AARMS

**Atlantic Association for Research in the Mathematical Sciences**

# Annual Report 2017

www.aarms.math.ca

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## *Message from the Director*

In 2017, AARMS has been diligently pursuing its mission of supporting mathematical sciences research, advanced training, and outreach throughout Atlantic Canada. In this report you will find a summary of AARMS activities in 2017; my purpose here is to highlight just a few of the institute's recent initiatives and some issues looming on the horizon.

One of the most exciting AARMS developments in 2017 is the appointment of two new collaborative research groups (CRGs). One of these is *Statistical Learning for Dependent Data*, which involves ten faculty members from four Atlantic Universities. The CRG aims to address emerging statistical learning and computing issues motivated by problems in medicine and the environment. The group's first workshop on "Health Data Analytics" was notable because of the fruitful interaction between researchers from diverse fields (i.e. statisticians, economists, computer scientists, etc.), which underscores the truly interdisciplinary scope of this CRG. The CRG is the central component of a current proposal for a CANSSI Health Science Collaborating Centre. The other new AARMS CRG is called *Dynamical System and Spatial Models in Ecology*. This CRG will use its expertise to address regionally vital issues such as the propagation of invasive green crabs throughout Atlantic Canada and the treatment of salmon lice in aquaculture. The CRG is planning its first annual meeting to take place in conjunction with the Canadian Mathematics Society (CMS) Summer Meeting to be held in Fredericton in June 2018. These two new CRGs replace three others whose term ended in September 2018. Final reports from each of these CRGs can be found below.

Another new development is the formation of a standing AARMS committee on Industrial Collaboration. This new body is chaired by Richard Karsten from Acadia University, and includes Hong Gu (Dalhousie), Scott MacLachlan (MUN) and James Watmough (UNB). The committee's purpose is to oversee, promote and expand AARMS's academic-industrial collaboration activities.

This committee is currently planning AARMS' first Industrial Problem Solving Workshop (IPSW), to be held at Dalhousie University in early July 2018. IPSWs are events where representatives from various companies present academically interesting and industrial relevant problems to graduate students and faculty mentors. The mentors and students work intensively on the problems for a few days and then present their solutions back to the industrial representatives. These workshops have been successfully operating elsewhere in Canada for over twenty years, but we have yet to host one in the Maritimes. Many thanks to due to AARMS Board Member David Magee (UNB Vice-President Research) and Nancy Mathis (Wallace McCain Institute) for putting AARMS in touch with partner companies for this IPSW.

The AARMS Summer School was held for the first time at the University of Prince Edward Island (UPEI) in 2017. The topic was financial mathematics, and the school was a great success by all measures. Next year, the school's main topic will be Data Analytics, and it will again take place in Charlottetown. The school's lecturers are Osmar Zaiane (Foundations in data science and applications), Mark Schmidt (Machine learning and data mining), Jiguo Cao (Functional data analysis), and Wenqing He (Statistical learning for high dimensional data). UPEI has proposed a novel modification of the Summer School paradigm: namely, inviting people from local industry to participate as summer school students. We are very interested to see how this experiment plays out.

The 2017 AARMS Postdoctoral Competition began in October 2017 with several new rules and procedures that were suggested by the AARMS community. Offers to the top three candidates went out in February 2018. The first AARMS outreach postdoctoral fellow, Christopher Duffy, came to the end of his term in the summer of 2017, and we are happy to report that he now holds a tenure-track position at the University of Saskatchewan. The competition for the next AARMS outreach postdoc recently concluded, and the successful candidate will start on August 1, 2018.

The Institute's website at aarms.math.ca went gone through a significant structural and visual refresh in the summer of 2017. All the content from the old site is still there, but is now easier to find. The new landing page features a slideshow where we plan to showcase both the Institute's activities as well as mathematical sciences research from the region. We welcome comments and suggestions for the website from the AARMS community.

AARMS formed a new partnership with the Girl Guides of Canada in 2017 to hold a series of provincial camps for girls aged 9-17. The purpose of these camps is to expose girls to the exciting mathematical science research undertaken at universities at an age when they are beginning to think seriously about their postsecondary education. AARMS believes that there should be more women working in the mathematical sciences, and the best way to do this is to reach out to them when they are young. Each camp is anticipated to involve 500 or more girls, and the first will take place May 12-13, 2018 at the University of New Brunswick's Fredericton campus (subsequent editions will be at Dalhousie and Memorial in 2019 and 2020, respectively). We were successful in obtaining a renewable $37,500 grant NSERC's *PromoScience* program to support this event. We are grateful to UNB for providing over $10,000 in additional funding for the inaugural 2018 camp.

In other funding news, we are pleased to announce that the government of Prince Edward Island has agreed to fund AARMS at the level of $5,000 per year on an ongoing basis. AARMS Board member Robert Gilmour (UPEI Vice-President Research) was instrumental in making this happen, and we are very appreciative of his efforts.

The next competition round for federal funding for Canada's mathematical sciences institutes has been delayed by one year by NSERC. Part of the rationale for this decision was a desire to hold the next competition well after the 2018 federal budget. In February of 2018, we were very pleased to learn that the federal budget incorporated several recommendations of 2017's *Fundamental Science Review* (also known as the "Naylor Report"), and that NSERC's funding over the next five years will be significantly increased. We are now hopeful for a commensurate enlargement of the Collaborative and Thematic Resources in the Mathematical Sciences (CTRMS) envelope.

Collaboration between AARMS and Canada's other mathematical science institutes (Fields, CRM, PIMS and CANSSI) greatly intensified in latter half of 2017 as we jointly prepared a letter of intent (LOI) for the federal Networks of Centres of Excellence (NCE) program. The purpose the proposed NCE was to develop and enhance partnerships between industry and Canada's mathematical scientists. We received pledges of over $8M in cash and in-kind support for the NCE from companies, non-academic entities, and the host university (Montreal). Unfortunately, the proposal did not advance beyond the LOI stage of the competition. Collectively, we are currently exploring ways in which the considerable momentum generated by this process can be exploited in the future.

Finally, I would like to express my appreciation to the Executive, the Board, members of the Scientific Review panel, and wider Atlantic mathematical community for their continued efforts in driving all of AARMS' programs and initiatives. As always, we owe David Langstroth special thanks for his continued professional and efficient management of the institute's administrative affairs. AARMS is grateful for the ongoing (and new) support of a number of organizations, including the provinces of Nova Scotia, New Brunswick, Newfoundland and Labrador, and Prince Edward Island; NSERC; and all of AARMS' member universities. We would also like to thank PIMS, Fields, CRM and CANSSI for their continuing and valued collaboration.

Sanjeev Seahra
AARMS Director
February, 2018

## *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, attract post-doctoral fellows and offer enhanced training programs attracting more graduate students.

In 2017 the third generation of AARMS CRGs completed their second and final year. They were: **The Collaborative Research Group in Numerical Analysis and Scientific Computing**, under the administration of Dr. Ron Haynes, **Mathematical and Physical Aspects of Black Holes**, under the administration of Dr. Ivan Booth, and **Iterated Function Systems (IFS), Fractals, Invariant Measures and Applications** under the administration of Dr. Shafiqul Islam. We report on these below.

In autumn 2017 two new AARMS CRGs began operations: **Dynamical Systems and Spatial Models in Ecology** under the administration of Dr. Amy Hurford, and **Statistical Learning for Dependent Data** under the administration of Dr. Ying Zhang. These two new CRGs will be included in next year's report.

## *The Collaborative Research Group in Numerical Analysis and Scientific Computing*

Members:

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

The AARMS CRG in Numerical Analysis and Scientific Computing was formed in September 1, 2013. Funding was renewed for the period from September 1, 2015-August 31, 2017. This note gives a summary of activities for the final year of the CRG, from 2016–2017.

### *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 activities of the CRG have been the organization of a Software Carpentry and PetSc workshop (June, 2017) and the planning of a BIRS workshop on adaptive methods for PDEs (coming in May 2018) and the 25th international Domain Decomposition Methods Conference (coming in July 2018). 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.

### *2017 Software Carpentry and PETSc workshops*

From May 27th to June 2nd, 2017, Memorial University hosted a combined Software Carpentry Workshop and tutorial on the Portable Extensible Toolkit for Scientific Computation (PETSc). The Software Carpentry Workshop, taught by ACEnet staff and assisted by Memorial students and 1postdoc, lasted two days and covered a broad array of basic research computing skills. The PETSC workshop included a three-day tutorial, taught primarily by Jed Brown (University of Colorado and a member of the PETSc development team), and two days of consulting sessions where Dr. Brown discussed PETSc usage with a cross-section of researchers and computing staff from across the Memorial campus. These workshops attracted 33 participants, primarily students and postdoctoral researchers from Memorial, but also including visiting researchers and other participants from the CRG.

