

AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

An abstract, three-dimensional mathematical surface, possibly a hyperboloid of two sheets, rendered with a fine grid pattern. The surface is colored with a gradient from light yellow to dark brown, with highlights and shadows that give it a sense of depth and curvature. It dominates the background of the cover.

Research Report

ANNUAL
2016 –17

ABOUT AMSI

The Australian Mathematical Sciences Institute (AMSI) is a national collaborative venture of Australia's leading universities, professional societies and government agencies.

The central voice for the Australian mathematical sciences, AMSI drives a strong policy and advocacy agenda to radically improve the effective and efficient delivery of mathematical and statistical capability and capacity to education, research and industry.

AMSI runs significant national programs to improve mathematical sciences outcomes within research, higher education, industry engagement and schools. Our activities include scientific workshops, distinguished visiting lectureships, short courses, research training events, PhD industry research internships, professional development for teachers, and industry liaison.

AMSI MEMBERS

Full Members

La Trobe University
Monash University
Queensland University of Technology
RMIT University
The Australian National University
The University of Melbourne
The University of Newcastle
The University of Queensland
The University of Sydney
The University of Western Australia
The University of Adelaide
The University of New South Wales

University of New England
University of South Australia
University of Southern Queensland
University of Tasmania
University of Technology Sydney
University of Wollongong
Victoria University
Western Sydney University

Government Agencies

Australian Bureau of Statistics
Bureau of Meteorology
CSIRO
The Defence Science and Technology Group
Reserve Bank of Australia

Societies

Australian and New Zealand Industrial and Applied Mathematics
Australian Bioinformatics and Computational Biology Society
Australian Mathematical Society
Australian Mathematics Trust
Mathematics Education Research Group of Australasia
Statistical Society of Australia

Funding bodies and sponsors

Department of Education and Training (Australian Government)
BHP Billiton Foundation (as part of the Choose Maths project)
Boeing

AMSI and its members acknowledge the significant contribution of The University of Melbourne as our Lead Agent and host

Associate Members

Curtin University of Technology
Deakin University
Edith Cowan University
Federation University Australia
Flinders University
James Cook University
Macquarie University
Murdoch University
Swinburne University of Technology

Member list as of December 2017

*Editorial team: Melissa Trudinger and Laura Watson
Design and layout: Michael Shaw*



STRENGTHENING THE FOUNDATIONS OF THE **MATHEMATICAL SCIENCES IN AUSTRALIA**

Welcome to the latest addition of the AMSI Research Report. It is an exciting time for the mathematical sciences with deepening international research engagement and new opportunities to collaborate with Australian industry.

Expanding our popular flagship training events with the new AMSI Optimise symposium has strengthened research-industry collaboration by responding to optimisation challenges, and deepened the experience and opportunity of the next generation of specialists. With the success of the launch hosted by Monash University, we look forward to growing the utility of mathematical optimisation for large and small business, public utilities and the health sector, all of whom are looking for maximise the benefits of the data deluge.

In 2016/17 AMSI hosted **23** workshops, **5** research-training events, and **2** national lecture tours. Over **100** international speakers attended these events

In late 2016, we partnered with the Australian Mathematical Society to launch MathsFest, a three-week mathematical event at ANU in Canberra. Featuring the AustMS Annual Meeting and two satellite workshops, the event proved a draw card for international researchers and a pathway for new collaboration. We are planning a follow up in 2018.

I am proud of AMSI's leadership in fostering engagement of women across the mathematical sciences. We are beginning to see positive impacts as a result of outreach and support through funding streams such as the Choose Maths Travel Grants. Excitingly, this has contributed to an increased number of women attending AMSI flagship events.

In what has been a busy period, AMSI has helped deliver 23 workshops, five research training events and two national lecture tours. These have allowed us to host over 100 international mathematical science leaders, including the extremely popular AMSI-SSA lecture tour featuring Canada's Professor Jeffrey Rosenthal.

Many of the programs and initiatives highlighted in this report would not have been possible without the support and leadership of the AMSI Research and Higher Education team. I would like to introduce our new Research and Higher Education Program Manager, Chloe Pearse, who joined us in 2017. I thank former Program Managers Simi Henderson and Paul Ulrick for their leadership of the program. In particular, I acknowledge Simi's major contribution in securing the Australian Government's continuing support for the delivery and expansion of AMSI's Research and Higher Education initiatives.

