dr. David Wagner, Waterloo
- **An Introduction to Special Functions and WZ Theory**
      Dr. Armin Straub, South Alabama

Coordinated with the summer school, there was an associated **International Category Theory Conference** in Halifax immediately afterwards (August 7-13).

From July 4 to 8, the week before the official start date of the school, one of the directors, Dr.Geoffrey Cruttwell, taught a week of preparatory lectures in category theory to prepare students for the category theory courses in the summer school. These lectures were attended by 15 participants, some of whom were postdocs and some of whom were not taking the category theory courses during the actual school, but were interested in getting an introduction to category theory.

The school itself was attended by 41 students and 4 postdocs. 12 students and one postdoc were from Dalhousie and there were two students from elsewhere in Atlantic Canada (one from PEI and one from Cape Breton). This was our first year to sponsor students affiliated with AIMS (the African Institute for the Mathematical Sciences). We were able to fund two students; one female student from Ghana who took

the category theory courses and one male student from Ethiopia who took the number theory and combinatorics courses. We ended up enrolling three students from Africa, because the third one, a female student, was already in Canada to work with Dr. David Kribs at the University of Guelph. Our other students came from other Canadian provinces (15 students), the United States (4 students), Australia (2 students) and various European countries (6 students). The other postdocs came from the USA, Turkey and one from Ottawa.

Aside from daily lectures in the four subjects, the courses in quantum computing and number theory featured computer labs and the two category theory courses included tutorials, which were taught by TAs. The TAs were hired to run the tutorials and answer student questions. They had office hours and stayed with the students in the mini-rez houses, so they were available to help at other times as well. All courses were evaluated through a set of assignments and a final examination.

The courses generated a fair amount of activity in the department: local researchers and students joined the lectures and discussion groups formed of students and faculty. The students would work on assignments in groups during the afternoons or meet one on one with instructor, and could be found in various locations in both the math and physics departments. The course instructors in category theory also took advantage of this time to do research together and to work with some of our local faculty on new research projects.

Generally, the workload for the students was rather high and their own social activities were organized based on when assignments were due. However, most of them did not let the large workload hold them back from exploring the new country they were visiting. We organized two excursions on the weekends: one to Cape Blomidon with Hall's Harbour and one to the South Shore (Blue Rocks, Lunenburg, Risser's Beach and Peggy's Cove). Both excursions were well attended and enjoyed by all who came along. The students talked one of our local graduate students, Darien DeWolf, into taking them on an additional hike to Cape Split and Darien used the fourth weekend to organize a workshop where most of the students gave a talk about their own research. This was quite interesting and encouraging to the students.

The category theory community took advantage of the summer school and organized the annual category theory conference during the week following the summer school. It was good to see that most of the students stayed for the additional week of the conference, and a large number of them presented their work during the meeting as well. We were impressed with the level of the work they had done and were pleased to see the variety in their work. (They would normally not all have been at the meeting, due to the travel expenses.) However, this also shows that the background of the students in the school varied widely. For some of the students attending the school this was just their second category theory course (or the first one after some preliminaryreading) and others had already been extensively involved in research. Since the courses were fairly demanding and doing a grad course in four weeks is challenging to start with, we decided to give students the option of receiving a certificate of participation rather than a grade if that grade would not have been to their normal standards.

Our final activity, after all exams were written, was a farewell lobster supper at the Saint Mary's Boat Club. We were grateful to receive the help from Christopher Duffy, the AARMS Outreach Postdoc, and Evangelia Aleiferi, one of our local graduate students, in organizing this. They did an excellent job and it was fun to introduce the students to another wonderful Maritime tradition.

List of Students

Ramon	Alcala	Sydney, Australia
Branko	Nikolic	Sydney, Australia
Catherine	Antwi	Ghana
Meretu	Dechassa	Ethiopia
Kadir	Emir	Turkey
Barbara	Bosnjak	Croatia
Josip	Novak	Croatia
Dimitrios	Askitis	Denmark
Pierre	Cagne	France
Alexander	Gietelink-Oldenziel	The Netherlands
Giulia	Frosoni	Italy
Jacob	Gross	USA (Pittsburgh)
Ed	Morehouse	USA (Pittsburgh)
Daniel	Cicala	USA (Riverside)
Laszlo	Kindrat	USA (U New Hampshire)
Benjamin	Macadam	Calgary, AB
Jean-Simon	Lemay	Calgary, AB
Comfort	Mintah	Guelph/South Africa
Esme	Tremblay	Kingston (Queens)
Eric	Massoud	Kingston (Queens)
Siddhi	Pathak	Kingston (Queens)
Marco	Vergura	London, ON
James	Richardson	London, ON
Andres Felipe	Fontalvo Orozco	London, ON
Mitchell	Riley	London, ON
Liam	Peet-Pare	Ottawa
Sakif	Khan	Ottawa
Christopher	Delaney	Ottawa
Jerome	Fortier	Ottawa
Noah	MacAulay	MUN
Hayden	VanIderstine	Charlottetown (UPEI)
Peter	Nicks	Halifax (MSVU)
Amitabh	Halder	Halifax (Dalhousie)
Alan	Shi	Halifax (Dalhousie)
Scott	Cameron	Halifax (Dalhousie)
Ben	Cameron	Halifax (Dalhousie)
Corey	Degagne	Halifax (Dalhousie)
Asmita	Sodhi	Halifax (Dalhousie)
Anne	Johnson	Halifax (Dalhousie)
Francisco	Rios	Halifax (Dalhousie)
Evangelia	Aleiferi	Halifax (Dalhousie)
Darien	DeWolf	Halifax (Dalhousie)
Michael	Lambert	Halifax (Dalhousie)
Alanod	Sibih	Halifax (Dalhousie)
Iam	MacDonald	Halifax

In a survey of participants taken after the summer school had finished, respondents gave scores to the four different courses. Average scores ranged between 74% and 93%. Ratings of lecturers ranged between 75% and 89%. When asked whether they would recommend the summer school to a friend or colleague, 90% or respondents said that they would. There were a few comments about the need for better coordination between lecturers who share the presentation of a given course. But the general tone of comments was positive:

The sixteenth annual Summer School will be held July 3 - 28, 2017 on the theme of Financial Mathematics and Actuarial Sciences at the University of Prince Edward Island. We will be offering the following courses:

- **Equity-Linked Life Insurance**
  Dr. Alexander Melnikov, University of Alberta
- **Statistical Modeling in Finance and Insurance: from data to real-time decision making**
  Dr. Manuel Morales, University of Montreal
- **Stochastic Control with applications to Mathematical Finance**
  Dr. Agnès Sulem, Centre de Recherche Inria de Paris

AARMS Postdoctoral Fellowship Program

AARMS awarded three new Postdoctoral Fellowships in 2016:

Marzieh Bayeh received her PhD in 2016 from the University of Regina. Her research interests include homotopy theory, topological invariants and category theory. She is currently working at Dalhousie University under the supervision of Dorette Pronk.


Joep Evers received his PhD from Eindhoven University of Technology (The Netherlands) in 2015. He is currently working at Dalhousie University under supervision of Theodore Kolokolnikov, and his research interests include pattern formation in nonlocal aggregation models, measure-valued evolution equations, interacting particle systems and discrete-to-continuum limits.

Aras Erzurumluoglu received his PhD from Auburn University in 2015. Currently he is working at Memorial University of Newfoundland, under the supervision of David Pike. His research interests are combinatorial design theory and graph theory.

Other ongoing AARMS Postdoctoral Fellowships in 2016:
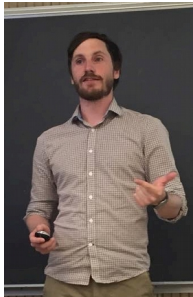
Christopher Duffy received his PhD (2015) from the University of Victoria and the University of Bordeaux. His research interests are graph homomorphisms and discrete time processes on graphs. He is currently working at Dalhousie University under the supervision of Jeannette Janssen and is the AARMS outreach coordinator postdoctoral fellow.


Daniele Gregoris received his PhD (2014) from Stockholm University within the Erasmus Mundus framework. His research interests are general relativity, cosmology and geometry and is currently working at Dalhousie University under the supervision of prof. Alan Coley.

Nathan Grieve received his PhD (2013) from Queen's University. His research interests include algebraic, complex, and differential geometry and is currently working at the University of New Brunswick under the supervision of Colin Ingalls.

Rory Lucyshyn-Wright received his PhD from York University in 2013 and was an NSERC Postdoctoral Fellow at the University of Ottawa and the University of Cambridge from 2013 to 2015. As an AARMS Postdoctoral Fellow he is currently working at Mount Allison University under the supervision of Geoffrey Cruttwell and Robert Rosebrugh.=16/24)
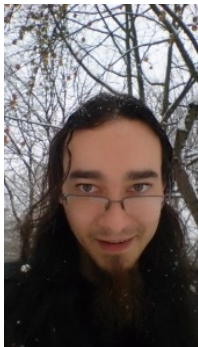
Israel Rocha received his PhD (2015) in applied mathematics from Federal University of Rio Grande do Sul. His research interests includes spectral graph theory focusing on partitioning, clustering and connectivity problems. He is currently working at Dalhousie University under the supervision of Jeannette Janssen as the AARMS Director Postdoctoral Fellow.

Peng Zhou received his PhD in 2015 in mathematics from Shanghai Jiao Tong University, Shanghai, China. As an AARMS postdoctoral fellow he is currently working at Memorial University under supervision of Prof. Xiaoqiang Zhao. His research interests lie in Nonlinear PDEs with application to mathematical biology.

Baocheng Zhu received his PhD in 2014 from Southwest University, Chongqing, China. He is currently working at Memorial University under the supervision of Dr. Deping Ye. His research interests are in convex geometric Analysis.

The competition for 2017 positions opened in November 2016 with final decisions on awards made in spring 2016.

Past holders of AARMS Postdoctoral Fellowships have gone on in many cases to continue in successful careers in mathematics.

Past Postdoctoral Fellows:

Evgeny Chibrikov, Memorial 2009-11 – Currently working in industry in St. John's
Alin Ciuperca, *UNB 2009-11* – Currently working in the Financial sector in Toronto
Kia Dalili, *Dalhousie 2005-07* - Currently working at the Stevens Institute of Technology in Hoboken,New Jersey
Mahya Ghandehari, *Dalhousie 2010-12* - Currently Assistant Professor, U. of Delaware
Alexei Gordienko, *Memorial 2010-12* - Currently working as a Marie Curie Postdoctoral Fellow at Vrije Universiteit in Brussels

Thomas Guedenon, *Mount Allison 2003-05* – no information

Rebecca Hammond, *Acadia 2007-09* - no information

Sigbjorn Hervik, *Dalhousie 2005-06* - Currently a full professor at the University of Stavanger in Norway.