### *Organization of the 2018 BIRS Adaptivity workshop*

One of the CRG members (Haynes) has been a co–organizer of an upcoming BIRS workshop on adaptive methods for PDEs to be held this coming May in Banff. This workshop brings together scientists from the fields of adaptive methods for PDEs to discuss similarities and differences between their respective approaches to adaptive space/time algorithms, their applications and, ultimately, their combination. Participants will include senior domain experts and young researchers to foster vigorous discussion and to advance the state-of-the-art in this exciting and emerging field.

### *Organization of the 25th International Domain Decomposition Methods Conference*

Three of the CRG members (Haynes, MacLachlan and Brunner) are amongst the local organizers for the upcoming 25th International Domain Decomposition Methods Conference. A successful proposal to host the meeting was presented to the international scientific committee at DD25 held in Svalbard Norway in February of 2017. This is a top level scientific computing meeting attracting 13 plenary speakers and so far 17 accepted minisymposia. See http://dd25.math.mun.ca for more information.

### *Group member publications and activities 2016–2017*

The following CRG members have submitted a summary of their 2016-2017 activities.

Hermann Brunner:

1. (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.

2. (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.
3. (with H. Liang) Integral-algebraic equations: theory of collocation methods II, SIAM J. Numer. Anal., 54 (2016), 2640-2663.
4. (with S. Seyed Allaei and W.Z. Yang) Numerical analysis of collocation methods for third-kind Volterra integral equations, IMA J. Numer. Anal. (published online 19 July 2016).
5. (with H. Liang) On the convergence of collocation solutions in continuous piecewise polynomial spaces for Volterra integral equations, BIT Numer. Math., 56 (2016), 1339-1367.
6. (with T. Tang and Z.W. Zhang) Numerical blow-up of nonlinear parabolic integro-differential equations on unbounded domains, J. Sci. Comput., 68 (2016), 1281-1298.
7. (with S. Seyed Allaei and Z.W. Yang) Collocation methods for third-kind Volterra integral equations, IMA J. Numer. Anal., 37 (2017), 1104-1124.
8. (with S. Gourley, R.S. Liu and Y.Y. Xiao) Pauses of larval development and its consequences for stage-structured populations, SIAM J. Appl. Math., 77 (2017), 977-994.
9. Volterra Integral Equations: An Introduction to Theory and Applications, Cambridge Monographs on Applied and Computational Mathematics, Vol. 30, Cambridge University Press, Cambridge/UK, 2017.

Scott MacLachlan
31. Multigrid methods with space-time concurrency, R. Falgout, S. Friedhoff, Tz. Kolev, S. MacLachlan, J. Schroder, and S. Vandewalle,Comput.Vis. Sci., 18(4-5):123-143, 2017.
2. A Gauged Finite-element Potential Formulation for Accurate Inductive and Galvanic Modelling of Three-dimensional ElectromagneticProblems, S.M. Ansari, C.G. Farquharson, and S.P. MacLachlan,Geophysical Journal International, 210(1):105-129, 2017
3. Preconditioning a mass-conserving discontinuous Galerkin discretization of the Stokes Equations, J. Adler, T. Benson, and S. MacLachlan,Numer. Linear Alg. Appl., 24(3):e2047, 2017
4. Effect of thermocapillary stress on slip length for a channel textured with parallel ridges, M. Hodes, T. Kirk, G. Karamanis, and S.MacLachlan,Journal of Fluid Mechanics, 814:301-324, 2017.
5. A deflation technique for detecting multiple liquid crystal equilibrium states, J.H. Adler, D.B. Emerson, P.E. Farrell, and S.P. MacLachlan,SIAM J. Sci. Comp., 39(1):B29-B52, 2017.

Scott was on the organizing committees of the 18th Copper Mountain Conference on Multigrid Methods, the IV AMMCS International Conference, and the International Conference On Preconditioning Techniques For Scientific And Industrial Applications 2017.

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

2. Haynes, R.D. and Kwok, F., Discrete analysis of Domain Decomposition Algorithms for Grid Generation via the Equidistribution Principle, MATHEMATICS OF COMPUTATION Volume 86, Number 303, January 2017, Pages 233-273 PDF Arxiv
3. Bihlo, A., Haynes, R.D., Farquharson, C., Loredo-Osti, J.C., Probabilistic Domain Decomposition for the Solution of the Two-Dimensional Magnetotelluric Problem, Comput. GeoSciences, February 2017, Volume 21, Issue 1, pp. 117-129. Arxiv
44. Hillier, S.H, Reid, G.D., Haynes, R.D., Robertson, Z., Robertson, M.D. On the Role of the Second-Order Derivative Term in the Calculation of Convergent Beam Electron Diffraction Patterns, Ultramicroscopy, Accepted April, 2017. Volume 179, pp. 73-80 PDF.
5. Haynes, R.D., Domain Decomposition Approaches for PDE based Mesh Generation, LNCSE, 12 pages, In Press, January 2018.
6. Mohagheghian, E., Haynes,Summary of Activities R.D., and James,L. Optimization of Hydrocarbon Water Alternating Gas (WAG) in the Norne Field: Applicationof Evolutionary Algorithms, Accepted in Fuel, January 2018.

Paul Muir's Publications and Activities
1. Paper: P.H. Muir, J. Pew, An Analysis of the Reliability of Error Control B- spline Gaussian Collocation PDE Software, 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. Paper: 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. Software: J. Pew, Z. Li, P.H. Muir, Algorithm 962: BACOLI: B-spline Adaptive Collocation Software for PDEs with Interpolation-based Spatial Error Control, Collected Algorithms of the ACM, 2016.
4. Technical Report: Application of Error Control Software to ODE and PDE-based Epidemiological Models, Conner Tannahill, Paul Muir, Technical Report, Department of Mathematics and Computing Science, Saint Mary's University, 2017.
5. Submitted: Performance Analysis of Error Control B-spline Gaussian Collocation Software for PDEs , Jack Pew, Zhi Li, Conner Tannahill, Paul Muir, Graeme Fairweather. 2018.
Other Activities:
1. I was one of the attendees at the PinT workshop
2. I was one of the organizers of the CAIMS 2017 meeting. The research areas covered in the conference certainly included the areas covered by our CRG. I organized and spoke at a MS (in hounour of Pat Keast) that was on ODEs/PDEs and that was also a research area of the group. And I gave a talk in that session.
3. I had three students finish their theses on topics in the area of numerical differential equations last summer:
• Fatima Dow, M.Sc. in Applied Science, Thesis: Breaking the Mono-implicit Runge-Kutta Method Stage Order Barrier, 2017.
• Hanan Drfoun, M.Sc. in Applied Science, Thesis: Efficient Continuous Runge-Kutta Methods for Asymptotically Correct Defect Control, 2017.
• Tom Murtha, Undergraduate Honours Thesis: Finite Difference Based Error Estimation for Boundary Value ODEs, 1D PDEs, and 2D PDEs, 2017.

4. I am currently supervising a Ph.D. student: Mark Adams, Thesis topic: Numerical Software for Collocation and Runge-Kutta Method based Solutions of Boundary Value Ordinary Differential Equations.

## *Mathematical and Physical Aspects of Black Holes*

Members:

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

### Summary

Over the last year our AARMS CRG concentrated on organizing a four-day workshop (May 28-May 31) that was held just before the annual Atlantic Canada General Relativity Meeting (June 1-2). 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.

There were also numerous activities encouraged by the existence of the CRG though not directly funded in this fiscal year. The year was very research-active for members with over 40 papers published by members of the collaboration (26 involved Atlantic Canadian members). Seven of these can be attributed to the CRG: they were inter-university collaborations involving group members and which were started or worked on during the 2016 and/or 2017 workshops.

### CRG Activities (September 2016 – August 2017)

Details – Workshop

The four-day workshop was collaboratively organized by Ivan Booth (MUN) and Hari Kunduri (MUN) along with Andrey Shoom (MUN) and Jonathan Ziprick (UNB). The joint website for this workshop and the Atlantic Canada GR Meeting can be found at: https://www.math.mun.ca/agr17/.

The workshop began (May 28) with a Post-Doc Day during which post-docs gave introductory lectures to graduate (and some undergraduate) students. The postdocs were Edward Wilson-Ewing (UNB), Suprit Singh (UNB), Jonathan Ziprick (UNB), Aghil Alaee (University of Alberta, PhD from MUN) and Andrey Shoom (MUN). Their lectures covered aspects of cosmology, quantum gravity, classical general relativity, Riemannian geometry and gravitational waves. The goal of all of these was to provide graduate students with more context for the upcoming lectures by the invited speakers as well as to encourage interactions between the postdocs and students from our groups.