Finally, I thank all those researchers who have contributed to this year's Research Report and to Laura Watson and Melissa Trudinger for producing it.

Professor Geoff Prince
Director

AMSI Milestones

AMSI established through \$1m grant from Victorian government's Science, Technology and Innovation infrastructure grants program

The International Centre of Excellence for Education in Mathematics (ICE-EM) is established with \$7.8m from the Department of Education, Science and Training, providing funding for AMSI's Schools and Higher Education programs

AMSI Winter School launched

AMSI supports the National Strategic Review of the Mathematical Sciences in Australia (Australian Academy of Science)

Annual AMSI Lecture Tour (alternately co-sponsored with ANZIAM and SSA) established

AMSI sponsors 100th Scientific Workshop

2002 **2003** **2004** **2005** **2006** **2007** **2008** **2009**

AMSI is collaborating partner and a significant influence in the establishment of the Centre of Excellence for Mathematics & Statistics of Complex Systems (MASCOS). Out of an Australian government grant of \$10.9m, \$2.2m jointly administered by AMSI and MASCOS

AMSI Summer school and BioInfoSummer established

\$750,000 funding provided through ICE-EM to establish Access Grid Rooms in 11 member universities

100th Vacation Research Scholarship awarded

AMSI commences sponsorship of AustMS Mahler Lectureship

AMSI awarded \$2m Collaboration and Structural Reform grant to fund flagship programs in Higher Education, industry collaboration through workshops and the establishment of AMSI Intern

AMSI Intern program is established



AMSI awarded \$2m government grant to expand research training programs

AMSI sponsors 200th Scientific Workshop

The Australian Academy of Sciences launches *The mathematical sciences in Australia: a vision for 2025*, with AMSI's support

AMSI delivers 10th Annual Winter and Summer Schools

Research Training programs expanded through \$2m government grant

AMSI Intern program expanded through the establishment of a \$6.7 co-investment partnership with eight NSW and Victorian member universities

AMSI partners with AustMS to launch MathsFest, a three week long multi-event including the AustMS conference flanked by two international workshops

2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017

AMSI Intern program is expanded through \$1.7m government grant

AMSI sponsors 150th Scientific Workshop

International Year of Mathematics of Planet Earth led by AMSI in Australia

500th Vacation Research Scholarship awarded

10th Annual AMSI Lecture Tour held

AMSI's Access Grid Network replaced by Advanced Collaborative Environment (ACE)

Choose Maths launched with \$22 million from BHP Billiton Foundation

AMSI Optimise launches in Melbourne

Australian Government awards \$28 million to fund APR.Intern program expansion

AMSI places 200th intern

1800 mathematicians and statisticians attend AMSI-sponsored events in 2016/17

ABOUT **AMSI RESEARCH**

AMSI Research has been supporting the advancement and communication of fundamental and applied mathematical sciences knowledge for 15 years.

Building critical links between universities, government agencies and industry, our programs foster cross-disciplinary collaboration and industry engagement to grow mathematical sciences capability and equip Australia as a STEM leader for the future.

Our research training schools, scholarships and graduate courses have enhanced learning outcomes and networking opportunities for students and early career researchers, helping grow the supply of emerging mathematical talent to support public and private sector innovation.

Research Committees

Reporting directly to the AMSI Board, the Scientific Advisory and Research & Higher Education committees are responsible for governance of all AMSI Research programs.

Research and Higher Education Committee (R&HE) 2016–2017

The R&HE Committee monitors mathematical sciences research across Australia and provides strategic advice to the AMSI Board and Executive.

Prof. Gary Froyland, The University of New South Wales (Chair, until July 2016)

Prof. Markus Hegland, MSI, The Australian National University (Chair)

Dr Nicola Armstrong, Murdoch University (from October 2016)

Prof. Nigel Bean, The University of Adelaide (from July 2017)

Assoc. Prof. Regina Burachik, University of South Australia (until October 2016)

Prof. Peter Caccetta, CSIRO (until October 2016)

Michael Cromer, The Australian National University (until Feb 2017)

Prof. Norm Dancer, The University of Sydney (until October 2016)

Tom Dyer, University of Wollongong (Student representative) (from June 2017)

Prof. Andrew Eberhard, RMIT University (until October 2016)

Prof. Jan De Gier, The University of Melbourne (until October 2016)

Prof. Joseph Grotowski, The University of Queensland (until October 2016)

Prof. Anthony Henderson, The University of Sydney

Dr Phil Isaac, The University of Queensland (from October 2016)

