



Newsletter

Winter 2016

CRG on the Mathematical and Physical Aspects of Black Holes

The AARMS collaborative research group (CRG) on the "Mathematical and physical aspects of black holes" was formed in September of 2015. It is a natural extension of the very successful AARMS funded "Atlantic General Relativity (GR)" annual meetings on all aspects of classical and quantum gravity. The CRG includes seven local faculty members from Dalhousie University, Memorial University and the University of New Brunswick. The group also has five senior researchers from outside of Atlantic Canada whose home institutions include the Perimeter Institute for Theoretical Physics in Ontario; Queen Mary, Nottingham and Edinburgh Universities in the UK; as well as the Universidad de Chile. Finally, the CRG has over a dozen grad student and postdoctoral members.

The purpose of the CRG is to initiate collaborative projects studying black holes in Einstein's general theory of relativity (and its extensions). In their most basic form, these fascinating objects are Lorentzian geometries which extremize the integral of the scalar curvature over a spacetime manifold. In four or fewer dimensions, static black holes are completely described by only a few parameters. Their central feature is the event horizon, a light-like surface with unusual physical and geometrical properties. They are classically stable to perturbations, but quantum mechanically unstable due to the Hawking effect, a mechanism by which black holes emit quantum particles. In higher dimensions, there exists a veritable zoo of black hole solutions possessing event horizons with non-trivial topology. The recent detection of gravitational waves by the Laser Interferometer Gravitational-Wave Observatory (LIGO) has provided strong evidence that binary black hole systems exist in Nature, and that these systems can experience violent, time-dependent phenomena; i.e., black hole collisions. This has given fresh motivation for the study of dynamic event horizons around black holes, which is one of the CRG's special interests.

The first event to be hosted by the CRG is a series of lectures to precede Atlantic GR in the summer of 2016. This five day event in Halifax will involve two parts: a series of introductory talks delivered by regional postdocs aimed at undergraduates and beginning graduate students, then a set of advanced pedagogical lectures delivered by leading experts on

current research topics. The latter group is comprised of James Lucietti (Edinburgh), José Geraldo Pereira (Universidade Estadual Paulista), and Jorge Zanelli (Chile). Topics covered will include both higher and lower dimensional black holes as well as extensions of general relativity involving manifolds with torsion. The format will leave plenty of time for discussion and collaboration.

The CRG lecture series will take place June 18-22. Atlantic GR will follow on June 23-24. Registration for both meetings at <http://www.math.unb.ca/~gravity/agr16>. More about the CRG at <http://www.math.unb.ca/~gravity/crg>.

AARMS Becomes a Sponsor of MSRI

The Mathematical Sciences Research Institute based in Berkeley, California has been around since 1982 and shares many objectives with AARMS. Being a sponsor of MSRI would probably be too expensive for any single mathematics/statistics department in our region, but as a representative of many Atlantic Canadian universities AARMS is able to absorb the cost and to bring the following benefits to our region:

- MSRI covers the travel and local expenses of 2-3 students to attend one of its Graduate Summer Schools. The rate for travel reimbursement is up to \$600 for students from US and Canadian universities, and up to \$700 for students from other sponsoring institutions.
- Visits by MSRI Members: Academic Sponsors are encouraged to invite MSRI members to visit and give a colloquium or seminar talk at the Sponsors' institutions. MSRI provides partial support for the member's visit (at present, up to \$250).
- MSRI will provide partial travel funding (up to a maximum of \$750) for postdoc or ladder faculty members of Academic Sponsor Institutions to attend workshops at the Banff International Research Station (BIRS).

Funding for all of these programs is limited, but please contact the AARMS director if you would like to take advantage of one or more of these opportunities.

There is more information on the MSRI website at: <http://www.msri.org/web/cms>

News

An AARMS Postdoc Reports



Having recently completed a two-year NSERC Postdoctoral Fellowship at the University of Cambridge and the University of Ottawa, I am pleased to now hold an AARMS Postdoctoral Fellowship at Mount Allison University. I was drawn to

Mount Allison by the inspiring mathematical work of my current supervisors Geoffrey Cruttwell and Robert Rosebrugh, with whom I first became acquainted at various conferences related to category theory. The AARMS Postdoctoral Fellowship has provided a very supportive environment in which to vigorously pursue multiple threads of research that interweave category theory, differential and algebraic geometry, functional analysis, and homotopical algebra. During these first seven months here at Mount Allison I have completed two new research papers and drafted another, spoken at conferences in Canada and Germany, taught a course in calculus, and collaborated with Geoffrey Cruttwell to develop a novel simplicial approach to generalized de Rham cohomology within a category-theoretic framework for differential geometry.