The main part of the workshop took place from May 29-31 with four invited speakers each giving a series of three lectures (one per day). The lectures were given

by one external member of the collaboration: Jorma Louko (Nottingham) along with Stefanos Aretakis (Toronto), Eric Poisson (Guelph) and Jeff Winicour. Jorma spoke on aspects of quantum field theory in curved spacetime, Stefanos reviewed the proof of the nonlinear stability of Minkowski and black hole spacetimes, Eric discussed the effects of tidal forces on black holes and neutron stars and Jeff gave a historical review (along with some recent developments) of the Bondi-Sachs formalism. We asked the speakers to pitch these at a grad student/summer school level and so they were quite accessible.

The schedule was set so that there were two one-hour lectures in the morning and then another two one-hour lectures in the afternoon. In between there was plenty of time for discussions about the lectures as well as other areas of research.

Attendance for the workshop was excellent. The official registration was 45 people but we estimate that 50 people attended at least part of the workshop or subsequent Atlantic GR meeting a . Average attendance during the workshop was 35 per day. Of the registered participants, 22 were from Atlantic Canadian universities: eight professors, four post-docs and the rest students.

Details – Other activities

External CRG member David Kubiznak was also an invited speaker at the Atlantic General Relativity meeting which followed the workshop. His participation was partially funded by CRG funds.

CRG Papers published

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 were assisted by the CRG. These were all either initiated or worked on at one of our workshops and in the case of (3) later supported by a CRG funded visit by Andrey to Dalhousie (previous fiscal year).

(1) A. Alaee, M. Khuri and H. Kunduri, “Bounding Horizon Area by Angular Momentum, Charge, and Cosmological Constant in 5-Dimensional Minimal Supergravity,” arXiv:1712.01764 [hep-th].
(2) A B. Alhulaimi, R.J. van den Hoogen and A.A. Coley, "Spatially homogeneous Einstein-aether cosmological models: scalar fields with a generalized harmonic potential", Journal of Cosmology and Astroparticle Physics, 1712 045 (2017).
(3) A. A. Coley, D. D. McNutt and A. A. Shoom, “Geometric horizons,” Phys. Lett. B 771, 131 (2017).
(4) A. Coley and D. McNutt, "Identification of black holes using discriminating scalar curvature invariants," Classical and Quantum Gravity 35 025013 (2018).
(5) H. K. Kunduri and J. Lucietti, “No static bubbling spacetimes in higher dimensional Einstein-Maxwell theory,” Class. Quant. Grav. 35 (2018) no.5, 054003.
(6) D. D. McNutt, M. A. H. MacCallum, D. Gregoris, A. Forget, A. A. Coley, P. C. Chavy-Waddy and D. Brooks, “Cartan Invariants and Event Horizon Detection,” arXiv:1709.03362 (submitted to General Relativity and Gravitation)
(7) A. B. Nielsen and A. .A. Shoom, “Conformal Killing horizons and their thermodynamics” arXiv:1708.08015 (submitted to Physical Review D).

## *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 second year, the CRG met and collaborated on some joint projects, continued their CRG Seminar Series, held a Group Meeting / minicourse at Dalhousie, and supervised one MSc student and two undergraduates.

### *Seminar Series*

The location of the seminar rotated between StFX, Acadia and UPEI and was broadcast to the other locations via Skype. The seminar was generally well attended at the three locations. Faculty members, graduate students and undergraduate students at Acadia, UPEI and StFX attended these seminars.

> Speaker: Shafiqul Islam (UPEI)
> Seminar title: Random composition of two chaotic maps can give rise to nearly ordered (non-chaotic) behaviour
> Date: Feb 6, 2017
>
> Speaker: Hayden Valderstein (UPEI)
> Seminar title: The Probabilistic Approach to Chaotic Dynamical systmes: Frobenius-Perron Operator
> Date: March 20, 2017

### *Group Meeting/MiniCourse: Iterated Function Systems (IFS)*

On April 29, 2017 the CRG Group Meeting / Minicourse was held at Dalhousie University. Franklin Mendivil presented some recent work and open problems. Graduate students and other participants attended the meeting and participated in discussions.

### *Bi-weekly or monthly Skype Group Meetings*

The CRG held a number of Skype meetings (monthly or bi-weekly). Usually these Skype meetings were an hour long and were very useful for discussions on supervision of graduate and undergraduate studnets, discussion on open research problems, discussion on organizing conferences and workshops.

### *Supervision of Graduate and Undergraduate Students*

- Hayden VanIderstine (M.Sc.)
  Current project: Computing infatiant measures of stochastically-perturbed deterministic dyamical systems on [0,1] and/or $[0,1]^N$ using Chebyshev approximation
- Leo Cromwell (undergrad) was supervised by Franklin Mendivil. His summer project focused on the the question of characterizing the absolute continuity of the invariant measure of diagonally self-affine measures on generalized Sierpinski trangiles
- Sean Rowley (undergrad) was supervised by Tara Taylor. His summer project on convex hulls of Sierpinski relatives are being incorporated into a paper which is soon to be submitted.

### *Publications*

1. T.D. Taylor and s. Rowley, “Convex Hulls of Sierpinski Relatives”, in progress.

## *AARMS Summer School*

***AARMS Summer School***

The sixteenth AARMS Summer School took place at the University of Prince Edward Island from July 3 – 28, 2017 under the direction of Alexander Alvarez, Gordon MacDonald and Nasser Saad. Three courses at the beginning graduate level were offered. In 2017 the theme was Financial Mathematics and Actuarial Sciences.

- **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*

This was AARMS' second year to sponsor students affiliated with AIMS (the African Institute for the Mathematical Sciences). We were able to fund three students; one female student from South Africa (North-West University), and two male students (Jaramogi Oginda University of Science and Technology, Kenya; and North-West University, South Africa). The fourth female student was a PhD self-supported student from the University of Science and Technology, Ghana.

For the first two weeks, the daily lectures started from 9 AM to 12 PM, while during the second period (also two weeks) one of the two courses ran from 9 AM to 12 PM while the second course ran from 1 to 4 PM. Some of these courses featured computer labs employing software such as R, Python, etc. The courses were evaluated through a set of assignments, presentations and examinations.

The courses generated a fair amount of activity in the department: some of the 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 the instructor, and could be found in various locations, mostly in the mathematics building and the Health-Science building. The workload for the students was high, especially for the students who took the two courses during the second period.

The students were residents of UPEI campus, within walking distance of local grocery stores and restaurants. Being accommodated together enabled the students to get to know their classmates quickly and restfully. Although all meals were not provided we were able to provide breakfasts during the month of July.

Extra curricular activities included two half-day excursions: one to the east side of the island where the students were given a brief tour of the city of Charlottetown, Confederation Bridge, and Victoria by the Sea. The second tour was to the north side of the island where the studnets visited the North Rustico Fishing Village, Cavendish Beach, Green Gables House and the PEI Preserve Company. All these activities were well attended and were followed by a BBQ supper on campus.

An exit survey of the students produced the following statistics:

- 82% of students felt that the courses were effective in teaching them the content.
- 18% of students felt that the courses were parially effective.
- Students rated the quality of the lecturers, on a scale of 1-10. The average results for the three lecturers were 8.2, 8.9 and 9.5.
- Students also rate the quality of the courses on a scale of 1-10. The average results for the three courses were 8.2, 8.2 and 9.5.
- 100% of students had a positive experience of UPEI.
- 100% of students would recommend the AARMS Summer School to a friend or colleague.

The following comment was posted by one of the survey respondents:

> *'The overall summer school was very intensive and of course, it was a success. I would love to recommend to the school that in the coming years, there should be an avenue where the graduate students briefly share what they are working on their research. If possible, one of the courses should be for intensive problem solving in which the students will be allowed to present their findings at a larger gathering or preferable a conference. The major setback of attending such programs like this is the fact that funding are readily not available. I will love to use this medium to thank the summer school organizers on the provision of accommodation, and breakfast to all the participants. They can still assist students to participate fully by giving them the opportunity to apply for travel grant that will probably cover their travel expenses."*

List of Students

| Student name | Country | Level |
|---|---|---|
| Isaiah Bishop | Canada (Mount Allison) | Undergrad |
| Josh Feldman | Canada (DAL) | Undergrad |
| Matt Johnson | Canada (UPEI) | Undergrad |
| Steve Etoua-Akono | Canada (UPEI) | Undergrad |
| Mayad Al-Saidi | Canada (York U.) | PhD |
| Nneka Ozioma Umeorah | AIMS | PhD |
| Alma Prell Bimbabou | AIMS | PhD |
| Benard Nyaare | AIMS | PhD |
| Banghee So | U.S.A. (UConn) | PhD |
| Gracia Yunruo Dong | Canada (Waterloo) | Undergrad |
| Maral Mazjini | Canada (Regina) | PhD |
| Zhao Yong | UK(London) | Undergrad |
| Diksha Agarwal | UK(London)coming from Indi | Undergrad |
| Ernest Dankwa | Canada (UQAM) | PhD |
| Hayden Vanlderstine | Canada (UPEI) | M.Sc. |
| Zhaonan Qu | U.S.A. (N.Y. University) | PhD |
| Courtney Yuen | U.S.A. (Massachussets) | Undergrad |
| Perpetual Andam | AIMS (no support) | PhD |
| Esther Yao | U.S.A. (Bentley U.) | Undergrad |
| Marco Giovenzana | Italy | M.Sc. |
| Yirong Weng | Canada (Waterloo) | Undergrad |
| Mun Teng Siew | UK(London) | Undergrad |