Daniel Horsley, *Memorial 2008-10* – Currently ARC DECRA Research Fellow in the School of Mathematical Sciences at Monash University

Golam Hossain, *University of New Brunswick 2008-10* – Currently Assistant professor at the Indian Institute of Science and Education in Kolkata.

Tobey Kenney, *Dalhousie 2006-08* - Currently Professor of mathematics at Dalhousie

Dawood Kothawala, *University of New Brunswick 2010-12* – Currently Assistant professor at the Indian Institute of Techology (IIT) in Madras.

Peter LeFanu Lumsdaine, *Dalhousie 2010-12* - Currently holds a postdoctoral position at Stockholm University

Rogers Mathew, *Dalhousie 2012-13* - is now a faculty member at IIT Karaghpur in India

Ping Wong Ng, *University of New Brunswick 2003-05* – Currently Assistant professor in the Mathematics Department at the University of Louisiana at Lafayette

Rui Peng, *Memorial 2010-12* - Currently is a postdoc in the Institute of Math. and its Applications,University of Minnesota.

Ryan Tifenbach, *Memorial 2012-14* – is a postdoctoral fellow at the University of Regina

Justin Tzou, Dalhousie *2013-15*

Francis Valiquette, *Dallhousie 2011-13* - is an assistant professor at SUNY New Paltz

Yuzhao Wang, Memorial *2013-15*

Michael A. Warren, *Dalhousie 2010-11* - Currently holds a postdoctoral position at the Institute of Advanced Studies in Princeton

Oliver Winkler, *University of New Brunswick 2004-06* - Currently Strategic Analyst with Siemens Canada

Dansheng Yu, *Saint Francis Xavier 2006-08* – Currently Associate Professor, Hangzhou Normal University, China

Jonathan Ziprick, UNB *2013-15*

Conferences and Workshops

In 2016 AARMS funded or partially funded the following workshops conferences and events. These involved over 600 participants, 211 of whom were from outside Atlantic Canada:

AARMS-AAC Minicourse: Professor István Heckenberger
Organizers: Y. Bahturin, M. Kotchetov, Y. Sommerhäus
Date: March 14-18, 2016
Location: Memorial University, St. John's
Also funded by the Atlantic Algebra Centre

Professor István Heckenberger from the University of Marburg in Germany gave a total of six lectures in the mini course and an additional colloquium on the related topic of Fomin-Kirillov algebras. Professor Heckenberger is one of the world-leading experts in the subject whose contributions have shaped the field. His introduction of Weyl groupoids as a

generalization of Weyl groups into the theory is certainly one of the most important developments in Lie theory in the last decades. Professor Heckenberger is also one of the coauthors of a major research monograph on Nichols algebras that is currently being written.

Professor Heckenberger lectured on braided vector spaces, their Nichols algebras, the Weyl groupoid associated to a Nichols algebra, the use of this Weyl groupoid for the decomposition and classification of Nichols algebras, and the relation to deformed enveloping algebras, where the Weyl groupoid reduces to the Weyl group.

Software Carpentry Bootcamp 2016
Organizers: Paul Muir, Linda Campbell, Ross Dickson
Location: Saint Mary's University, Halifax
Date: May 5-6, 2016
Also funded by registration fees and St. Mary's University

On May 5-6, 2014, Saint Mary's University hosted a Software Carpentry Bootcamp, led by Dr. James Desjardins, a certified Software Carpentry Bootcamp instructor, Brock University, and Joey Bernard, ACEnet. Additional technical support was provided by Daniel Deveau, Ross Dickson, and Chris Geroux. The local organizers for the workshop were Paul Muir and Linda Campbell, from Saint Mary's University, and Ross Dickson, from ACEnet. An additional feature of this workshop is that it also provided interpreting services for the Deaf.

The bootcamp consisted of short tutorials alternating with hands-on practical exercises; learners worked on their own laptops and each had a working software environment by the time the bootcamp was completed. The primary areas covered by the bootcamp were the Unix shell (and how to automate repetitive tasks), R (and how to grow a program in a modular, testable way), and Git and GitHub (version control software that allows one to track software or document development and share work efficiently). A pre-assessment survey of the registered learners, provided by Software Carpentry, allowed the teaching team to customize the material to the learning community.

The bootcamp had approximately 40 participants. The intense two day workshop featured hands-on learning by all participants, with enthusiastic participation from the instructors and the technical support team. A large fraction of the participants were graduate students from Saint Mary's and Dalhousie University, but the learning community also included some undergraduates, faculty, and a few industry participants, local to the Halifax region.

Hopf Algebras, Algebraic Groups and Related Structures
Organizers: Y. Bahturin, M. Kotchetov, Y. Sommerhäuser, K. Zainoullline
Date: June 13-17, 2016
Location: Memorial University, St. John's
Also funded by registration fees, the Fields Institutne and the Atlantic Algebra Centre

The mini-courses and one-hour talks were given by senior researchers and leading experts:

Andruskiewitsch, Nicolas (Universidad Nacional de Córdoba, Argentina)
Arzhantsev, Ivan (Higher School of Economics, Russia)
Etingof, Pavel (Massachusetts Institute of Technology, USA)
Karpenko, Nikita (University of Alberta, Canada)
Kharchenko, Vladislav (Universidad Nacional Autónoma de México, Mexico)
Merkurjev, Alexander (University of California-Los Angeles, USA)
Montgomery, Susan (University of Southern California, USA)8. Nikshych, Dmitri (University of New Hampshire, USA)
Ostrik, Victor (University of Oregon, USA)
Popov, Vladimir (Steklov Institute, Moscow, Russia)
Schneider, Hans-Juergen (University of Munich, Germany)

The organizers consider the workshop to be a great success. The quantity and quality of speakers (including students) was exceptional. The organizers feel that the new ideas and methods that the participants learned during the workshop will be valuable.

Public Lecture: From Simple Algebras to the Bloch-Kato Conjecture feat. Prof. Alexander Merkurjev
Location: Memorial University, St. John's
Date: June 15, 2016

Alexander Merkurjev (University of California – Los Angeles) is an illustrious mathematician working in the area of Algebra. The list of his achievements is long and impressive. In 2016, Dr. Merkurjev was named an AARMS Distinguished Lecturer. He delivered two lectures on the St. John's campus of Memorial University of Newfoundland (MUN). The first one, on June 14, was a plenary lecture for the participants of the International Workshop "Hopf Algebras, Algebraic Groups and Related Structures" organized by Atlantic Algebra Centre (AAC) and the Network of Ontario Lie Theorists (NOLT). The title was "Rationality problem for classifying spaces of algebraic groups". The lecture was also attended by some students and faculty of the Department of Mathematics and Statistics of MUN, to the total of 40 people. The second one, on June 15, was a public lecture for anyone interested in modern mathematics.

In recent years, the theory of algebraic groups has witnessed an "intrusion" of cohomological methods of algebraic geometry and algebraic topology. These new methods have led to breakthroughs on a number of classical problems in algebra, which were beyond the reach of earlier, purely algebraic techniques. Voevodsky's use of techniques from homotopy and cobordism in the context of algebraic categories have resulted in the solution of, first, the Milnor conjecture and, later, the Bloch-Kato conjecture, which is a vast generalizations of the celebrated Merkurjev-Suslin norm residue isomorphism theorem.

In his public lecture, Professor Merkurjev gave a historical overview of these methods, starting from the celebrated result from the 1980's about the structure of central simple algebras of period 2, which relates the 2-torsion of the

Brauer group with Milnor K-theory, and culminating in the Milnor and Bloch-Kato conjectures. One of the key techniques deals with the notion of a norm variety. Professor Merkurjev explained the role of these geometric objects (Severi-Brauer varieties and norm quadrics) and their relation to the proofs of the mentioned conjectures. There were about 50 people in the audience, including students and postdoctoral fellows (primarily associated with AAC and NOLT, but also from other universities) as well as a number of specialists from Canada and abroad (Argentina, Brazil, Mexico, Russia, Spain, Germany, UK and USA).

Atlantic General Relativity 2016
Organizers: A. Coley, R. van den Hoogen, S. Seahra
Location: Dalhousie University, Halifax
Date: June 23-24, 2016

The Atlantic General Relativity Conference 2016 (AGR16 conference) was held from June 23-24 at Dalhousie University. It was the latest in an annual series of meetings covering all aspects of classical and quantum gravity. Proceeding the formal AGR15 conference was the Atlantic General Relativity 2016 Workshop (AGR16 workshop) consisting of a series of introductory and advanced lectures organized by the AARMS Collaborative Research Group (CRC) Mathematical and physical aspects of black holes. For the AGR16 conference, there were 36 participants and 19 talks. Twenty-five participants were from the Atlantic region, two from elsewhere in Canada, and nine from outside Canada. The principal invited speaker for the conference was Cliff Burgess (McMaster University), who spoke about infrared divergences in cosmological inflation. In addition, three invited lecturers from the AGR16 workshop stayed on to give presentations in the conference: Jorge Zanelli (Universidad de Chile), James Lucietti (University of Edinburgh) and Jose Pereira (Universidade Estadual Paulista, Brazil). Topics covered by these speakers and by the other contributed talks included quantum fields in curved space, quantum gravity, exotic classical solutions of the Einstein equation, and alternative gravity models.

East Coast Combinatorics Conference
Organizers: S. Seager, D. Cox
Location: Mount St. Vincent University, Halifax
Date: July 18-19, 2016
Also funded by Mount St. Vincent University

The highlight of the conference were the two plenary talks. Mateja Sajna spoke on Eulerian Properties of Hypergraphs and Triple Systems, and Anthony Bonato spoke on The New World of Infinite Random Geometric Graphs; both spoke well and included open problems. There were also informal meetings between attendees on common research interests, particularly among those attendees who continued on to GrasCan, where some problems raised at ECCC continued to be discussed.

We were also pleased that 13 students attended the conference: 7 undergraduates and 6 graduates. With 30 minutes for the contributed talks, most

of the speakers were able to explain their basic concepts well, so that the students were able to get a good general idea of what was going on without needing to understand the technical details of the final slides. The students we talked to enjoyed the conference and felt that they learned from it (and they all came back for the second day). Most of the mathematics taught at the undergraduate level is necessarily relatively old and fixed, so we believe it is highly beneficial for undergraduates to attend a conference such as this, filled with new material, plenty of open problems, and mathematicians enthusiastic about their research.