One facet of my research studies the categorical structure surrounding notions of measure and distribution in various contexts, applying novel categorical methods for functional analysis. My research output in this area began with an article titled Algebraic theory of vector-valued integration that was published in *Advances in Mathematics* during my PhD degree at York University under the supervision of Walter Tholen. This line of inquiry and its offshoots have formed the basis for my 2013 doctoral thesis and several papers that develop and apply categorical methods for functional analysis and study related topics in category theory and general algebraic systems.

Having also studied algebraic geometry with Alexander Nenashev at York University, I am fascinated by the way in which various differential-geometric notions are connected to algebraic phenomena involving nilpotent elements in rings. During my NSERC Postdoctoral Fellowship I worked with Richard Blute and his student Keith O'Neill at the University of Ottawa to develop a way of extending the theory of Kähler differentials to novel settings through monoidal category theory, leading to an extension of the algebro-geometric construction of the tangent bundle to unusual contexts.

At Mount Allison, Geoffrey Cruttwell and I have recently proved that the familiar de Rham complex of differential forms arises on the basis of a symmetric (co)simplicial structure carried by J. E. White's sector forms. We have developed this novel simplicial view on differential forms within the general context of the tangent categories of Rosický and Cockett-Cruttwell, which provide a framework for differential geometry that includes the familiar category of smooth manifolds as an example alongside many others including categories of schemes in algebraic geometry.

- *Rory Lucyshyn-Wright*

Graph Searching and Combinatorics Conferences in Atlantic Canada

The East Coast Combinatorics Conference (ECCC) will be held at Mount Saint Vincent University in Halifax on Monday, July 18 and Tuesday, July 19, 2016. This conference series has been bringing together mathematicians and computer scientists interested in all aspects of combinatorics for 11 years. There will be two invited speakers, Mateja Sajna from the University of Ottawa and Anthony Bonato from Ryerson University, as well as contributed talks of 25 minutes. For more information, see <https://sites.google.com/site/eccc2016/>.

The 5th Graph Searching in Canada (GRASCan) Workshop will be held July 20-21, 2016 at Dalhousie University in Halifax, Nova Scotia. The purpose of the workshop is to bring together researchers for a few days of talks and collaboration on the topic of graph searching. Graph searching is defined in a broad sense, with topics such as Cops and Robbers games and their variants, edge searching, graph cleaning, eternal security, and firefighting. Work in the area touches on structural, probabilistic, spectral, algorithmic and topological graph theory. The plenary speakers will be Pawel Pralat (Ryerson University) and Gena Hahn (Université de Montréal). Each morning, there will be a plenary and a small number of ½ hour talks; the afternoons will be free for discussion, networking, and collaboration. For more information, see <http://www.math.ryerson.ca/~abonato/GRASCan/GRASCan16/index.html>.

AARMS Summer School 2016

Preparations are well underway for the Annual AARMS Summer School, to take place this year at Dalhousie University from July 11 to August 5, under the direction of Dr. Dorette Pronk (Dalhousie) and Dr. Geoffrey Cruttwell (Mount Allison). As usual four graduate level courses are offered as follows:

Higher Category Theory and Categorical Logic - Drs. Michael Shulman (San Diego) and Peter Lumsdaine (Stockholm)

Categories, Quantum Computation and Topology - Dr. Jamie Vicary, University of Oxford

Stable polynomials: with applications to graphs, matrices, and probability - Dr. David Wagner (Waterloo)

An Introduction to Special Functions and WZ Theory - Dr. Armin Straub (South Alabama)

Students are currently being admitted into the summer school. This year, as part of our partnership with the African Institute for Mathematical Sciences (AIMS) we expect some participants from Africa to complement the international mix of students.

The International Category Theory Conference CT 2016 has been organized to take place in association with the Summer School. It will be held August 7-13 at Dalhousie and St. Mary's.