The seventeenth annual Summer School will be held June 4-29, 2017 on the theme of Data Analytics at the University of Prince Edward Island. We will be offering the following courses:

**Functional Data Analysis for Big Data**
Dr. Jiguo Cao
*Canada Research Chair in Data Science*
*Simon Fraser University*

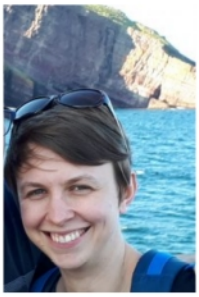
**Machine Learning and Data Mining**
Dr. Mark Schmidt
*University of British Columbia*

**Statistical Analysis for High Dimensional Data**
Dr. Wenqing He
*University of Western Ontario*

**Foundations in Data Science and Applications**
Dr. Osmar Zaiane
*University of Alberta*

## *AARMS Postdoctoral Fellowship Program*

AARMS awarded three new Postdoctoral Fellowships in 2017:



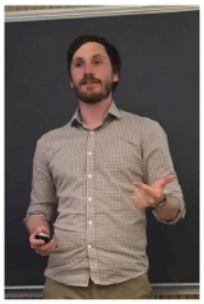
**Rosalind Cameron** is currently a postdoctoral fellow at Memorial University of Newfoundland, working with David Pike. She received her PhD from Monash University in 2017 and her research interests include graph theory and combinatorial design theory.

**Shuaibing Luo** received his PhD from University of Tennessee in 2014. He iscurrently working at Memorial University of Newfoundland under supervision of Jie Xiao. His research interests include Complex analysis, operator theory and partial differential equations.

**Viraj A A Sanghai** received his PhD in 2017 from Queen Mary University of London. Currently he is a postdoctoral fellow at Dalhousie University under the supervision of Alan Coley. His research interests include linking Einstein's theory of gravity and its modifications to observations on cosmological and astrophysical scales.

**Other ongoing AARMS Postdoctoral Fellowships in 2017:**

**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.



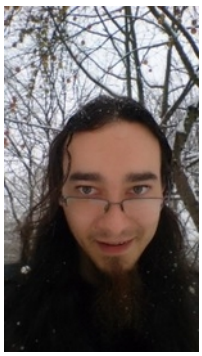
**Christopher Duffy** received his PhD (2015) from the University of Victoria and the University of Bordeaux. His research interests are graph homomorphisms and discrete time processes on graphs. He is currently working at Dalhousie University under the supervision of Jeannette Janssen and is the AARMS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

**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.

**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 PDF he is working at Mount Allison University under the supervision of Geoffrey Cruttwell and RobertRosebrugh.



**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 2018 positions opened in November 2017 with final decisions on awards made in spring 2017.

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 2017 AARMS funded or partially funded the following workshops conferences and events. These involved over 900 participants, 388 of whom were from outside Atlantic Canada:

**Hopf Algebras and their Generalizations from a Categorical Point of View**
Memorial University (St. John's Campus)
March 6-10, 2017

During the week from March 6 to 10, the AARMS-AAC-mini course Hopf algebras and their Generalizations from a Categorical Point of View took place at the St. John's campus of Memorial University. Professor Gabriella Böhm of the Hungarian Academy of Sciences gave five lectures on Hopf algebras and their generalizations, such as weak Hopf algebras, within monoidal categories. Professor Böhm is one of the leading experts in the area and has published widely on the subject. The now intensively studied concept of a weak Hopf algebra was introduced by her.

Professor Böhm lectured on monoidal categories, monoidal structures on functors between such categories, monads and bimonads in these categories, Hopf algebras and Hopf algebroids, weak Hopf algebras, and duoidal categories. She had written lecture notes in advance that were handed out before every lecture and are now available from the web page of the mini course. Nineteen people with a variety of roles in the university participated in the mini course, ranging from four faculty members, two postdocs, seven graduate students, to even six undergraduate students. Most participants came from Memorial University, but there were two external guests from the University of New Brunswick and the Université Libre de Bruxelles, who experienced an intense week with many mathematical discussions in a relaxed atmosphere.

**2017 AARMS Workshops on Scientific Computing Software**
Memorial University (St. John's Campus)
May 27-31, 2017
Also funded by Memorial University, Saint Mary's University and ACEnet.

These workshops were organized and funded by the AARMS Collaborative Research Group in Numerical Analysis and Scientific Computing, the Centre for Numerical Analysis and Scientific Computing at Memorial University of Newfoundland, and the Department of Mathematics and Computing Science at Saint Mary's University. They brought students and researchers interested in scientific computing to a 5-day workshop in beautiful St. John's, NL, Canada. The meeting consisted of two independent workshops, a 2-day Software Carpentry workshop, presented by ACENET Research Consultants on May 27-28, and a 3-day PETSc tutorial, led by Prof. Jed Brown of CU-Boulder, on May 29-31.

**Atlantic General Relativity 2017**
Memorial University (St. John's Campus)
May 28, 2017 - June 2, 2017

The Atlantic General Relativity Conference 2017 was the latest in an annual series of meetings covering all aspects of classical and quantum gravity. The aim of the conference is to allow members of regional Atlantic universities, particularly students and postdocs, a chance to meet and talk about their research. The meeting attracted 45 participants, of which 21 came from outside the Atlantic region.

The AGR Conference featured two invited speakers. Luis Lehner (Perimeter Institute) opened the conference each morning with a plenary talk. The first was "Multimessenger astronomy with binary neutron stars" which discussed the implications of the (up to then unobserved) detection of gravitational waves from neutron star mergers for general relativity and astrophysics. This turned out to be very pertinent as it was in August of last year (a month and a half after the meeting) that the first such detection was made! He second lecture was "Surprises in nonlinear gravity and implications" which reviewed recent work using numerical relativity to explore the behaviour of the Einstein equations in the strong gravity/highly dynamical regime. He focused on unexpected behaviours which await future analytical investigations.

The second invited speaker was David Kubiznak (also Perimeter Institute and a member of the AARMS CRG: Mathematical and Physical Aspects of Black Holes)

spoke on the afternoon of June 1 on the “Thermodynamics of accelerating black holes”. He reviewed recent work which extends classical black hole thermodynamics to spacetimes with conical singularities manifesting themselves as cosmic strings which accelerate black holes.

Beyond the two invited speakers there were 29 contributed talks which covered the full range of mathematical, classical and quantum gravity. Talks covered cosmology, black holes, gravitational waves, higher dimensional gravity and gauge-gravity dualities.

As mentioned above, the schedule was set so that each day started with a 60 minute lecture by Luis Lehner and on Thursday afternoon there was a 60 minute lecture by David Kubiznak. Contributed talks were then 20 minutes each. There were morning and afternoon coffee breaks of 30 minutes to allow for discussion and interactions as well as a one-hour break for lunch. Average daily attendance each day was 35-40 people.

**CanaDAM 2017**
Ryerson University
June 12, 2017 - June 15, 2017

CanaDAM is held biennially in odd-numbered years; the SIAM Conference on Discrete Mathematics is held biennially in even-numbered years. Unlike SIAM, the CanaDAM conferences are not affiliated with a learned society. Rather, the conference series is overseen by an Executive Committee of six volunteer faculty members, each of whom normally serves for six years. The CanaDAM conference series has become internationally known and respected in discrete mathematics. CanaDAM 2017 will be one of the largest discrete mathematics meetings in the world this year, quite possibly the largest.

The scientific program was excellent. The Program Committee was chaired by Bruce Shepherd from McGill. He first assembled a committee of internationally recognized experts, and then the Program Committee assembled an absolutely outstanding collection of plenary speakers and associated invited minisymposia. The members of the Program Committee were:

- Peter Cameron (St. Andrews, Scotland)
- Fritz Eisenbrand (EPFL, Switzerland)
- David Eppstein (UC Irvine, USA)
- Ian Goulden (Waterloo, Canada)
- Catherine Greenhill (UNSW, Australia)
- Venkat Guruswami (CMU, USA)
- Nick Harvey (UBC, Canada)
- Christine Heitsch (Georgia Tech, USA)
- Nicole Immorlica (Microsoft Research, USA)
- Daniel Král’ (Warwick, England)
- Cheryl Praeger (UWA, Australia)• Bruce Shepherd (McGill, Canada) – Chair
- Jozsef Solymosi (UBC, Canada)

Details of the plenary lectures are as follows.