Graph Searching in Canada Workshop
Organizers: A. Bonato, M.E. Messinger
Location: Dalhousie University, Halifax
Date: July 20-21, 2016
Also funded by Dalhousie University

GRASCan 2016 was held July 20-21 at Dalhousie University, NS. Now in its fifth year, the workshop brought together researchers (both faculty and graduate students) in graph searching for two days of talks and collaboration. The workshop follows the model of plenary and contributed talks in the mornings, with the afternoons free for discussion, networking, and collaboration. To maintain an inclusive and collaborative atmosphere, the workshop is purposely kept small. Post-docs and graduate students are encouraged to attend, upon recommendation by their supervisors. This year, the workshop had 22 participants.

The plenary speakers were leading experts in graph searching problems: Geňa Hahn from l'Université de Montréal, QC and Paweł Prałat from Ryerson University, ON. The workshop also featured six contributed talks. The plenary and contributed talks generated interesting discussions and new ideas.
After the lunches, participants with existing collaborative projects retreated to quiet campus spaces to work (several additional spaces were booked for participants to use) while the remaining participants returned to the main space for the workshop. There, small groups formed and participants shared ideas and some new research collaborations were born. Though there were many discussions and groups, and we mention several working groups below.

1. (On-going work) Danny Dyer (MUN), Jared Howell (MUN - Grenfell), and Boting Yang (Regina) worked on the late stages of an on-going project related to the watchman walk problem on Halin graphs.
2. (New Collaboration) Kerry Ojakian (Bronx) and Geňa Hahn (Montréal) discussed issues related to the game of infinite cops and robber; in particular, they discussed some issues related to a recent submitted paper of Hahn. After the discussion, they discussed the possibility of meeting soon to continue work
3. (New Collaboration) Nancy Clarke (Acadia), Shannon Fitzpatrick (UPEI), M.E. Messinger (MtA), and R.J. Nowakowski (Dal) worked on some pursuit-evasion tunnel games as well as a new graph burning game. Some progress was made, with a plan for future work.
4. (New Collaboration) M.E. Messinger (MtA) and Jared Howell (MUN - Grenfell)

began work on a new variation of chip-firing, where at each step, the vertices with maximum number of chips are fired simultaneously. The problem is inherently periodic (like parallel chip-firing and dislike the diffusion game). Preliminary results were found for paths and cycles.

5. (New Collaboration) C. Duffy (Dal), S. Seager (MSVU), K. Ojakian (Bronx) worked on the Diffusion Game, a variant of chip-firing. They focused on proving periodicity of paths for any finite initial chip configuration and obtained some partial results.

Numerical Analysis of Singularly Perturbed Differential Equations
Organizers: S. MacLachlan, R. Haynes, H. Brunner, P. Muir, D. Iron, T. Kolokolnikov
Location: Saint Mary's University, Halifax
Date: July 25-29, 2016
Also funded by CRM, NSF and St Mary's University

The 2016 AARMS-CRM-NSF Workshop on Numerical Analysis of Singularly Perturbed Differential Equations was held from July 24-29 at St. Mary's University in Halifax, NS. The workshop was attended by 22 participants, from Canada (including 11 from Atlantic Canada), the United States, Europe, and China. A two-day short course (with both lectures and computing sessions) was led by Dr. Niall Madden from the National University of Ireland, Galway. The third day of the workshop consisted of presentations by three speakers who subsequently led "breakout sessions" (detailed below). The final two days of the workshop consisted of breakout sessions interspersed with plenary lectures, by Dr. Madden, Prof. Natalia Kopteva (University of Limerick), Prof. Torsten Linß (University of Hagen), and Prof. Martin Stynes (Beijing Computational Science Research Center).

Three breakout sessions were led by Prof. Andrew Bernoff (Harvey Mudd College), Prof. Adriana Dawes (Ohio State University), and Prof. Alan Lindsay (Notre Dame University). Each speaker first presented a problem (or class of problems) where singularly perturbed behaviour occurs and rigorous numerical analysis is needed to shed better light on the application of choice. The plenary lecturers facilitated these breakout sessions by posing questions about the applications at hand, and offering insight and advice into possible research directions.

Prof. Bernoff led a breakout session focused on diffusive signaling problems, such as the stamen of a flower waiting to catch a grain of pollen, a lymphocyte waiting to be stimulated by an antigen to produce antibodies, or an anteater randomly foraging for an ant nest to plunder. Each of these problems can be modeled as a diffusive process with mixed boundary conditions. The agent (pollen, antigen, anteater) finding its target (stamen, lymphocyte, ant nest) is then modeled by a first passage time problem for the distribution of the time when a particle executing a random walk is absorbed. The group discussed several possible strategies for simulation of these systems, and formulated a finite-difference method for attacking the problem that cleverly removes the initial condition singularity by subtracting off the analytical solution known in free space.

The breakout session led by Prof. Dawes was focused on understanding the consequences of a small parameter limit in a biologically motivated model of

protein levels in cells exposed to an external, spatially graded, signal. One immediate direction suggested was to use geometric singular perturbations to analyze the model, which consists of coupled DEs. This analysis is currently being followed up on by a graduate student. The group also devised alternative geometries for the model in order to simplify further analysis. A particularly successful reorganization resulted in a circular array of cells with periodic boundary conditions. Numerical simulations were carried out on the original model to better understand the behavior of the model under the small parameter limit. Interesting insights that are now being pursued include that the initial conditions strongly influence the pattern of cell fates, despite the imposed signal, and that the small parameter strongly dictates whether any patterns can form.

The breakout session led by Prof. Lindsay focused on efficient and accurate simulation of sharp interfaces arising in elastic contact problems. These moving interfaces are boundary layers of associated nonlinear parabolic differential equations, centered around points in 1D and closed curves in 2D. The session discussed monitor function and element-marking approaches to generate moving meshes that track the interface motion. Efficient time discretization strategies, which incorporate analytical solution features, were also discussed, as were related free-boundary problems and their behaviour. A collaboration in this direction was begun between Prof. Lindsay and Prof. Haynes at MUN, and a focused mini-workshop on these problems will take place in 2017.

International Category Theory Conference
Organizers: R. Blute, R. Cockett, P. Hofstra, R. Dawson, D. Pronk
Location: Dalhousie University and Saint Mary's University, Halifax
Date: August 7-13, 2016
Also funded by registration fees, Dalhousie University and St. Mary's University

This year's meeting of the annual category theory conference, Category Theory 2016, held in Halifax, was a showcase of the large variety in developments and applications of category theory in mathematics. The meeting started with a welcome reception at the Lord Nelson Hotel on Sunday evening, August 7, 2016. The scientific program ran from Monday August 8 until Saturday August 13. On Monday evening there was a public lecture on quantum computation, organized by the math department and featuring one of our participants, Dr. Jamie Vicary from the University of Oxford. On Wednesday afternoon there was an excursion with various options to explore the city and the harbor and on Thursday night the conference banquet was a lobster dinner at the Shore Club in Hubbards.

There were 84 registered participants from countries all around the world, including a large group from Australia and a large group from Japan. There were 14 participants from Atlantic Canada, 17 more from the rest of Canada, and 53 international participants, of which 12 came from the United States. The numbers were a bit lower than what is usual at Category Theory meetings. This was primarily due to the unusual timing of the event, with the meeting being held in August rather than June or early July. This was due to the fact that we wanted to hold it after the AARMS Summer School.

The conference featured invited lectures by: John Bourke (Masaryk University), Nicola Gambino (University of Leeds), André Joyal (Université de Quebec à Montréal), Dorette Pronk (Dalhousie University), Catharina Stroppel (University of Bonn) and Dominic Verity (Macquarie University).

The average age of the participants at this meeting was considerably lower than at previous years. Joyal and Tierney, two of our older participants, commented on this during the welcome reception and remarked how this felt like the old days when they came to meetings excited to talk about the new structures they had discovered. Part of the reason that we had a larger number of graduate students and early career researchers present was the fact that we had held the AARMS Summer School with two category theory courses during the four weeks before the meeting. There was a large number of talks given by graduate students and recent graduates, most of a very high quality and covering a broad range of areas within category theory and its applications. The general atmosphere of the conference was very open and friendly and there were a lot of research discussions being held over coffee and between sessions. This was very encouraging and bodes well for the field.

Scientifically, this meeting showcased both the breadth and depth of current research in category theory. We highlight here a couple of topics and talks that stood out to us as organizers. Susan Niefield's characterization of exponentiable objects in additive categories showed a great culmination of her work with Richard Wood on this topic. The connection between category theory and geometry (both differential and algebraic) through (Cartesian) differential and integral categories has been a recurring theme in previous category theory meetings, but this meeting saw a very large number of talks in this area with significant breakthroughs. These categorical structures were originally developed to study certain types of linear logic, but are now used to give algebraic foundations for geometry and homotopy theory. This was most evident in the talk by Emily Riehl (from Johns Hopkins University), which was joint work with a group of algebraic topologists (done as part of the Women in Topology workshop at BIRS in April of this year). She showed that the abelian functor calculus naturally forms a Cartesian differential category (which is one of the structures that came out of the work on semantics of differential linear logic).

There were several strong presentations on new developments of the theory of higher categories and the relations with homotopy type theory as well. Less expected applications of category theory were presented by Andre Joyal and Clemens Berger. Clemens Berger presented a way to represent hyperplane arrangements by so called graphic monoids and then proceeded to further categorify this to a moment category and make connections between the resulting categorical structure and the categories used in the study of higher homotopy theory and topos theory. Andre Joyal presented us with a classifying topos for Penrose tilings, showing us that the concept of Penrose tiling is geometric in the topos theoretic sense.Another noteworthy development we witnessed were talks on truly new applications of category theory outside of mathematics: industrial scheduling (by Spencer Breiner), fibred signal representation (by Salil Samant), and a new view on machine learning and big data analytics through a new (categorical) understanding of the link between kernel functions and reproducing kernel Hilbert spaces.

Conference on Selected Areas in Cryptography (SAC 2016) and SAC Summer School (S3)
Organizer: Howard Heys et al
Location: Memorial University, St. John's
Date: August 8-12, 2016
Also funded by registration fees and Memorial University

During the last 23 years, SAC has established itself as an internationally reputed venue for researchers in cryptography to present and discuss new work on selected areas of current interest in a relaxed and friendly atmosphere. Besides advancing cryptologic research, one of the goals of SAC is to promote young researchers. This is achieved by various means, such as organizing a summer schoo and involving junior scientists in the program committee with a lighter reviewing load and mentoring them.