Activities at the Atlantic Algebra Centre

During the last semester, several events were held at the Atlantic Algebra Centre. During the week March 14 - 18, the AARMS-AAC mini course "Nichols algebras" took place at Memorial's St. John's campus. Nichols algebras are a class of algebras that have recently appeared in a number of different fields in mathematics. Originally, they were introduced in the classification of pointed Hopf algebras, but they have now also shown up in combinatorics, algebraic geometry, and conformal field theory. The lecturer of the mini course was Professor István Heckenberger from the University of Marburg in Germany, who gave a total of six lectures during the course. Professor Heckenberger is one of the world-leading experts on the subject whose contributions have shaped the field. His introduction of Weyl groupoids, as a generalization of Weyl groups in the classical theory, is certainly one of the most important developments in Lie theory in the last decades.



participants at the Minicourse with Dr. Heckenberger

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

Fifteen people participated in the mini course, ranging from undergraduate students to faculty members, including several external guests from Canada and the United States. The audience experienced an intense and stimulating week of mathematics at the forefront of current research in a nonetheless relaxed atmosphere. On March 18, Professor Heckenberger also gave an AAC colloquium on the related topic of Fomin-Kirillov algebras.

Still another AAC colloquium was given on March 31 by Professor Colin Ingalls from the University of New Brunswick at Fredericton. The title of the Colloquium was "Birational Classification of Noncommutative Varieties that are Finite over their Centres". Professor Ingalls' lecture was also well received by a large audience.

The activities of the Atlantic Algebra Centre will continue in the summer. During the week from June 13-17, the Atlantic Algebra Centre will join forces with the Network of Ontario Lie Theorists to organize the International Workshop "Hopf Algebras, Algebraic Groups and Related Structures", with the support of AARMS and the Fields Institute. The workshop will again take place at the St. John's campus of Memorial University

and will focus on the various connections between topics in the theory of Hopf algebras, like finite generation of cohomology, Nichols algebras, and invariant theory, and analogous topics in the theory of linear algebraic groups, like exceptional groups, torsors, cohomological invariants, and central simple algebras. The workshop will also look toward applications to representation theory, graded algebras, superalgebras and quantum groups. We hope that the interaction of researchers during the meeting will have a substantial impact on the mutual understanding of the results, techniques and present problems in these areas. The organizing committee consists of Yuri Bahturin, Mikhail Kochetov, and Yorck Sommerhäuser on the side of the Atlantic Algebra Centre and Kirill Zaynullin on the side of the Network of Ontario Lie Theorists. Registration for the workshop is still open; the deadline for registration is May 1.

Additional information about the events described above can be found on the web page of Atlantic Algebra Centre at <http://www.mun.ca/aac/>

Outreach Activities at STFX

The 2015-2016 academic year saw the implementation of a pilot project entitled "Connecting Math to Our Lives and Communities" through St. Francis Xavier University. The program was designed for students in grades 7 through 12 as a means to encourage youth to examine and investigate the value of mathematics in their lives and develop an appreciation for how mathematics can have power to shape their futures. Through such learning, students are supported and encouraged to participate in further studies in mathematics and science, and develop an increased confidence in their mathematical abilities as well as provide opportunities for students to see that mathematics can be a powerful tool for helping the world.



Connecting Math to Our Lives and Communities has run in four Mi'kmaw and two African Nova Scotian communities in Eastern Nova Scotia. The program brings St.FX Bachelor of Education students and undergraduate science and math students into the communities biweekly to explore topics of interest to the youth. Project work has focused on reading and

writing the world with mathematics through the explorations of social justice issues such as water security and the environment to patterns and logical reasoning, including technology and coding.

29 sessions were held, with attendance reaching over 180 participants. While the program was designed for students in grades 7-12, interest from students in the communities caused us to expand the grade levels to include grades 5 and 6.

A successful final celebration day was held on campus at St.FX on Saturday, April 2, which brought 50 students together with community leaders, elders, and university faculty to share traditional knowledge and make mathematical connections through workshops and an Amazing Math Race.



Playing with Mathematics in Harvey

Math outreach continues in New Brunswick with the support of AARMS. Recent events included our annual appearance at STEAM Expo where we hosted a popular exhibit of mathematical games and activities for people of all ages. (See the Winter 2014 newsletter for more on this initiative.) Upcoming activities include out of town school visits to Fredericton Junction and Sackville, along with basketball math at the UNB Math Camp. Here we will share about a recent example of a full day in schools.