- TANYA BERGER-WOLF, U. Illinois at Chicago
  Dynamic Networks in Behavioral Ecology: Baboons and Zebras as Mobile Social Users

• JORDAN ELLENBERG, Wisconsin
Around the cap set conjecture; Public Lecture
• PETER KEEVASH, Oxford
Hypergraph matchings
• ROBERT KLEINBERG, Cornell
Recharging Bandits
• BOJAN MOHAR, Simon Fraser
Totally odd immersions of graphs
• SHUBHANGI SARAF, Rutgers
High rate locally-correctable and locally-testable codes
• ANDREW SUK, U. Illinois at Chicago
On the Erdos-Szekeres convex polygon problem
• LAUREN WILLIAMS, Berkeley
Tableaux combinatorics of hopping particles and Koornwinder polynomials
• JULIA WOLF, Bristol
Counting monochromatic structures in finite Abelian groups

The plenary lectures were each supported by an invited minisymposium (four or five speakers) on a similar topic, with an extra minisymposium invited for balance among areas ofdiscrete mathematics in the program. Here are the details of the invited minisymposia.

• Algebraic Combinatorics, Org: Mike Zabrocki (York, Canada)
• Algorithmic Game Theory, Org: Brendan Lucier (Microsoft Research, USA)
• Arithmetic Combinatorics, Org: Pablo Candela (Universidad Autnoma de Madrid,Spain)
• Biological Networks, Org: Elena Dimitrova (Clemson, USA)
• Convex Geometry, Org: Sinai Robins (University of Sao Paulo, Brazil)
• Extremal Combinatorics, Org: Sergey Norine (McGill, Canada)
• Locality in Coding Theory, Org: Parikshit Gopalan (VMWare, USA)
• Matroids, Org: Peter Nelson (Waterloo, Canada)
• Structural Graph Theory, Org: Luke Postle (Waterloo, Canada)
• The Cap Set Problem, Org: Dion Gijswijt (TU Delft, Netherlands)

In addition there were 23 contributed minisymposia. There were approximately 230 talks in all, spanning all areas of discrete mathematics.

**CAIMS 2017 – Public Lecture**
Dalhousie University,
July 18, 2017
Speaker: Chad Topaz, Williams College

Abstract: Schools of fish, flocks of birds, herds of mammals, and even colonies of bacteria all show behavior we call ‘swarming’, but these groups are difficult to understand biologically and mathematically. I will give an overview of how social and biological interactions lead to swarming behavior. I will also discuss how mathematical modeling (describing the real world with mathematics) can be used to study locust swarms, which are the most massive and destructive swarms on Earth. Swarming is related to many phenomena of collective behavior in nature and society, where

seemingly independent objects — like neurons, metronomes, and even people — start to act in the same way.

**Canadian Undergraduate Mathematics Conference**
Montreal
July 19, 2017 - July 23, 2017
Also funded by McGill, Concordia, U. de Montreal, U. de Quebec, PIMS, Fields, CRM, SSC, STUDC, AMQ, ISM and registration fees.

The Canadian Undergraduate Mathematics Conference took place in Montreal for its twenty-fourth edition from July 19 th to July 23 rd and gathered 155 students. In the five days of the event, the participants enjoyed 96 students talks and 8 plenaries 4 . Six exceptional women also accepted our invitation to participate in a Women in Mathematics evening which was a huge success. pParticipation is steadily increasing from year to year those last three years : 115 people in 2015, 130 in 2016 and 155 this year.

After three difficult years for the CUMC bilingualism 5 , the organizers were proud to have a viable proportion of francophone talks : half for the plenaries and 15 student talks. Diversity was also a main objectivs and it was realized in an organic way, without having to temper too much for it. Four men and four women were our invited speakers and there was parity in the organizing committee. On the 40 women participants, 30 gave a talk.

**12th East Coast Combinatorics Conference**
University of New Brunswick (Saint John Campus)
July 20, 2017 - July 21, 2017
Also funded by University of New Brunswick

The 12th ECCC (East Coast Combinatorics Conference) was held July 20-21st, 2017 at the University of New Brunswick Saint John. There is a vibrant combinatorial community in Atlantic Canada. This annual conference series was designed to bring together regional mathematicians and computer scientists interested in all aspects of combinatorics, and has regularly done so for over a decade. The scope of the conference is intended to cover most aspects of modern combinatorics, including but not limited to graph theory, extremal combinatorics, combinatorial optimization, probabilistic combinatorics, combinatorial number theory, design theory, finite geometries, and applications of combinatorics to computer science. The conference has consistently provided an intimate venue for researchers in Atlantic Canada with combinatorial interests to disseminate their research, share ideas, introduce students to the ”conference experience”, and to foster collaboration throughout our region.

There were two plenary speakers, Aiden Bruen (University of Calgary), and Brett Stevens (Carleton), and eleven contributed talks. In total there were 35 registered participants. Most attendees were regional, coming from New Brunswick, Nova Scotia, or Newfoundland. In addition to the plenary speakers from Ontario and Alberta we had attendees from Maine, and the U.K.

The highlights of the conference include the two plenary talks. Aiden Bruen spoke on graphs, geometries, block designs, codes and their interconnections, and

Brett Stevens spoke on design theory, tournaments and cryptography. Both talks were well received and included open problems. Also of note was the presentation, proposal, and discussion led by Keith De'Bell regarding the establishment of an Atlantic Research Group focused on the Mathematics of Social Networks. There was keen interest in this rather exciting venture, and active discussion ensued. Those interested in the project have continued discussions, and it is likely that a formal research group will be realised as a result.

There were also informal collaborative meetings between attendees with common research interests.

**Mathematical Congress of the Americas 2017**
Edmonton
July 24, 2017 - July 28, 2017
Also funded by CRM, Fields, PIMS, NSF , University of Alberta, Springer and Conference Registration fees.

The XI Americas Conference brings together mathematicians from throughout the Americas to share their recent research findings, to assess recent research developments, to identify new research directions, and to strengthen existing and foster new collaborations in the broad field of differential equations and nonlinear analysis. The first three days of the conference, August 12-14, 2017, were for the Summer School on New Trends and Applications of Differential Equations and Dynamical Systems for graduate students and postdoctoral fellows. The XI Americas Conference ran from August 15-19, 2017. Funding from AARMS was earmarked to provide travel support for 5 graduate students and postdocs from Atlantic Canada.

**Graph Searching in Canada**
Memorial University (Grenfell Campus)
August 7, 2017 - August 8, 2017
Also funded by Memorial University

The sixth GRASCan workshop was held August 7-8 at the Grenfell Campus of Memorial University of Newfoundland. The workshop aims to bring together researchers interested in graph searching and follows the model of plenary and contributed talks in the mornings, with the afternoons free for discussion, networking, and collaboration. The conscious decision to keep afternoons free for collaboration has been well received and each year, new groups of collaborators form. To maintain an inclusive and collaborative atmosphere, the workshop is purposely kept small, but post-docs and graduate students are encouraged to attend, upon recommendation by their supervisors. This year, the workshop had 18 faculty, graduate students, and post-docs (listed on page 3), along with 4 undergraduate students.

Each morning began with a plenary talk. On Monday, August 7th, the plenary talk was given by Nancy Clarke (Acadia University, NS). Dr. Clarke's research has been supported by NSERC, MITACS, the Harrison McCain Foundation, and Acadia University. She is a respected and established researcher in graph searching problems. Her focus has been on characterizing k-cop-win graphs, and introducing important

variants such as tandem-win Cops and Robbers. Dr. Clarke's talk considered variations of the Cops & Robber game in which the cop side plays with incomplete information; it surveyed results and for each variation, worked toward characterization of the graphs on which a single cop can guarantee win. On Tuesday, August 8th, the plenary talk was given by Jan Kratochvil (Charles University, Czech Republic). Dr. Kratochvil is a full professor of computer science at Charles University in Prague, Czech Republic, and currently serves as the Dean of its Faculty of Mathematics and Physics. He has published over 100 papers in scientific journals and proceedings of computer science conferences and Web of Science registers over 1100 citations to his papers. He delivered plenary talks at EUROCOMB 2007, Symposium on Computational Geometry 22011 and other renowned conferences. Dr. Kratochvil's talk surveyed results on the classical Nowakowski-Winkler Cops & Robber pursuit game played geometric intersection graphs and generalizations to surfaces of higher genus.

The workshop also featured seven 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 while the remaining participants returned to the main meeting room of the workshop. There 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) David Pike (MUN), Jared Howell (MUN – Grenfell), and Jessica Enright (Stirling) worked on the Fire-break problem. This is a scenario where a fire starts at some vertex of a graph and spreads to vertices that are reachable after a fire-break (set of vertices) have been removed from the graph. This is work continuing work started in the Summer of 2016.