This year, SAC took place on August 10th to 12th at Memorial University of Newfoundland (MUN), St. John's. This is the second time that SAC has been hosted in St. John's, and the fourth time in an Atlantic Canadian province.

To keep the conference series focused, each year only results in four themes are presented. Three themes are fixed, and the fourth theme is specially chosen every year. The four themes for SAC 2016 were:

1. Design and analysis of symmetric key primitives and cryptosystems including block and stream ciphers, hash functions, MAC algorithms, and authenticated encryption schemes,
2. Efficient implementations of symmetric and public key algorithms,
3. Mathematical and algorithmic aspects of applied cryptology, and
4. Side channel, fault and related attacks on symmetric and asymmetric cryptographic primitives and their countermeasures.

A total of 100 submissions were received and reviewed, with only 28 papers accepted for presentation. The large number of submissions, resulting in an acceptance rate of only 28% is a testament to the strong reputation of the SAC conference, which has established itself as one of the best cryptography conferences held each year.

In addition to these 28 papers, two renowned international researchers were invited to give presentations at the conference. Douglas Stebila gave the Stafford Tavares Lecture on "Post-Quantum Key Exchange for the Internet" and Francesco Regazzoni talked on "Physical Attacks and Beyond".

Games at Dal 2016
Organizers: Richard Nowakowski and Urban Larsson
Location: Dalhousie University, Halifax
Date: August 9-23, 2016

The event was held August 10-13,   2016. Talks were presented on the first day. The other days were spent in groups working on problems. Fifteen people, including four students, from North America and Portugal attended the talks and workshops. Another six people from Dalhousie attended the talks or parts of the workshops.

For the workshops, several problems were identified in advance and the participants divided into groups and worked on these problems. Participants were free, and encouraged, to wander between groups. Before lunch and at the end of each day, progress on each problem was discussed.

TheGames@Dal workshops differ from most other meetings in that it brings a diverse group of experts and students together to work on various aspects of important research topics in a free-flowing atmosphere. At the same time, students are also able to work with these top researchers and participate and contribute to research. The workshop is very popular and the award from AARMS makes it all possible. (The organizers have already received enquiries about the next workshop from new potential attendees in Israel, France and USA.)

From the Workshop, there are four papers in preparation, and each student is a co-author. Specifically, the papers are:
- M. Fisher, M. Huggan, S. Huntemann, *Split-ends Nim*;
- T. Khovanova, R. Nowakowski, *Nim on Ideals*;
- K. Burke, T. Khovanova, R. Nowakowski, A. Rowland, C. Tennhouse, *Hiding counterfeit coins.*
- A. Carvalho, N. McKay, R. Nowakowski, C. Santos, *Short Disjunctive Sum: a new approach*.

Atlantic Universities Conference including special session on **Partial Differential Equations and Numerical Analysis**
Organizers: George Chen et al
Location: Cape Breton University, Sydney
Date: October 16, 2016

The 2016 Atlantic Universities Mathematics, Statistics and Computer Science Conference was held at Cape Breton University, the weekend of October 14-16. On the afternoon of Friday the 14 th the Science Atlantic Math/Stats committee and the Computer Science committee met, and the ACM programming competition and the Mathematics competition were held. The Blundon lecture on Friday evening was given by Dr. Kabe Moen from the University of Alabama whose talk title was "Hearing the shape of a drum". After that the traditional wine and reception took place.

On Saturday Morning, the first activity was a NSERC Scholarship Presentation by Dorette Pronk (Dalhousie) followed by undergraduate math and CS student presentations. Then two special presentations were given by Dr. Daniel Silver from Acadia University (CS) and Dr. Shannon Ezzat from University of Winnipeg (Math) in parallel. After a nutrition break, the Sedgwick Lecture was given by Dr. Anne Condon from the University of British Columbia whose title was "Models and hardness results for predicting secondary structure and kinetics of interacting DNA strands". Then, more undergraduate math and CS student presentations were held.

Saturday afternoon began with mixed graduate and math undergraduate student presentations. Following the afternoon nutrition break, the Field Lecture in Statistics was given by Hugh Chipman of Acadia University whose title was

"An Overview of Statistical Learning". After that the ACENET session and the final undergraduate mathematics student presentations were held.

The banquet took place on Saturday evening. The room was crowded, but there was space for everyone and the food was good too. There were plenty of opportunities for renewing old acquaintances and making new ones. Following the meal, announcements were made and certificates were issued to all prize winners. Finally, the Science Atlantic representative, Jasmine Golf, conferred a plaque to Dr. Robert Dawson for being inducted into the Science Atlantic Hall of Fame as an Outstanding Member for 2016. She also awarded 13 faculty who had served as Science Atlantic committee members for more than ten years with a commemorative pin.

On Sunday morning, an AARMS session was held. The Title was "Partial Differential Equations: Regularity, Numerics, and Applications". There were 7 presentations (5professors, 2 Ph. D students and 1 researcher) with nearly 20 researchers in attendance.

Fifth Parallel-in-time Integration Workshop
Organizers: M. Emmett, M. Minion, M. Gander, R. Haynes, R. Krause
Location: Banff International Research Station
Date: November 27 – December 2, 2016

(report pending)

Prizes

In 2016 AARMS also funded the student poster prize at the winter and summer meetings of the Candian Mathematical Society. The winners, who each received a prize of $1000 were:

> Summer 2016 – **Harry Richman** (University of Michigan)
> Winter 2016 - **Emilia Alvarez** (Concordia University)

And, AARMS funded annual algebra prizes awarded by the Atlantic Algebra Centre.

Outreach

In 2016 AARMS supported the following outreach programs:

Nova Scotia Math Outreach Discussion Meeting

On June 22nd 2016 AARMS hosted its third annual outreach meeting at Dalhousie University in Halifax, NS.This meeting drew educators and researchers from across Nova Scotia to discuss their current outreach programs, problems and challenges they face, and plans for the future. Following the presentation of each of the programs, there was an opportunity for small-group discussion on a variety of pertinent topics. Broadly speaking the outreach programs presented may be divided in to three categories — camps, school visits and contests. Though many programs in each of these categories were discussed, what follows is a brief report on a single program from each category.

Camps: Each year the Black Educators Association hosts a math camp at Dalhousie for approximately 30 students from grades 6-8 in the African Nova Scotian community. The camp consists of classroom sessions on problem solving and computer science, as well as activities in the local Halifax community. In addition to the instructors, the camp is staffed by two Dalhousie student chaperones. The campers stay overnight for a week in the Dalhousie student residence. Students are invited to participate though the Black Educators Association and regional representatives at local school boards. The registration fee for campers is a nominal cost. Now in its 26th year, the camp continues to be a success. The main issue of the camp is one of communication. Though the information about the camp is forward to the same groups from year to year, the number of applications can vary greatly, depending on if the information is forwarded on.

Contests: The Kangaroo Math Contest is a Canada-wide math contest for students of all grades. Students write at a variety of locations throughout the country. Last year 64 students wrote the contest through Dalhousie University, of which nine were ranked nationally and one had a perfect score. The grading and invigilation are all done locally on a volunteer basis. In Nova Scotia the growth and participation in this contest is challenged by the timing. As it is a national contest, the date is not sensitive to Nova Scotia holidays and school-breaks. In order for this program to continue grow in Nova Scotia a renewed effort in advertising and preparation is required. As this is a rather difficult contest, it is easy for students to feel discouraged early on if they receive a seemingly poor score, not realizing that a good score is well below what they are used to receiving in the classroom.

School Visits
A program out of St. Francis Xavier moves mathematics in to the community through partnerships with African Nova Scotian and Aboriginal Nova Scotian communities. Rather than bringing general presentations in to these communities, the organizers collaborate with the community to develop culturally relevant material. The program is designed for students in grade 7-12 with the aim of helping them explore how mathematics shapes their lives and their futures. In this its first year, 29 sessions were held, reaching over 180 students. The program culminated with a celebration day

attended by students, community leaders, elders and faculty members. This celebration day consisted of morning workshops and an afternoon math scavenger hunt.

An overwhelming theme of discussion at the meeting was communication. Many outreach programs are aimed at school-aged students and as a result many of the meeting attendees are unsure how to reliably announce the availability of their programs. There was a sense that the teachers of these students are inundated with program and other announcements via email. There was also a concern that trying to filter these announcements through school principals met with limited success. Erick Lee, the HRSB Mathematics Consultant, suggested that he may have a role to play in solving this problem, and proposed a regular email newsletter to collect all of the pertinent outreach programs for a particular area. By putting all of this information in a single place and having it appear at a regular interval he suspects that we may better reach students for these programs.

The success of this meeting came not only in the presentation of the various programs, but in the opportunities for informal discussion between the formal agenda. During the lunch break and after the meeting, the attendees took the opportunity to discuss more nuanced issues related to their programs. These discussions allowed attendees to consider more in-depth and meaningful questions and solutions, ones which may have distracted discussion during the presentation portion of the agenda. Each of the attendees indicated that attending this meeting was time well spent and that they plan to attend this meeting in future years.

Attendees:
Sanjeev Seahra (University of New Brunswick, AARMS)
Tara Taylor (St. Francis Xavier University)
Robert van den Hoogen (St. Francis Xavier University)
Caroline Cochrane (Acadia University)
Jim Pulsifer (Acadia University)
Hugh Chipman (Acadia University)
Lois Murray (Dalhousie University)
Svenja Huntemann (Math Circles)
Danielle Cox (Mount Saint Vincent University)
John Irving (Saint Mary's University)
Jeannette Janssen (Dalhousie University, AARMS)
Nauzer Kalyaniwalla (Dalhousie University)
David Langstroth (Dalhousie University, AARMS)
R.P. Gupta (Dalhousie University)
Prenan Edwards (Halifax Regional School Board)
Erick Lee (Halifax Regional School Board)
Roman Smirnov (Dalhousie University)
Christopher Duffy (Dalhousie University, AARMS)
Dorette Pronk (Dalhousie University)

Annapolis Valley Regional School Board Outreach

Three types of Math Outreach activities were undertaken by Acadia University faculty. These activities were for Middle and High School students in Annapolis Valley Regional School Board (AVRSB), at a variety of schools. The activities were as follows:

1. Middle school (grade 7 and 8) visits at 4 AVRSB schools over the year
2. A "math circle" event at Acadia for high school students (grades 9-12)
3. Three Math League team competitions for high school students, held over the year

Middle school visits were hour-long sessions with grade 7 and 8 classes. The typical format is a short introduction to the topic by the instructor, followed by hands-on work by the students, and then more info from the leader as necessary. Sessions were held at 4 AVRSB schools (Pineridge in Aylesford, Kings County Academy in Kentville, Evangeline Middle School in New Minas, and Wolfville School). Math Circles events were held at Acadia University after school, with a target audience of high school (gr. 9-12) students. These were extended versions (2 hours sessions, with pizza break) of the middle school visits, with more advanced topics. Math League events involved organizing a regional chapter of a provincial math contest. There were 3 events, on Saturdays mornings, over the school year.