Grade 5 in the elementary school to Grade 9 in the community high school and back to Grade 1-2 and then to Grade 9 again followed by an afterschool visit at the elementary school where the puzzles and games would be left for a couple more weeks. That aptly describes the day of February 15, 2016 in Harvey, NB.



The day in Harvey featured three planned classroom visits starting with two Grade 5 classes combined. The picture shows Grade 5 students beginning a game of Suspend in which rods of various forms must be placed so as to balance on an existing structure. This game was one of many played by about 70 students in Grade 5 or Grade 9, with each class having at least an hour with the games.

Outreach comes with surprises that grow as we build relationships in communities. Julie Glaspy, a former B.Ed. student and outreach volunteer, was substitute teaching a Grade 1-2 split class that day. We improvised to visit that class in which we played other games stressing number sense. Finally, the value of the experience was enhanced by an extended loan of various games to Carole Lapointe-Novak for use with Grade 5's over the remaining two weeks prior to the break.

We wish to acknowledge teachers and volunteers who have played a helpful role in these activities including Leah Bidlake and Jacob Wolfe (Harvey High), Carole Lapointe-Novak, Jonathan Lim, April Murphy and Kathy Szo (Harvey Elementary), Dara Glaspy, Julie Glaspy, and Heather Grant-McLoughlin (STEAM Expo volunteers).

- John McLoughlin and Ryan Jones

In Partnership with AIMS

A memorandum of understanding was signed late last year between AARMS and the African Institute of Mathematical Sciences (AIMS). AARMS is happy to aid AIMS in its goal to develop capacity of mathematical talent in Africa, and to foster collaboration between universities in Atlantic Canada, and AIMS centres in Africa. The collaboration between AARMS and AIMS involves support for participation of African graduate students in the AARMS summer school, and a faculty exchange program.

In the Faculty Exchange program, faculty from AARMS institutions are allocated teaching positions across the network of centres of excellence to deliver three-week courses within the AIMS one-year Structured Master's Program. For more information contact a member of the AARMS Executive.

Brief Announcements

Hundreds of used books from all areas of pure and applied mathematics, including some computer science, statistics, and mathematical physics, are for sale at <http://www.mathstat.dal.ca/~dilcher/oldbooks.html>. This is a fundraiser, and prices are moderate. All proceeds go, in equal parts, to the CMS and to the Dalhousie Department of Mathematics & Statistics.

- Karl Dilcher (Dalhousie)

The paper "A Scalable Unsupervised Deep Multimodal Learning System" by Shameer Iqbal and Daniel Silver of the Jodrey School of Computer Science, Acadia University, was nominated along with two other papers for the Best Paper Award for FLAIRS-29, The 29th International FLAIRS Conference - <http://www.flairs.com> May 16 - 18, 2016 Key Largo, Florida, USA

Recent and Upcoming Events

AARMS Workshops and Minicourses

Hopf Algebras, Algebraic Groups and Related Structures
Organizers: Y. Bahturin, M. Kotchetov, Y. Sommerhäuser, K. Zainoulline
Date: June 13-17, 2016
Location: Memorial University, St. John's

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

Graphs and Combinatorics (ECCC/GRAScan)
Organizers: S. Seager, D. Cox, M. Messinger, A. Bonato
Location: Mount St. Vincent University and Dalhousie University, Halifax
Date: July 18-21, 2016

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

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

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

AARMS-Sponsored Events

Software Carpentry Bootcamp 2016
Organizers: Paul Muir, Linda Campbell, Ross Dickson
Location: Saint Mary's University, Halifax
Date: May 5-6, 2016

MBI Summer School on Mathematical Epidemiology
Organizers: James Watmough et al
Location: Mathematical Biosciences Institute, Columbus, Ohio
Date: May 12-24, 2016

Workshop on Homotopy Type Theory
Organizers: Dan Christensen et al
Location: Fields Institute, Toronto
Date: May 16-20, 2016

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

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"All science requires mathematics. The knowledge of mathematical things is almost innate in us. This is the easiest of sciences, a fact which is obvious in that no one's brain rejects it; for laymen and people who are utterly illiterate know how to count and reckon."

-David Hilbert