2. (New Collaboration) Stephen Finbow (St.FX.), Anthony Bonato (Ryerson), Danielle Cox (MSVU), Nancy Clarke (Acadia), Fionn Mc Inerney (Inria), discussed a new variant of Cops & Robber in which the Cop has limited visibility: he can only see the robber if the robber is location in his non-neighbourhood. Initial results were discussed and a document was later shared on Dropbox to facilitate further work after the workshop.

3. (New Collaboration) Anthony Bonato (Ryerson) introduced a problem of whether graphs generated by the ILAT model for complex networks are cop-win. A discussion ensued with the bulk of the conference participants in the afternoon of the second day, and limited results were obtained.

**Combinatorics of Group Actions and its Applications**
Memorial University (St. John's Campus)
August 28, 2017 - September 1, 2017
Also funded by Fields, Pims and  by registration fees

The workshop was jointly organized by the Atlantic Algebra Centre and the Network of Ontario Lie Theorists with the focus on modern developments in the theory of group actions (gradings on algebras, actions on lattices and varieties) and its applications (polynomial identities, representation theory and Schubert calculus). It included several mini-courses given by leading experts addressed at graduate students, as well as research talks given by senior researchers and short communications by young

researchers. The workshop ran for 4 full days (Monday – Friday, except Wednesday) and featured a unique combination of several introductory mini-courses, research-level talks and short communications by young researchers.

**Symposium for South Asian Women in Mathematics**
Tribhuvan University
October 12, 2017 - October 15, 2017
Also funded by Dalhousie University, a variety of European Institutions and registration fees.

The purpose of this event was to promote scientific communication in mathematics, to establish a mathematical network for sharing and communicating with women mathematicians, experts and organizations with similar goals in this region. The symposium brought together leaders of professional organizations for women working in mathematical sciences, particularly in mathematics teaching, research and mathematics education. Participants had the opportunity to interact and share their research work in both pure and applied fields of mathematics, they discussed how to support and promote researchers and professionals in the respective countries, and exchanged experiences with outreach activities for female students. A major goal of the Symposium was to strengthen and create opportunities for women in mathematics in Nepal and motivate the undergrad Nepalese students especially girls. Another goal was to create a regional nucleus for women in mathematics.

Out of 61 participants there were 59 women participants from 12 countries including Nepal. The Participants were: 1 from Bangladesh, 1 from Canada, 2 from France, 9 from India, 1 from Indonesia, 1 from Italy, 1 from Japan, 1 from Korea, 1 from Pakistan, 1 from Philippines, 6 from USA, 36 from Nepal (22 from Tribhuvan University (TU), 5 from Kathmandu University (KU), 6 from High school and 3 from affiliated campuses of TU) and 9 undergraduate students from Padmakanya Campus and Tri-Chandra Campus of Tribhuvan University. The 25 foreign participants and two local participants were accommodated in Kirtipur Hillside Hotel and Resort (KHHR) near the venue of the symposium.

**Science Atlantic Math/Stats/CS Conference**
**(including Special Session on Statistical Learning and Health Data Analytics)**
University of New Brunswick (Fredericton Campus)
October 13, 2017 - October 14, 2017

The annual Science Atlantic Math/Stats/CS conference took place at UNB Fredericton, Fri Oct 13 – Sun Oct 15. The three-day event was comprised of a two-day conference aimed primarily (but by no means exclusively) at undergraduate students, followed by an AARMS session: a one-day specialized research workshop. The conference featured three keynote addresses by invited speakers, with recognized expertise in one of the three disciplines (Math, Stats, CS), a host of short undergraduate research talks, a banquet, opportunities for graduate students, faculty, and undergraduates, to network, and information on graduate studies and NSERC funding. Undergraduate participants had the chance to write either a programming competition or a mathematics competition.

The AARMS Workshop on Statistical Learning and Health Data Analytics was organized by an AARMS Collaborative Research Group (CRG), Statistical Learning for Dependent Data under the Administration of Ying Zhang to promote the statistical research in the region through numerous confirmed speakers and to strengthen connections among professors and researchers in the field of statistical learning and health data analytics. Most importantly provided a training opportunity in this highly demanded multidisciplinary field to students that is not available in their own university program.

## *Prizes*

In 2017 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 2017 – **Masoumeh Sajedi** (Université de Montréal)
Winter 2017 – **Farinaz Forouzannia** (University of Waterloo)

## *Outreach*

In 2017 AARMS supported the following outreach programs:

### *Nova Scotia Math Outreach Discussion Meeting*

On June 6 2017 AARMS hosted its fourth 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, contests and school visits. Some of programs in each of these categories were discussed, and are presented later in this report.

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:

Danielle Cox (MSVU)
Rajendra Gupta (Dalhousie)
David Langstroth (AARMS Administrator)
Nancy Clarke (Acadia)
Roman Smirnov (Dalhousie)
Jeff Hooper (Acadia)
Erick Lee (Halifax School Board)
Dorette Pronk (Dalhousie)
Richard Nowakowski (Dalhousie)
Lois Murray (Dalhousie)
Preman Edwards (Auburn High School)
Tara Taylor (STFX)
Hugh Chipman (Acadia)
Svenja Huntemann (Dalhousie)
Melissa Huggan (Dalhousie)
Caroline Cochran (Acadia)
Alyssa Sankey (UNB)
Caroline Purdy ( UNB)
Mayada Shahada (Incoming MathCircles Postdoc)
Wen Wilson Lu (Acadia)
Keith Taylor (Dalhousie)

**New Brunswick Math League**
University of New Brunswick (Fredericton Campus)
February 16, 2017
*Also funded by UNB*

This event took place on March 2 nd , 2017, from 9:30am – 4pm, in the UNBSU Ballroom. Around 100 high school students, grades 9-12, from Fredericton and the surrounding area were in attendance. Students arrived in teams of four, and were either placed into the junior(grades 9-10), or senior (grades 11-12) categories depending on the most senior group member.

The competition was made up of three parts, with the questions provided to us by AARMS. In the Team Event, all team members worked together to solve 10 questions with a 90 minute time limit. Next, in the Pairs Relay, each team was split into two groups of two and had to complete a series of 4 problems in a relay fashion. The first group had to successfully complete their problem before the second group could begin using the previous answer from the first group. The last event was the Individual Relay and was very similar to the pairs relay, only now questions had to be answered individually in succession.

The schedule for the rest of the day included a provided lunch, a presentation from the recruitment office, a math jeopardy game, and an awards ceremony. We received a lot of positive feedback from the teachers and the students for different reasons. The teachers were glad for the opportunity to challenge their students to material outside their normal school curriculum; the students had a lot of fun and got to miss a day of school.

**UPEI Integration Tournament and Boolean Bash 2017**
University of Prince Edward Island
March 15, 2017

The 2017 UPEI Integration Tournament was planned on March 14, 2017. Because of severe weather condition, the Integration Tournament was held on the evening of March 15, 2017 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. 16 students were selected to participate in the Integration Tournament. Twelve were first-year students and four were upper-year students. They were sent to the white board two at a time and the first two receive 2 points (one point was awarded for being first to complete an integral) advanced (see attached for more detailed rules). 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.

**University of PEI Math Camp**
University of Prince Edward Island
May 5, 2017 - May 7, 2017
*Also funded by UPEI and the CMS*

The annual UPEI Math Camp was held May 5-7, 2017. Nominations are solicited from all PEI high schools. High school teachers identify talented and interested students in their classes, and submit the applications. Funds permitting, efforts are made to accept all applicants. This year there were 19 high school students in attendance.

Over the weekend, the students participated in education sessions conducted by faculty members from the UPEI School of Mathematical and Computation Sciences. The students also competed in team problem solving, math relays, and math trivia. During evening hours, social activities included a pizza and games night, and a movie night. In addition to faculty participation, five undergraduates from the school volunteered their time to the camp. The undergrads supervised students during the various competitions, as well as spent social time with the students. The camp provides a great opportunity for undergrads to mentor younger students.

**35th Annual New Brunswick Mathematics Competition**
New Brunswick
May 12, 2017

The Department of Mathematics and Statistics at the University of New Brunswick and the Faculty of Science and Faculty of Engineering of l'Université de Moncton hosted students in Grades 7, 8 and 9 of the Province of New Brunswick participating in the Thirty-fifth Annual Mathematics Competition to be held on Friday May 12, 2017. The Competition was written on the same day and at the same time on the campuses of l'Université de Moncton at Moncton, Edmundston and Shippagan and on both the Fredericton and Saint John campuses of the University of New Brunswick. The exam was available in both French and English at all five campuses, and provincial winners were identified by combining the results from the five locations.