In both the middle school visits and the math circles, the intention was to engage Acadia students as assistants and instructors who would work with Acadia faculty. However, difficulties with scheduling meant that Acadia students did not participate in the activities. Additionally, only one Math Circle was
held, due to difficulties getting a critical mass of students.

Middle school visits engaged 78 students with 5 to 7 sessions during the year.
- Pineridge: 20 students in five 90-minute sessions over a 3-day period
- KCA: 30 students (2 separate classes of 15) in 7 hour-long sessions
- EMS: 12 students (drawn from all grade 7 students) in 7 hour-long sessions
- Wolfville: 16 students (drawn from all grade 7 students) in 7 hour-long sessions

Pineridge School was an intensive 3-day activity, while the other schools were hour-long sessions spread out from December to May. The Math Circle engaged 10 students in a 2-hour session. The math league had 3 events, each 3 hours long. Each event had 5 or 6 teams of students. 1 Event was held in December and 2 events in April (1 was rescheduled due to bad weather).

Math Challenge Club

We, (Jeannette Janssen and Dorette Pronk) started the Math Challenge Club in September 2015 to reach out to junior high and high school students who want to engage in problem solving. We meet weekly in the Chase Building at Dalhousie Unviersity and serve pizza during our time together. We started with five regular attendees in September, but after receiving support from AARMS the group has grown to about 20 students. With the AARMS support we have been able to advertize more effectively and word of mouth has brought us further growth. We were also able to hire a graduate student to help us with instruction and with the development of course material

and problems to discuss. The student, Elham Roshanbin, has a strong background in problem solving and math competitions. Her education was in her native country, Iran, and she participated in several advanced level competitions both as a high school student and as an undergraduate student.

The program is now most popular with junior high students and has also attracted some very bright elementary school students. One of our explicit goals is to make the club welcoming and attractive to female students, but male students are welcome as well. So far this has worked well. Just before the summer break we had nine regularly attending female students and most weeks we had about as many male as female students. We have received very positive feedback from the parents of our students and some of the girls continue to comment on how much they enjoy solving math problems and making new friends who have similar interests in mathematics. They enjoy both the problem solving and the relationships. One of the girls wrote at the end of the spring term, "I would like to thank you for organizing the sessions on Tuesday. They were a lot of fun and I learned a lot." And the mother of one of our boys wrote, "Ethan is thoroughly enjoying the math challenge club. It is a real highlight of his week." Several parents have also commented that they are grateful that we are providing their daughters with engaging and challenging problems, because they are bored at school.

This past year we had two students in grade 4, one in grade 5, two in grade 6, ten students in grade 7, and five in grade 8. With this large range in ages it is absolutely essential to have several instructors in the classroom. Usually, we had one person who made sure that our youngest students were able to participate, and one person who encouraged the most advanced students to work on more challenging problems and one person who walked around and helped others who need help at any point. We also took turns in presenting new material or leading the group through a particular problem.

During the time of the training our students have participated in the Kangaroo contest and performed extremely well, taking several medals home. Two of our students were invited to participate in the National Camp, organized by the CMS, and there is a chance that they will continue on with special training to become part of Math Team Canada. Unfortunately, they moved to Ottawa, so they won't be part of our group anymore. However, during the summer another young student joined us, who has been home-schooled and is well ahead of the curriculum. We hope to be able to coach her to successfully participate in the Canadian Open Math Competition this fall. (This is the qualifying competition to participate in the Canadian Math Olympiad and represent Canada in international contests.)

In the atumn about 75% of students returned (and they were already sending emails in mid August to ask us when we would start again). We have also received considerable interest from new students, especially from several new immigrant families from the Middle East. Five girls in grade 7 have signed up from this community.

UPEI Integration Tournament

The 2016 UPEI Integration Tournament was held on the evening of March 14, 2016 in conjunction with other Pi day festivities. In the month leading up to the tournament, it was announced in all Math classes that students who wished to participate could sign up. Over 30 students signed up, so on March 7 a Qualifying Quiz was   held and based on the results of that Quiz, 16 students were selected to participate in the Integration Tournament. Eight were first-year students and eight were upper-year

students. They were sent to the white board two at a time and the first to receive 2 points (one point was awarded for being first to complete an integral) advanced.

All 16 participant received School of Mathematical and Computational Sciences T-shirts. In addition, the top four finishers received a top-hat and a monetary prize. Gordon MacDonald acted as moderator for the event. Chris Vessey was technical support. Professors Justin Gulati and Shafiqul Islam were judges along with Morgan Erskine, who was the reigning champion.

As mentioned earlier, this was part of our Pi day festivities, which also included a Mathematical and Computational Sciences Trivia Contest (about Math, Stats & CS in movies, songs, TV shows and other areas of popular culture) and the eating of Pie. Total attendance at the event was approximately 50 students and faculty.

UPEI Mathematics Achievement Program (MAP)

The UPEI Mathematics Achievement Program delivers free day-camps to elementary students in PEI. The goal of this initiative is to create excitement about Mathematics and to help remove the fear and feelings of inadequacy that is often associated with learning math. Ideally, the program's goal is to show that mathematics does not have to be scary, but can be both challenging and fun. MAP strives to assist and motivate students who struggle with mathematics, while providing job opportunities for UPEI Mathematics Society members and pre-service teachers to develop and hone skills which will be relevant to their career path. The pilot phase of MAP involves the participation of students from six elementary schools in the Charlottetown area. The MAP Director and Coordinator worked closely with the Executive Director of the PEI Literacy Alliance and the UPEI Dean of Education, and to coordinate all aspects of the program, develop program evaluations and launch the program. This required many hours of dedicated work and ongoing communication with local elementary schools, the Department of Education, and the English Language School Board. The program had seven successful camps involving 30 students between late 2015 until the end of the 2016 school year:
- November 20, 2015: Shapes
- February 2, 2016: Forces&Friction
- February 26, 2016: Fractions
- March 11, 2016: Finance
- April 15, 2016: Patterns
- April 29, 2016: Probability
- May 6, 2016: Final Day

Evaluations of students, teachers and camp leaders were all positive.
Also sponsored by Skills PEI and UPEI

STFX AARMS-CMS Math Camp:

This camp is held annually in May each year and isfunded by a collaboration between AARMS and the Canadian Mathematical Society. The goal of the Math Camps is to provide students in North-Eastern and Central Nova Scotia with opportunities for personal growth in the mathematical sciences within a supportive environment. It is hoped that some of the students will develop capacity to be future leaders in the scientific community of the province.

This year's camp consisted of lectures delivered by experienced instructors from StFX, and fun filled activities included math relays, math trivia, problem solving, games, and hands-on activities from guest presenters .

Number of participants: 21.
Number indicating increased interest in math, science or engineering: 17
Number considering math, science or engineering careers: 16

Other Students' Comments:

'The group activities were fun."
'Makes math more enjoyable and gives more information about how math affects the world."
'I got to meet new friends while in my group and see new methods to solve problems."

Also sponsored by the St. Francis Xavier University and the CMS

Nova Scotia Math League

The Nova Scotia High School Math League is a competition run by the Dalhousie University Mathematics and Statistics Department designed to stimulate and challenge high school students across the province. The NSML is based on the very successful Newfoundland Math League which has been running since 1987. The first game was run in Halifax in 2002 by Richard Hoshino and Sarah McCurdy.

The NSML is an excellent venue for students to compete in a friendly manner and learn some mathematics in the process. Over the next years, we anticipate the NSML to expand to include additional regions and eventually encompass the entire province.

Also sponsored by Saint Mary's University

Math Camp for Black Students

The Dal-BEA Math camp for black students was held by the Dept of Mathematics and Statistics, Dalhousie University and the Black Educators Association on July 10-16, 2016. BEA sends out posters to all schools in Nova Scotia in the month of January. Applications from black students from grades 7 and 8 are solicited together with the recommendation from the heads of mathematics and guidance counsellors. Thirty campers were selected; however only 28 attended (18 female and 10 male). They came from junior high schools from all over Nova Scotia.

This year the focus of the camp was logic. The instructors were Mr. Gerry Clarke, Ms. Melina Kennedy, Mr. Preman Edward and dr. Elham Roshanbin. In the mathematics classroom students were taught via lectures, student-led discussions, partner work, group work, games and independent discovery. Throughout the week the students were introduced to new topics as well as building on topics and ideas that they were introduced to throughout the school year. These included playing the game 10 and NIM, where studnets discussed strategies on winning and looked at the mathematics behind simple games that they play. Also, students were introduced to the Fibonacci sequence via a hnds-on actiivity using the mating rituals of enclosed rabbits. These activities were well received by the studnetns, they were interested in using math to "always win" at games, thus allowing them to think about when they use mathematics in their everyday life and how the use of mathematics is important when thinking logically and solving problems..

The math teachers also wanted to enhance the educational experience by giving the students information that would help them in the upcoming school year. For some students, algebra and subsequently rearranging equations were new concepts. So, explaining these ideas in a different manner gave several students more clarity for the following shchool year. Also, explaining different tricks on how to multiply or divide large numbers quickly and mentally was a lesson that we found would increase the confidence students needed for the following school year. We also introduced the students to ArithmeCodes and Sudokus , allowing students to learn how we complete these puzzles and giving gthem opportunities to try them on their own.

At the end of the week we found that the students were much more confident in the math classroom. Also, the students were given the tools to show that they are capable of being leaders in the classroom when they retrun to their repsepctive schools in September.

Enhancing Our Appreciation of Mathematics Through Intentional Community Outreach

An ongoing program for developing public appreciation of mathematics: by creating a recreational mathematics exhibit, displayed in libraries; by implementing a public lecture series in the Fredericton Library; and by interactive visits to schools. Organized by John Grant McLoughlin (staffed by volunteers from the UNB Faculty of Education, UNB).

In 2016 these activities were enhanced by including sessions to develop mathematical problem solving for teachers and a project to accumulate an outreach loaning library, providing resources to other practitioners and facilitating their activities in classrooms.