Assoc. Prof. Inge Koch, Executive Director, Choose Maths

Prof. Tim Marchant, AustMS (until December 2016)

Anne Nuguid, Acting AMSI Research and Higher Education Program Manager (until September 2016)

Chloe Pearse, AMSI Research and Higher Education Program Manager (from June 2017)

Prof. Geoff Prince, AMSI Director

Dr Matt Ritchie, The Walter Eliza Hall Institute of Medical Research (until October 2016)

Prof. Aidan Sims, University of Wollongong (from October 2016)

Prof. Scott Sisson, The University of New South Wales (from October 2016)

Prof. Kate Smith-Miles, The University of Melbourne (from December 2016)

Prof. Terry Speed, The Walter and Eliza Hall Institute of Medical Research (from October 2016)

Paul Ulrick, AMSI Research and Higher Education Program Manager (September 2016 – January 2017)

Maaïke Wienk, ACE Network, AMSI

Scientific Advisory Committee (SAC) 2016–2017

The SAC provides scientific advice for AMSI Research activities and reviews, as well as AMSI Scientific Workshops.

Prof. Jonathan Borwein, The University of Newcastle, (deceased, was Chair, until August 2016)

Prof. Terry Speed, The Walter and Eliza Hall Institute of Medical Research (Chair, from October 2016)

Prof. Ben Andrews, The Australian National University

Prof. Philip Broadbridge, La Trobe University

Prof. Darren Crowdy, Imperial College London

Prof. Ezra Getzler, Northwestern University

Assoc. Prof. Frances Kuo, The University of New South Wales (until May 2017)

Prof. Elizabeth Mansfield, University of Kent

Prof. Geoff Prince, AMSI Director

Prof. Kate Smith-Miles, The University of Melbourne (until September 2016)

Prof. Terry Tao, UCLA; Clay Mathematics Institute, USA

Prof. Ole Warnaar, The University of Queensland

Disclaimer

Important

The following research workshop and event reports are not intended to be a comprehensive overview of research activities and events within the Australian mathematical sciences. These reports are developed in collaboration with event partners and may include views or recommendations from third parties that do not necessarily reflect those of the Australian Mathematical Sciences Institute. Links to event websites and contact information provided are not intended as endorsements of views or information but are provided for the convenience of the reader.

CONTENTS

Research Workshops	9
Ergodic Theory and its Applications	10
MODU2016	11
Winter of Disconnectedness	12
International Conference in K-Theory.....	13
Geometry at ANU	14
Animal, Vegetal, Mineral? Emergence and Function of Complex Shapes in Self-Assembly	15
Number Theory Down Under 4	16
Topological Matter, Strings, K-theory and Related Areas	17
Workshop on Low-Dimensional Topology and Quantum Algebra	18
Mathematical Methods for Applications: ANZIAM-ZPAMS Joint Meeting	20
International Conference on Nonlinear Partial Differential Equations	21
Interactions Between Topological Recursion, Modularity, Quantum Invariants and Low-Dimensional Topology.....	22
Feature: Interactions Between Topological Recursion, Modularity, Quantum Invariants and Low-Dimensional Topology.....	24
Hypergeometric Motives and Calabi-Yau Differential Equations.....	26
International Conference in PDE, Geometric Analysis and Functional Inequalities.....	27
Applied Probability at the Rock	29
Feature: Applied Probability at the Rock.....	30
China-Australia Joint Conference on PDE and Related Topics.....	32
Topology in Australia and South Korea 2017	33
Tensor Categories and Field Theory	34
Computational Inverse Problems	35
Integrability in Low-Dimensional Quantum Systems	36
CATS 2017: Computational and Algorithmic Topology, Sydney.....	38
MathsFest Australia 2016	40
Advances in Ergodic Theory, Hyperbolic Dynamics and Statistical Laws	40
Feature: Advances in Ergodic Theory, Hyperbolic Dynamics and Statistical Laws.....	42
Nonlinear and Geometric Partial Differential Equations	43
Feature: Nonlinear and Geometric Partial Differential Equations	44
Lecture Series	47
AMSI-SSA Lecturer.....	48
Interview: Encounters with Randomness	49
2017 AMSI-ANZIAM Lecturer.....	50
Interview: Making Decisions in the Face of Uncertainty	51
ACE Short Courses and Seminars.....	52
Research Training.....	54
AMSI Winter School on Biological and Environmental Modelling, 2016	56
Land of Geometry to Environmental Modelling	57
AMSI BioInfoSummer 2016	60
YouTube to BioInfoSummer: the Guts of Data Analysis	61
AMSI Summer School 2017.....	62
AMSI Optimise	66
AMSI Vacation Research Scholarships 2016/17.....	70
VRS STORIES	72
Choose Maths Grants	74
Advanced Collaborative Environment (ACE) Network.....	75
Heidelberg Laureate Forum	76
Early Career Workshop at the AustMS 2016 Conference.....	77
Women in Mathematics.....	78
Interview with Professor Asha Rao: Mentoring the Next Generation.....	80
Industry Research Programs	82
APR.INTERN.....	84
APR.Intern A Step Forward for Innovation Company	84
Advancing Defence Innovation With APR.Intern.....	85
Mentor Honoured for Researcher Development.....	85
Mathematics in Industry Study Group (MISG).....	86
Parks Victoria Partnership	88
Acronyms	90
AMSI Mission.....	91