**University of New Brunswick Math Camp**
University of New Brunswick (Fredericton Campus)
May 12, 2017 - May 14, 2017

The annual UNB-CMS Spring Math Camp, for Grade 10 and 11 students, started on the same day as the annual NB Math Competition. The camp is by invitation with selection based, primarily, on performance in the NB Math Competition. Students work on math problems (some fun, some quite challenging); they hear interesting talks about mathematics, and applications of mathematics; they get to know some UNB profs; they live in residence for the weekend; they go home on Sunday afternoon.

**Blundon Seminar Camp at Memorial**
Memorial University (St. John's Campus)
May 14, 2017 - May 19, 2017
*Also funded by CMS, MUN, CAIMS, and Nelson Publishing*

The Blundon Seminar is an annual three-day math camp for senior high school students from Newfoundland who are interested in mathematics and demonstrate consistently good performance in mathematics competitions. Participation in the math camp is by invitation only based on the results of preceding Blundon, COMC, Euclid, Fermat and Cayley contests. This year there were 39 participants. The students attended two one-hour talks given by professors from MUN and there were several problem solving sessions as well as other activities such as the Mathletics and Papers Chase.

**St. Francis Xavier University Math Camp**
St. Francis Xavier University
May 19, 2017 - May 21, 2017
*Also funded by STFX and the CMS*

This Camp was the fourth of a recurring series of annual Math Camps to be held at StFX. These Camps are designed for grades 10 and 11 students. The goal of the Math Camps is to provide students in 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. The camp consisted of lectures delivered by experienced instructors from StFX, and fun filled activities included: math relays, math trivia, problem solving, games, Polyhedra and Euler's Formula, and hands-on activities from guest presenters. There were 27 participants.

**Dalhousie University Math Camp**
Dalhousie University
July 9, 2017 - July 14, 2017
*Also funded by Dalhousie*

The Dalhousie Math Camp was attended by 20 students in grades 10 and 11 from all over the province of Nova Scotia. It involved a wide range of seminars, mathematical

games and social activities. In the words of one of the campers, “The academic part of the camp was very interesting and enlightening, it provided us and enlightening, it provided a chance to see the different fields of mathematics that are not covered in school. Also, it allowed us to see the different courses offered at Dalhousie. I was also quite happy to learn about new concepts and various problems within the mathematical society today and in the past.” On July 12 the campers spent one day at Acadia University taking part in activities arranged by the faculty there.

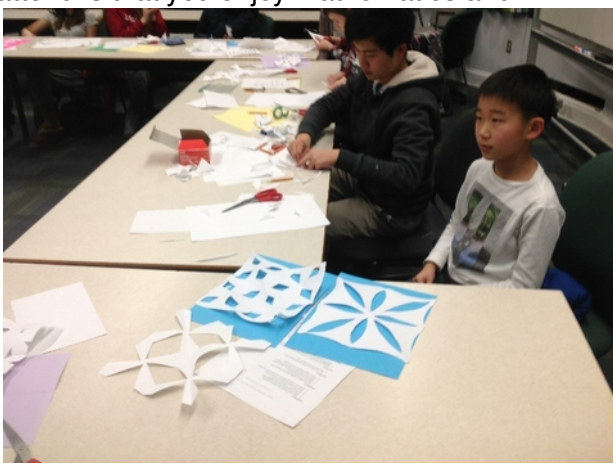
**Black Educators Association/Dalhousie University Math Camp**
Dalhousie University
July 9, 2017 - July 15, 2017
*Also funded by the BEA and Dalhousie*

The Dal-BEA math camp for Black Studnest was held July 9-15. Twenty-nine campers attended, 23 female and 6 male. They came from Junior High Schools all over Nova Scotia. Throughout the week the students were introduced to new topics as well as working on the building of old topics and ideas that they are introduced to in the school year. Social activities also include museum visits, sporting events and a career workshop.

**Math Challenge Club**

This past year every Monday night Chase Room 319 has been buzzing with activity: new math results are introduced, students of all through junior high and some from high school put their efforts and skills together and problems are being solved. Pizza and newly emerging friendships are an essential part of this mix. Encouragements across the classroom are extremely important as well. The club has been meeting from 5 till 7 PM each week.

The club was started to provide problem solving training in a format that would appeal to female students. Hence, community is far more important in the training than winning or competitiveness. The only requirement to attend is that you enjoy mathematics and problem solving and the main goal is to create a community of problem solvers. The students have as much fun as they learn in the club. In the words of one of the parents (who wants to send three kids to the clubs this coming year):
“We really value the math club. Our two oldest had a fantastic time last year, and learned a heck of a lot!! Thank you, Lana S.”



Thus far, this approach seems to work. The club started with 4 students at the start of the first year and ended the second year with about 25 students attending for the final weeks. On average there were 20 students

each week and at least 50% was female, sometimes there were just one or two more female students than male. The other wonderful new aspect this year has been that it seems our students come from all around the world: from Romania, from Pakistan and Bangladesh, from China and Japan and from Nova Scotia! We have become an international and multicultural community of problem solvers.

**Enhancing Our Appreciation of Mathematics Through Intentional Community Outreach** Also sponsored by the University of New Brunswick

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 2017 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.

## *Administration and Governance*

**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
Richard Karsten (Acadia)
David Langstroth (Dalhousie)
Chunhua Ou (Memorial)
Dorette Pronk(Dalhousie)
Nasser Saad (UPEI)

**The AARMS Industrial Collaboration Committee**
Richard Karsten (Acadia), Chair
Rhong Gu (Dalhousie)
Scott MacLachlan (Memorial)
James Watmough (UNB)

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**

**Jeannette Janssen, Chair** - is a professor and department Chair at Dalhousie University. She has made contributions to various areas of graph theory, especially related to graph colourings and frequency assignment, modeling and mining of complex networks, and infinite graphs. Her recent work involves an exploration of graph models for complex networks that have a natural spatial embedding. Dr. Janssen has been invited to present her work nationally and internationally, including as a guest lecturer at a summer school on Network Science at USC, as a participant of a thematic program on Discrete Structures at the IMA in Minnesota, at a workshop at CRM in Montreal, and, most recently, at a workshop at the Newton Institute in Cambridge. Dr. Janssen was director of the Atlantic Association for Research in the Mathematical Sciences (AARMS) from 2011 to 2016, and she is currently a program officer of the SIAM activity group on Discrete Mathematics, and member of the NSERC-Math liaison committee.

**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.

**Mary Courage** - is currently Dean of Science (pro tempore) at Memorial University in St. John's, where she is also a University Research Professor in the Department of Psychology. Over 25 years she has developed a research program on the early development of human attention and cognition with applications of those processes to issues of learning and health in very young children. Her work has been funded by NSERC and Health Canada and has been published widely. She has extensive experience in teaching and university service including six years as the Associate Dean of Science (Research and Graduate). She was educated at Memorial University and at the University of Alberta.

**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** – is the Director of the Fields Institute for Research in Mathematical Sciences. He received his doctorate from Yale University in 1973, and was an L. E. Dickson Instructor at the University of Chicago before joining McMaster University, where he has served as Chair of the Department of Mathematics and Statistics for three terms, was active in university affairs as President of the McMaster Faculty Association, and was several times elected to the Senate and Board of Governors. He is a prominent mathematician with more than 75 published articles in leading international journals, whose research in geometry and topology connects to a broad range of mathematics. His distinguished record of scholarship has been recognized by a high level of NSERC funding for almost 40 years, supporting an extensive program of graduate and postdoctoral training. He was a Member of the School of Mathematics at the Institute for Advanced Study in Princeton for two years, and a Visiting Professor for three years at the Max Planck Institute for Mathematics in Bonn, in addition to numerous other visiting positions at major mathematical centres.

**Ian Hill –** Associate VP Research, Dalhousie University

**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.

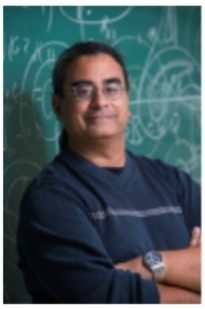
**David MaGee -** is the acting vice-president (research) at the University of New Brunswick. He received both his BSc in chemistry and his PhD in synthetic organic chemistry from UNB. Dr. MaGee has been active with UNB in a faculty role since 1990, serving in many capacities, including assistant professor, associate professor, professor, chair of the department of chemistry, and dean of science, in addition to serving on numerous university committees.

John McLoughlin - is a Professor in the Faculty of Education at University of New Brunswick. He holds a cross-appointment to the Department of Mathematics and Statistics. John is extensively involved in math outreach and was honoured by the Canadian Mathematical Society (CMS) as the 2013 recipient of the Adrien Pouliot Award. John has co-edited Education Notes for the CMS Notes and served on the editorial board of CRUX Mathematicorum for many years.

**Chunhua Ou** - is a Professor at the Department of Mathematics and Statistics, Memorial University. Dr. Ou received his Ph.D degree from City University of Hong Kong in 2003 and held a postdoctoral position at York University, Canada during 2003-2005. His research interest is in the area of applied dynamical system and asymptotic analysis.