Also sponsored by the University of New Brunswick

The Blundon Seminar - Math Camp

The W.J. Blundon Seminar is an annual three-day event organised by the Department of Mathematics and Statistics at Memorial University of Newfoundland, and held at its St. John's campus. Senior high school students from across Newfoundland and Labrador are invited to the Seminar based on their performance in the Euclid, Fermat and Cayley contests run by the University of Waterloo, as well as the Blundon contest administered by Memorial University. The Seminar runs for three days and two nights, during which students room together in a University residence. The goals of the Seminar are to expose Newfoundland and Labrador's best high school students to university-level mathematics and mathematical research; to help them hone their mathematical problem-solving skills; and to familiarise them with the University, with the Department, and with their peers. In addition to interacting with faculty from the Department, the students are also proctored by two senior undergraduate mathematics students (one male and one female), giving them the opportunity to gain insight into the university experience from individuals of a comparable age. The 2016 Math Camp and Seminar included 41 participants.

Also sponsored by the Province of Newfoundland, Newfoundland Power, CAIMS, MacMillan Publishing and the CMS

UPEI CMS-AARMS Math Camp

The 14th annual UPEI/CMS/AARMS Math Camp was held on the weekend of April 29 – May1, 2016, bringing to the UPEI campus some of the strongest math students in grades 10 & 11 in the PEI high school system. The goals are to offer these students an opportunity to participate in challenging, intellectual activities with their peers, guided by our faculty, and to encourage them to continue studying mathematics at the post-secondary level, whether as a major in mathematics or in one of the many disciplines that relies on mathematics. They also get a look at what life as a university student is like. The main activities at the camp are:

- Problem solving sessions by teams of 3 or 4 students, with current undergaduate students providing guiadance.
- Faculty sessions, where faculty members discuss some mathematical topic, outside the normal high school curriculum.
- A Careers in Math session, where a math faculty member tells the students about career opportunities in Canada for a mathematician or statistician.
- A Campus Tour
- A Math Trivia session
- Evening Recreational Activities

This year's math camp attracted 19 high school participants. They were joined by a group fo 6 current UPEI undergraduate students., who worked in shifts to accompany the campers around campus, mentor them during the probem solving sessions, and chaperone them during the evenings/overnights. All 8 full-time Math and Stats faculty also participated, either by conducting a session or as organizers.

Also sponsored by the Province of Newfoundland, Newfoundland Power, CAIMS, MacMillan Publishing and the CMS

New Programs

In 2016 AARMS embarked on two new programs:

1. Academic Sponsorship of MSRI
As a sponsor of MSRI, AARMS is able to offer the following limited funding opportunities to faculty and students at universities in Atlantic Canada:

Graduate Summer Schools: MSRI covers the travel and local expenses of 2-3 students to attend one of its Graduate Summer Schools. The rate for travel reimbursement is up to USD $600 for students from US and Canadian universities.

Visits by MSRI Members: AARMS can invite MSRI members to visit and give a colloquium or seminar talk at universities in Atlantic Canada. MSRI provides partial support for the member's visit (at present, up to USD $250).

Travel Support to BIRS events: MSRI will provide partial travel funding (up to a maximum of $750) for postdoc or ladder faculty members of Academic Sponsor Institutions to attend workshops at the Banff International Research Station (BIRS).

In this first year we have had some requests for funding for travel to BIRS events, but have come up against complications concerning US tax regulations which will need to be sorted out before this can work. We have not yet had any applications for the summer schools and we have had one request for a visit by an MSRI members to Dalhousie University.

2. African Institute of Mathematical Sciences (AIMS)

A memorandum of understanding was signed late last year between AARMS and the African Institute of Mathematical Sciences (AIMS). AARMS is happy to aid AIMS in its goal to develop capacity of mathematical talent in Africa, and to foster collaboration between universities in Atlantic Canada, and AIMS centres in Africa. The collaboration between AARMS and AIMS involves support for participation of African graduate students in the AARMS summer school, and a faculty exchange program. In the Faculty Exchange program, faculty from AARMS institutions are allocated teaching positions across the network of centres of excellence to deliver three-week courses within the AIMS one-year Structured Master's Program.

In this first year we sponsored to AIMS students at our annual Summer School. We have also directed some faculty members towards the faculty exchange program who have shown an interest

Administration and Governance

The significant administrative issue of 2016 concerned the need to change supplier for our online proposal systems. Our past supplier, Petrus IT, had created a custom-designed system which worked well for many years. Petrus IT also provided maintenance, upgrading and system administration services as required, billing us on an hourly basis. However, when an unusual number of necessary security fixes and system upgrades were all required in a short space of time the costs rapidly became too high.

In 2016 we researched alternatives and selected "Wizehive" to be the new supplier of our online system system services. The new supplier offered more functionality at a significantly lower price. This was possible because the system would be not a custom-made system but an adaptation of an existing online product. With many clients using the same product economies of scale enable this suppier to offer the service at a lower price. Furthermore, a fixed annual fee instead of an hourly rate would shield us from the risk of fluctuating system administration costs.

Going forward the annual cost will be USD $4000/year. There may be some additional expenses if we require any significant alterations to the system, but any such modifications would be expected to be under $2000.

Sanjeev Seahra, Director
Department of Mathematics and Statistics
University of New Brunswick

David Langstroth, Executive Administrator
Dalhousie University

The AARMS Executive Committee

Sanjeev Seahra (UNB), Chair
Colin Ingalls (UNB)
Richard Karsten (Acadia)
Dorette Pronk(Dalhousie)
Nasser Saad (UPEI)
Yuan Yuan (Memorial)

The AARMS Editorial Board

Yuri Bahturin (Memorial), Chair
Robert Dawson (Saint Mary's)
Theodore Kolokolnikov (Dalhousie)
Lin Wang (New Brunswick)
David Langstroth, Managing Editor (AARMS Executive Administrator)

AARMS is established through a set of statutes signed by the largest university in each Atlantic Province: Dalhousie University, Memorial University, University of New Brunswick and University of Prince Edward Island. These statutes define an organizational structure which includes a Board, an Executive Committee and a Scientific Review Panel.

The Director is based at the University of New Brunswick and the Executive Administrator of AARMS is based at Dalhousie University. The other members of the Executive Committee are drawn from Acadia, Dalhousie, Memorial, The University of New Brunswick and The University of Prince Edward Island, a distributed membership which includes large universities and small ones and enables AARMS to be in touch with current issues through Atlantic Canada and to be in dialogue with researchers in all provinces.

The Board is comprised of major sponsors of AARMS including Directors of the three Institutes and senior administrators from the universities; it also includes representatives of industry members of the Executive Committee and other mathematical scientists.

Our Scientific Review Panel is composed of mathematical scientists from Canada and abroad who are nationally and internationally respected in their fields. This panel assesses applications to our postdoctoral fellowship program, our collaborative research group program, and evaluates the larger requests for funding for workshops and converences. It provides scientific advice when requested.

The AARMS Board

Mark Abrahams – a behavioural ecologist who studies the risk of predation and its impact upon aquatic ecosystems. This work is of fundamental importance to understanding how ecosystems operate, as well as having application to conservation ecology and invasion dynamics. He worked at the University of Manitoba for 18 years before moving to Memorial University where he is the Dean of Science

Jim Colliander – is Professor of Mathematics at UBC and serves as Director of the Pacific Institute for the Mathematical Sciences. He is also the Founder/CEO of Crowdmark, an education technology company based in Toronto. Colliander's research intertwines partial differential equations, harmonic analysis, and dynamical systems to address problems arising from mathematical physics and other sources. He received his PhD in 1997 from the University of Illinois. After an NSF Postdoc at the University of California Berkeley, Colliander joined the University of Toronto and became Professor in 2007. He moved to UBC in 2015. Colliander was Professeur Invité at the Université de Paris-Nord, Université de Paris-Sud, and at the Institute Henri Poincaré. He has been a member of the Institute for Advanced Study. Colliander received a Sloan Fellowship, the McLean Award, and is an award winning teacher.

David Burns – Vice-President Research, UNB.

Robert Gilmour – currently is Vice President, Research at the University of Prince Edward Island. He formerly was a Professor of Physiology in the Department of Biomedical Sciences and Associate Dean for Research and Graduate Education at Cornell University, where he led a multidisciplinary group of investigators whose publications have appeared in both cardiovascular and physics journals. He also was a member of the Executive Committee for the IGERT-sponsored program in non-linear systems at Cornell and was a member of the Graduate Fields of Physiology, Pharmacology, Bioengineering and Computational Biology. His research interests are centered on theoretical and experimental studies of heart rhythm disorders.

Ian Hambleton – Director of The Fields Institute.

Ian Hill – Associate VP Research, Dalhousie University

Colin Ingalls – Professor, Department of Mathematics and Statistics, University of New Brunswick. He received hie Ph.D. in Pure Mathematics at the Massachusetts Institute of Technology in 1997. He works on interactions between noncommutative algebra and algebraic geometry.

Suman Kalyan – Suman is the visionary behind the evolution of Singolar – the leading AI and automated Machine Learning (auto ML) platform. Suman has a well rounded techno functional and Leadership experience (18 years) that includes Business Development, leading cross functional teams to build products, 'C' level management consulting, Solution Sales, building Analytics/ Machine Learning products,. He has a rich experience in applying state of the art Machine Learning techniques, Adaptive Learning, Control systems logic and statistical methodologies to create Intelligent Analytical software, for solving business problems. Prior to Singolar, Suman worked as Director of Technology for Allied Media with a focus on Big Data Analytics. Suman has worked for companies like General Electric, and consulted for companies Rogers and Telus. He started his career building neural networks software for Japan companies in the area of analytical chemistry and mathematical modeling. He lives in Halifax, Nova Scotia, Canada with his family. He enjoys sailing the lovely waters off the coast of Nova Scotia, golfing and teaches Taichi in his spare time. Suman graduated with a B.Tech and MS (by research) degrees with a focus on Systems Engineering, Statistics, Forecasting and neural networks from the Indian Institute of Technology (IIT), Madras, India. His research focus in his Masters Thesis was using artificial neural networks within time series analysis.

Richard Karsten – received his Bachelor's degree in Applied Mathematics in 1992 from the University of Waterloo and his PhD in Applied Mathematics in 1998 from the University of Alberta. He held a NSERC postdoctoral fellowship at M.I.T. from 1998 to 2001. He is currently a Professor (Mathematics and Statistics) at Acadia University in Nova Scotia. Dr. Karsten's research interests are in tidal energy, physical oceanography, fluid dynamics and computational mathematics.

Dorette Pronk – Associate Professor in the Department of Mathematics and Statistics at Dalhousie University. Dorette is a category theorist with a particular interest in higher category theory and in applications to the homotopy theory of orbifolds. She is part of the Atlantic Category Theory group with researchers at Dalhousie University, Saint Mary's University, Mount Allison University and Saint Francis Xavier University. Dorette is also involved in math outreach and in problem solving competitions such as the International Mathematical Olympiad. Dorette received her PhD in 1995 from Utrecht University in the Netherlands.

Nasser Saad – Professor, Department of Mathematics and Statistics, University of Prince Edward Island. He received his Ph.D. from Concordia University in 1998 (Mathematical Physics). Dr. Saad's research is in the area of special functions and their applications in mathematical and theoretical physics; his specialties include the asymptotic iterations method, Heun equation and supersymmetric quantum mechanics.
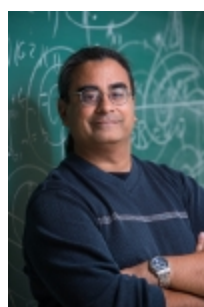
Sanjeev Seahra– **Director of AARMS** and Associate Professor at the Department of Mathematics and Statistics at the University of New Brunswick (Fredericton). He obtained his PhD in Theoretical Physics from the University of Waterloo in 2003 and held NSERC and PPARC postdoctoral fellowships at the University of Portsmouth in the United Kingdom. He is an affiliate member of the Perimeter Institute for Theoretical Physics and his research interests include general relativity, cosmology and quantum gravity.

Henrik Stryhn – Professor in Biostatistics, Department of Health Management, Atlantic Veterinary College (AVC), University of PEI. He received his PhD from the Royal Veterinary and Agricultural University of Denmark (now part of the University of Copenhagen) in 1994. A statistician by training, he has been working extensively with applications of statistics in agriculture and veterinary science. Dr. Stryhn emigrated from his native Denmark to Canada in 2001 to take up a position at AVC. His research interests include a

broad range of methods in statistics and epidemiology, in particular models involving random effects and other latent variables.

Luc Vinet – is Aisenstadt Professor of Physics at the Université de Montréal and the Director of the Centre de Recherches Mathématiques (CRM). Born in Montreal in 1953, he holds a doctorate (3rd cycle) from the Université Pierre et Marie Curie (Paris) and a PhD from the Université de Montréal, both in theoretical physics. After two years as a research associate at MIT, he was appointed as assistant professor in the Physics Department at the Université de Montréal in the early 1980's and promoted to full professorship in 1992. His research interests in Theoretical and Mathematical Physics include : exactly solvable problems, symmetries, algebraic structures, special functions and quantum information. Luc Vinet has sat on the board of many organizations. He is currently a Director of the National Institute for Nanotechnology and chairs the Fulbright Canada Board of Directors. He was a member of the Council of Canadian Academies' Expert Panel which assessed the State of Science and Technology in Canada in 2012. He holds an honorary doctorate from the Université Claude-Bernard (Lyon). He was made an Officer of the Ordre des Palmes académiques by the French Government and Knight of the Ordre de la Pléiade by the Parliamentary Assembly of the Francophonie. In 2009, the Government of Quebec awarded him the Armand-Frappier Prize in recognition of his outstanding research career and of his contributions to the creation and development of research institutions. In 2012, he received the CAP/CRM prize in Theoretical and Mathematical Physics as well as the Queen Elizabeth II Diamond Jubilee Medal recognizing his contribution to the establishment of Mitacs.

David Wolfe – Senior Software Engineeer at QRAcorp, a company which automates the verification of design of control systems. David received his PhD from UC Berkeley in Computer Science, and was an Assistant Professor at Gustavus Adolphus College. He has since worked for several small software development firms and for Google, Zurich. David's research publications are in the fields of recreational mathematics and the mathematics of games.

Yuan Yuan – Professor at Memorial University of Newfoundland. She received her PhD in Applied Mathematics at the University of Western Ontario in 2002. Her research interests include Applied Dynamical Systems, Functional Differential Equations and Applications.

The AARMS Scientific Review Panel

Jason Bell - is a Professor of Pure Mathematics at the University of Waterloo. He obtained his PhD from the University of California, San Diego in 2002 and did a three-year postdoc at the University of Michigan before starting as an Assistant Professor at Simon Fraser University in 2005. He became a Full Professor in 2012 and moved to the University of Waterloo in 2013. His main research area is noncommutative algebra, with a focus on its applications to number theory and other areas of mathematics. He currently serves on the editorial board for the Canadian Journal of Mathematics, the International Journal of Algebra and Computation, and Communications in Algebra, where he is editor-in-chief.

Darryn Bryant – is a Professor in Mathematics at the University of Queensland, where he obtained his Ph.D. under the supervision of Sheila Williams in 1993. He has held several Australian Research Council Fellowships, and has served on the Council of the Combinatorial Mathematics Society of Australasia since 2001. His research interests lie predominantly in graph theory and design theory, and he is a member of the editorial board for the Journal of Combinatorial Designs and the Australasian Jnl of Combinatorics.

Stephen Cantrell – is Professor and Chair of the Department of Mathematics at the University of Miami, where he joined the faculty in 1982, after earning his B.S. degree summa cum laude from Furman University in mathematics in 1976 and his Ph.D. from the University of Utah in 1981 under the supervision of Klaus Schmitt. His research interests lie at the interface of nonlinear analysis and partial differential equations with mathematical biology, particularly in relation to spatial ecology, epidemiology and evolutionary biology. He is the author or co-author of over 80 papers and the co-author (with Chris Cosner) of the book Spatial Ecology via Reaction-Diffusion Equations, and his work with Cosner at the interface of mathematics and biology has enjoyed continuous support from the US National Science Foundation since 1988.

Steven Carlip – is a professor of physics at the University of California at Davis, specializing in quantum gravity. He received an undergraduate degree in physics from Harvard in 1975, and after seven years as a printer, editor, and factory worker, returned to school at the University of Texas, where he earned his Ph.D. in 1987. Following a postdoctoral position at the Institute for Advanced Study, he joined the faculty at Davis in 1990. He is a Fellow of the American Physical Society and the Institute of Physics, has served on the editorial boards of four journals (including Physical Review Letters), and has reviewed grant proposals for the national science agencies of 14 countries. His particular research interests include lower dimensional quantum gravity, quantum black holes, numerical approaches to the

Feynman path integral, quantum fluctuations of topology, and "spontaneous dimensional reduction" at short distances.

Richard Cook – is Professor of Statistics in the Department of Statistics and Actuarial Science at the University of Waterloo and Tier I Canada Research Chair in Statistical Methods for Health Research. He also holds a cross-appointment to the School of Public Health and Health Systems and is an Affiliate Scientist at the PROPEL Centre for Population Health Impact at the University of Waterloo. His research interests include the life history analysis, the design and analysis of clinical and epidemiological studies, and statistical methods for incomplete data. He is currently Associate Editor for Statistics in Medicine, Biometrics, and Statistics in Bioscience. He was the recipient of the CRM–SSC Prize in 2007 and in 2008 was elected Fellow of the American Statistical Association.

Chantal David – works in number theory, and her work focuses on understanding distribution questions associated to arithmetic objects such as elliptic curves, abelian varieties and families of curves over nite elds. This touches the fields of arithmetic statistics, analytic number theory and random matrix theory. Chantal David obtained her Ph.D. from McGill University in 1993 under the supervision of Ram Murty, and she joined the mathematics faculty at Concordia University in the same year, where she is now a Full Professor. From 2004-2014, she was the Deputy Director of the Centre de Recherches Mathematiques (CRM). She is now serving on the Board of Director of the Canadian Mathematical Society (Director-VP Quebec). She was a Member of the Institute for Advanced Study for the theme year in Analytic Number Theory in 2009-2010, and will be member of the MSRI for the theme semester in Analytic Number Theory in 2017. She received the CMS Krieger-Nelson Prize for outstanding research by a female mathematician in 2013.

Ruth Gregory – is a Professor in Mathematics and Physics at Durham University, UK. She received her BA in Mathematics from Trinity College Cambridge in 1984, and her PhD from DAMTP, Cambridge in 1988. Following post-docs in Fermilab and the University of Chicago, she returned to Cambridge, then moved to Durham on a Royal Society Research Fellowship. Her research interests lie at the interface of gravity, high energy particle physics and cosmology. In 2006 she was awarded the Institute of Physics Maxwell Medal, and in 2011 a Royal Society Wolfson Merit Award. She has served on several research council panels, advisory panels and editorial boards. She is currently a Managing Editor of International Journal of Modern Physics D, and lectures regularly for the Perimeter Scholars Program at the Perimeter Institute.

Leslie Hogben – is Dio Lewis Holl Chair in Applied Mathematics and Professor of Mathematics at Iowa State University, and Associate Director for Diversity of the American Institute of Mathematics. She received her BA from Swarthmore College and her PhD from Yale University. Her research is in linear algebra, graph theory, and applications of linear algebra. She is the editor of the Handbook of Linear Algebra, associate editor of the journals Linear Algebra and its Applications and Electronic Journal of Linear Algebra, and is the Secretary/Treasurer of the International Linear Algebra Society.
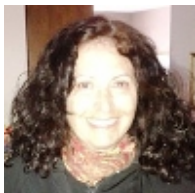
Weizhang Huang – is a professor at the University of Kansas. He received his PhD degree from the Chinese Academy of Sciences in Beijing in 1989. His research interest is in numerical analysis and scientific computing with emphasis on the numerical solution of partial differential equations. Recent topics include mesh movement, mesh adaptation, anisotropic mesh generation, finite element analysis, collocation and spectral methods, geometric integration, and their applications.
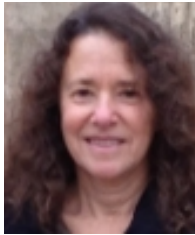
Susan Niefield – earned her BA from Douglass College in 1974 and PhD from Rutgers University in 1978. Following a Killam postdoctoral fellowship at Dalhousie University, she joined the Department of Mathematics at Union College (Schenectady, NY) where she was named Professor Emerita in 2015. Her research interests include double categories, exponentiability, locales, quantales, and toposes.

Susan Sierra – received her Ph.D. in 2008 from the University of Michigan. After an NSF postdoctoral fellowship at the University of Washington and at Princeton, she began a lectureship at the University of Edinburgh in 2011. She is now a Senior Lecturer at the University of Edinburgh. Her research is in noncommutative ring theory; she is particularly interested in interactions with algebraic geometry and with infinite-dimensional Lie algebras.

Gail Wolkowicz – received her BSc and MSc degrees from McGill University and her PhD degree from the University of Alberta in 1984. Before joining the Department of Mathematics and Statistics at McMaster University in 1986, where she is currently a full professor, she obtained an NSERC postdoctoral fellowship which she held for one year at Emory University followed by one year at Brown University. She has served on the Board of Directors of the Canadian Mathematical Society. She was the recipient of the 2014 Krieger-Nelson prize and the 2015 Lord Robert May Prize for the best paper in the Journal of Biological Dynamics for

2013-2014. Her research interests are in dynamical systems and bifurcation theory with applications in biology and ecology.