**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.

**Xiaoqiang Zhao** – is a University Research Professor at the Memorial University of Newfoundland. He received his Ph.D. in Applied Mathematics from the Chinese Academy of Sciences in 1990. His research interests are Applied Dynamical Systems, Nonlinear Evolution Equations, and Mathematical Biology.

## 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.

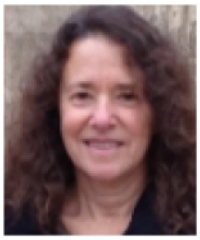
**Richard Cook** – is Professor of Statistics in the Department of Statistics and Actuarial Science at the University of Waterloo and Tier I Canada Research Chair in Statistical Methods for Health Research. He also holds a cross-appointment to the School of Public Health and Health Systems and is an 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** – professor at the University of Kansas. He received his PhD from the Chinese Academy of Sciences 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 2016 is paid for in 2017 then it will show up in the 2017 accounts. A significant event in 2017 was the delay in processing financial transactions at Memorial University related to our RDC project. This has created a significant backlog of payments to be made but we are confident things will start moving again in 2018.

# Income and Expenditure Account
## 2017

| ***Income***[1] | $ | $ | 2016 |
|---|---|---|---|
| Carried forward from previous year | | 325,478 | 202,999 |
| Mathematical Institutes | | 105,000 | 105,000 |
| Universities | | 102,000 | 106,000 |
| Provinces | | 150,744 | 321,096 |
| Other Revenue | | 2,131 | 378 |
| **Total Income** | | **685,353** | **735,473** |
| ***Expenditure*** | | | |
| Summer School (2) | | 96,163 | 62,219 |
| Workshops and Events (3) | | 35,624 | 63,189 |
| Outreach (4) | | 38,113 | 38,299 |
| PDF Program (5) | | 84,316 | 113,750 |
| Collaborative Research Groups (6) | | 20,000 | 53,178 |
| Distinguished Lecturers | | 0 | 2,000 |
| Book Series | | 0 | 0 |
| Administrator Salary | | 31,753 | 31,811 |
| AARMS Online system (7) | | 5,962 | 27,026 |
| Travel | | 4,435 | 2,990 |
| Office Expenses | | 1,083 | 2,533 |
| Dalhousie Overheads | | 13,000 | 13,000 |
| **Total Expenditure** | | **330,449** | **409,995** |
| **Surplus: Income Less Expenditure** | | **354,905** | **325,478** |

**Notes**

1. For a breakdown see Appendix 1
2. Includes $46,687 from 2016 Summer School
3. See Appendix 2
4. See Appendix 2
5. See Appendix 3
6. See Appendix 4
7. See Appendix 5

# Balance Sheet

31-12-2017

| ***Assets*** | $ | $ |
|---|---|---|
| Surplus from Operations (Income less expenditure) | | 354,905 |
| Accounts Receivable[1] | | |
| 2017 University support | 6,000 | |
| 2017 Institutes support | 5,000 | |
| 2017 Provinces support | 25,000 | |
| 2017 Other | 3,225 | |
| | | 39,225 |
| 2018 University support | 106,000 | |
| 2018 Institutes Support | 90,000 | |
| 2018 Provinces support | 180,000 | |
| 2018 Other | 1,000 | |
| | | 377,000 |
| **Total Assets** | | **771,130** |

| ***Liabilities*** | | |
|---|---|---|
| Accounts Payable[2] | | |
| 2016 Postdocs | 46,666 | |
| 2016 Conferences & Workshops | 8,500 | |
| 2016 Outreach | 4,300 | |
| 2016 CRG in Numerical Analysis | 18,000 | |
| | | 77,466 |
| 2017 Postdocs | 69,018 | |
| 2017 Conferences & Workshops | 28,720 | |
| 2017 Outreach | 8,933 | |
| 2017 CRGs | 20,000 | |
| | | 126,671 |
| 2018 Postdocs | 130,250 | |
| 2018 Conferences & Workshops | 70,855 | |
| 2018 Outreach | 38,827 | |
| 2018 CRGs | 40,000 | |
| 2018 Summer School | 80,000 | |
| 2018 Administrator | 32,000 | |
| 2018 Dal overheads | 13,000 | |
| 2018 Travel, office, poster expenses | 5,000 | |
| 2018 Online systems expenses | 4,000 | |
| | | 413,932 |
| Unallocated funds - for AARMS activities | | 153,061 |
| **Total Liabilities** | | **771,130** |

Notes

1. Fees due to be collected in 2018
2. Funding Commitments in 2018

# Annual Accounts 2017

## Appendix 1

### *Revenue Breakdown*

| | | | |
|---|---|---|---|
| Provinces | | | |
| | New Brunswick | 50,000 | |
| | Newfoundland (1) | 744 | |
| | Nova Scotia | 100,000 | |
| | | | **150,744** |
| Mathematical Institutes | | | |
| | CRM (2) | 45,000 | |
| | Fields | 30,000 | |
| | PIMS | 30,000 | |
| | | | **105,000** |
| Universities | | | |
| | Acadia | 5,000 | |
| | Cape Breton | 1,000 | |
| | Dalhousie (3) | 25,000 | |
| | Memorial | 30,000 | |
| | Moncton | 1,000 | |
| | Mount Allison | 1,000 | |
| | Mount Saint Vincent | 2,000 | |
| | Saint Francis Xavier | 1,000 | |
| | Saint Mary's | 1,000 | |
| | UNB | 30,000 | |
| | UPEI | 5,000 | |
| | | | **102,000** |
| Other Revenue | | | |
| | book royalties | 303 | |
| | MSRI | 1,828 | |
| | | | **2,131** |
| | | **total:** | **359,875.02** |

**Notes**

1. Cash transactions delayed due to administrative revision at MUN
2. includes summer school sponsorship for 2016 and 2017
3. $5000 from Dal Math received Jan. 2018

# Annual Accounts 2017

# Appendix 2

## *Workshops and Scientific Events*

| | |
|---|---|
| 2016 Games at Dal  Workshop | 3,000 |
| 2016 GRASCan | 2,741 |
| 2016 Category Theory Meeting | 4,971 |
| 2016 Atlantic General Relativity | 4,940 |
| 2017 Canadian Undergraduate Math Conference | 500 |
| 2017 MSRI Sponsorship | 5,935 |
| 2017 MSRI travel (Faridi) to BIRS event | 1,064 |
| 2017 East Coast Combinatorics Conference | 3,100 |
| 2017 GRASCan | 4,000 |
| 2017 Symposium for South Aisian Women in Math | 1,500 |
| 2017 Science Atlantic | 2,773 |
| 2017 CanaDAM | 1,100 |
| **total** | **35,624** |

## *Outreach*

| | |
|---|---|
| 2016 Math League in New Brunswick | 182.46 |
| 2017 Outreach Meeting at Dalhousie | 1,268.26 |
| 2017 Blundon Seminar Camp | 3,000.00 |
| 2017 Connecting Math to Our Lives and Communities | 5,000.00 |
| 2017 UPEI Math Camp | 455.11 |
| 2017 STFX Math Camp | 2,608.00 |
| 2017 Dal Math Camp – Acadia Day | 892.63 |
| 2017 Annapolis Valley Outreach (Acadia) | 456.75 |
| 2017 Black Educators Assn. Math Camp | 1,250.00 |
| 2017 Dalhousie Math Camp | 3,000.00 |
| 2017 AARMS Outreach Coordinator | 20,000.00 |
| | **38,113.21** |

# Annual Accounts 2017

## Appendix 3

### *Postdoctoral Fellowships*

| | | |
|---|---|---|
| Marzieh Bayeh | | 4,375 |
| Chris Duffy | | 11,400 |
| Israel Rocha | | 14,583 |
| Daniele Gregoris | | 17,500 |
| Joep Evers | | 10,208 |
| Nathan Greive | | 8,750 |
| Wison-Ewing | | 8,750 |
| Lucyshyn-Wrignt | | 8,750 |
| Aras Erzumluoglu (1) | | 0 |
| Baocheng zhu (1) | | 0 |
| Peng Zhou (1) | | 0 |
| | **total** | **84,316** |

## Appendix 4

### *Collaborative Research Groups*

| | |
|---|---|
| Statistical Learning for Dependent Data | 20,000 |
| Dynamical Systems and Spatial Models in Ecology (1) | 0 |
| **total** | **20,000.00** |

**Notes**

1. Due to lengthy administrative delays at MUN this cash has not yet been transferred. but these postdocs and the CRG are up and running

# Annual Accounts
# 2017

## Appendix 5

### *Online System Expenditures*

| | | |
|---|---|---|
| MathJobs Fee | | 699.3 |
| Wizehive annual fee | | 5,263.16 |
| | **total** | **5,962.46** |