Yingfei Yi – obtained his B.S. degree from Jilin University and Ph.D. degree from the University of Southern California. He worked at Georgia Institute of Technology for twenty-four years before joining the University of Alberta in 2014 as a Killam Memorial Chair. He also held adjunct/visiting positions at the University of Minnesota where he was a visiting member of the IMA, the University of Cambridge where he was awarded a Rosenbaum Fellowship at the Isaac Newton Institute, the National University of Singapore where he was appointed as a visiting professor, director of NUS-IMRE Lab for Multidisciplinary Research and deputy director of the University Center for Dynamical Systems, and Jilin University where he received a University Research Fellowship, an Outstanding Young Scientist Award from NSFC, a Changjiang Scholarship, a Qianren Scholarship, and was appointed as director of JLU-GT Joint Institute for Theoretical Sciences. He is a co-editor in chief for the Journal of Dynamics and Differential Equations, a handling editor for the Journal of Differential Equations, an editor for the Proceedings of the American Mathematical Society, the SIAM DSweb Magazine, and three other journals. His research interests lie in dynamical systems and qualitative theory of differential equations.

AARMS Financial Statements

AARMS funds are held in accounts at Dalhousie University and The University of New Brunswick and are subject to the oversight and auditing of the Financial Services Departments of those universities. The following accounts are a view of the data compiled by Dalhousie and UNB.

The financial year is January 1 – December 31. The statements employ cash-flow accounting which is the method which records transactions when funds move, rather than when transactions are accrued. This is consistent with university statements but may create timing anomalies: if an event which occurs in 2015 is paid for in 2016 then it will show up in the 2016 accounts.

Income and Expenditure Account
2016

A A R M S

Income[1]	$	$	2015
Carried forward from previous year		202,999	190,875
Mathematical Institutes		105,000	110,000
Universities		106,000	129,000
Provinces		321,096	150,000
Other Revenue (1)		378	694
Total Income		**735,472.94**	**580,569**

Expenditure

	$	$	2015
Summer School		62,219	75,496
Workshops and Events (5)		63,189	76,238
Outreach (5)		38,299	16,645
PDF Program (6)		113,750	70,000
Collaborative Research Groups (7)		53,178	75,920
Distinguished Lecturers		2,000	0
Book Series		0	0
Administrator Salary		31,811	31,762
AARMS Online system (8)		27,026	14,369
Travel		2,990	1,962
Office Expenses		2,533	2,177
Dalhousie Overheads		13,000	13,000
Total Expenditure		**409,994.64**	**377,570**
Surplus: Income Less Expenditure		**325,478.30**	**202,999**

Notes

1. For a breakdown see Appendix 1
2. Travel, Accommodation and stipends of $5,000 each
3. Residence and Meals
4. Texts and course materials, promotion, secretarial, computing , hospitality

5. See Appendix 2
6. See Appendix 3
7. See Appendix 4
8. See Appendix 5

Balance Sheet
31-12-2016

A A R M S

**Assets**	$	$
Surplus from Operations (Income less expenditure)		325,478
Accounts Receivable[1]		
2016 funds from Moncton	1,000	
2016 funds from Mount St. Vincent	1,000	
2016 funds from Cape Breton	1,000	
2016 support from, CRM for summer school	10,000	
2017 Acadia Funds	5,000	
2017 Dalhousie Funds	30,000	
2017 Memorial Funds	30,000	
2017 Mount Allison Funds	1,000	
2017 UNB Funds	30,000	
2017 UPEI Funds	5,000	
2017 St. Mary's Funds	1,000	
2017 STFX Funds	1,000	
2017 CBU Funds	1,000	
2017 Moncton Funds	1,000	
2017 Mount St Vincent Funds	1,000	
2017 CRM Funds	30,000	
2017 Fields Funds	30,000	
2017 PIMS Funds	30,000	
2017 Province of NB Funds	50,000	
2017 Province of NL Funds (through RDC)	25,000	
		284,000
Total Assets		**609,478**

**Liabilities**		
Accounts Payable[2]		
2016 AAC Prizes	1,000	
2016 Combinatorial Albegra	2,000	
2016 Summer School on Math Epidemiology	2,000	
2016 Workshop on Homotopy Type Theory	2,000	
2016 GRASCan	3,000	
2016 Category Theory	7,500	
2016 Atlantic General Relativity	4,940	
2016 Numerical Analysis Singularly Pertrubed...	7,500	
2016 Parallel in Time Integration	2,000	
2016 Games at Dal	3,000	
2016 Math League	6,250	
2016 Math Problem Solving w. Teachers	3,000	
2016 Annapolis Valley RSB outreach	457	
2016 Mathj Challenge Club	1,000	
2016 Data Science/Analytics in Fredericton	2,500	
2016 Outreach Loaning Library	1,300	
2016 Outreach Coordinator	7,317	

2016 Summer School expenses	48,189
2016 Postdoctoral Fellowships	75,833
2016 CRGs	37,920
2017 AAC Prizes	1,000
2017 Atlantic General Relativity	4,370
2017 Americas Conf on Diff Eq.	5,000
2017 Canadam	2,500
2017 East Coast Combinatorics	3,100
2017 Minicourse on Hopf Algebroids	3,850
2017 CAIMS Public Lecture	5,000
2017 AARMS Poster Awards at CMS	2,000
2017 MSRI sponsorship	5,855
2017 UPEI Math Camp	1,230
2017 STFX Math Camp	2,608
2017 Annapolis Valley RSB outreach	638
2017 Dalhousie Math Camp	3,000
2017 Math Challenge Club	3,000
2017 Mathematics in the World	1,500
2017 Connecting Math to Our Lives	5,000
2017 UPEI Integration Tournament	600
2017 Blundon Seminar Camp	3,000
2017 Outreach Coordinator	20,000
2017 AARMS Summer School	75,000
2017 CRGs	40,000
2017 PDFs	123,333
2017 Administrator Salary	31,000
2017 Dalhousie Overheads	13,000
2017 Online System	5,400
2017 AARMS Poster	1,000
2017 Travel	1,500
2017 Office Expense	2,000

	582,189

Unallocated funds - for AARMS activities	27,290

Total Liabilities	**609,478**

Notes

1. Fees due to be collected in 2017
2. Funding Commitments in 2017

A A R M S

Appendix 1

Revenue Breakdown

Provinces

New Brunswick	50,000	
Newfoundland (1)	71,096	
Nova Scotia (2)	200,000	
		321,096

Mathematical Institutes

CRM (3)	45,000	
Fields	30,000	
PIMS	30,000	
		105,000

Universities

Acadia	5,000	
Cape Breton (4)	0	
Dalhousie	30,000	
Memorial	30,000	
Moncton (5)	0	
Mount Allison	1,000	
Mount Saint Vincent	1,000	
Saint Francis Xavier (6)	2,000	
Saint Mary's (7)	2,000	
UNB	30,000	
UPEI	5,000	
		106,000

Other Revenue

book royalties	378	
		378

total:		**532,474**

Notes

1. RDC funds for 2014-16
2. includes sponsorship for 2016 and 2017
3. includes $15,000 from 2015
4. expecting this payment of $1000 in 2017
5. expecting this payment of $1000 in 2017
6. Including $1000 owed from 2015
7. Including $1000 owed from 2015

Appendix 2

Workshops and Scientific Events

2015 Domain Decomposition Methods	7,500
2015 Pattern Formation and Differential Equations	5,000
2015 CMS Session – Interplay of Convexity	3,457
2015 CMS Session – Dynamical Systems	3,000
2015 Algebraic Groups and Lie Algebras	5,000
2015 Selected Areas of Cryptography and SAC Summer School	5,000
2015 Atlantic Math/Stats/CS Conference	4,000
2016 AARMS-AAC Minicourse: Dr. Istvan Heckenberger	2,500
2016 CMS Poster Prizes	2,000
2016 Software Carpentry Bootcamp	2,174
2016 East Coast Combinatorics Conference	3,000
2016 MSRI Sponsorship	5,808
2016 Workshop on Hopf Algebras, Algebraic Groups	5,000
2016 Selected Areas of Cryptography and SAC Summer School	5,000
2016 Amy Hurford MSRI reimbursement for conference travel	750
2016 Atlantic Universities Math/Stats/CS Conference	4,000

total   **63,188.74**

Outreach

2015 UPEI Math Camp	1,400
2015/16 UPEI Math Challenge	5,000
2015/16 Dalhousie Math Challenge Club	960
2015/16 John McLoughlin outreach in NB	2,500
2016 UPEI Integration Tournament	500
2016 AARMS Outreach meeting	1,939
2016 Blundon Seminar Camp	2,500
2016 STFX Math Camp	2,000
2016 Black Educators Math Camp	4,000
AARMS Outreach Coordinator	17,500

38,298.94

A A R M S

Annual Accounts
2016

Appendix 3

Postdoctoral Fellowships

Israel Rocha	20,417
Daniele Gregoris	14,583
Rory Lucyshyn-Wright	26,250
Baocheng zhu	8,750
Peng Zhou	8,750
Yuzhao Wang	8,750
Jonathan Ziprick	8,750
Nathan Grieve	17,500
total	**113,750.00**

Appendix 4

Collaborative Research Groups

Numerical Analysis and Scientific Computing	18,000
Graphs and Games (return of surplus funds)	-4,742
Iterated Function Systems, Fractals	20,000
Black Holes	19,920
total	**53,177.73**

Annual Accounts
2016

Appendix 5

Online Sysem Expenditures

Linode hosting fees	338.81
2015 Petrus IT system upgrade fees charged at $160/hr	8,396.00
2016 Petrus IT monthly administration fees	5,765.97
Wizehive setup fee	7,339.70
Wizehive annual fee	5,185.60
total	**27,026.08**

Appendix 6

A Breakdown of the amount carried forward to 2017

Carried forward (from the Income and Expenditure Account)   **325,478**

MINUS Outstanding expenses for 2016

2016 Conferences and Workshops	34,940	
2016 Outreach	21,823	
2016 Summer School	48,189	
2016 Postdoctoral fellowships	75,833	
2016 CRGs	37,920	
		218,705

MINUS Funding for 2017 already received

2017 funds from Province of NS   **100,000**

Plus Outstanding income for 2016

2016 Institutes and Universities   **13,000**

reconciled amount carried forward   **19,773**