Research Workshops 1

International Conference in PDE, Geometric Analysis, and Functional Inequalities, The University of Sydney

PHOTO: SUPPLIED BY GLEN WHEELER

1 RESEARCH WORKSHOPS

AMSI builds mathematical research collaboration through its internationally recognised program of scientific workshops.

In 2016–17 AMSI-sponsored **23 workshops and conferences** through the Scientific Workshops Program and as part of **MathsFest**

AMSI sponsored workshops and conferences attracted

1214 participants from academia, industry and government

AMSI sponsored **112 speakers** to attend workshops, of which

93% were international

49% of participants were **international visitors**

Female mathematicians made up **17%** per cent of the participants

19% of participants were **postgraduate students**, and another

15% were **early career researchers** (ECRs)

59 students and early career researchers **received travel funding** to attend AMSI-sponsored research events

Research Workshops

1.01	Ergodic Theory and its Applications.....	10
1.02	MODU2016.....	11
1.03	Winter of Disconnectedness.....	12
1.04	International Conference in K-Theory.....	13
1.05	Geometry at ANU.....	14
1.06	Animal, Vegetal, Mineral? Emergence and Function of Complex Shapes in Self-Assembly.....	15
1.07	Number Theory Down Under 4.....	16
1.08	Topological Matter, Strings, K-theory and Related Areas.....	17
1.09	Workshop on Low-Dimensional Topology and Quantum Algebra.....	18
1.10	Mathematical Methods for Applications: ANZIAM-ZPAMS Joint Meeting.....	20
1.11	International Conference on Nonlinear Partial Differential Equations.....	21
1.12	Interactions Between Topological Recursion, Modularity, Quantum Invariants and Low-Dimensional Topology.....	22
	Feature: Interactions Between Topological Recursion, Modularity, Quantum Invariants and Low-Dimensional Topology.....	24
1.13	Hypergeometric Motives and Calabi-Yau Differential Equations.....	26
1.14	International Conference in PDE, Geometric Analysis and Functional Inequalities.....	27
1.15	Applied Probability at the Rock.....	29
	Feature: Applied Probability at the Rock.....	30
1.16	China-Australia Joint Conference on PDE and Related Topics.....	32
1.17	Topology in Australia and South Korea 2017.....	33
1.18	Tensor Categories and Field Theory.....	34
1.19	Computational Inverse Problems.....	35
1.20	Integrability in Low-Dimensional Quantum Systems.....	36
1.21	CATS 2017: Computational and Algorithmic Topology, Sydney.....	38
	MathsFest Australia 2016.....	40
1.22	Advances in Ergodic Theory, Hyperbolic Dynamics and Statistical Laws.....	40
	Feature: Advances in Ergodic Theory, Hyperbolic Dynamics and Statistical Laws.....	42
1.23	Nonlinear and Geometric Partial Differential Equations.....	43
	Feature: Nonlinear and Geometric Partial Differential Equations.....	44

1.01 ERGODIC THEORY AND ITS APPLICATIONS

The University of Sydney, 18–22 July 2016

An opportunity for Australian and international mathematicians with an interest in ergodic theory, this workshop encouraged leading field specialists to share ideas and establish collaborative links.

Ergodic theory focuses on the mathematics behind the behaviour of dynamical systems, an area also strongly linked to number theory. With a key aim of fostering global collaboration, this meeting provided a collaborative platform to explore new avenues of discovery and discuss current work. It was also an important chance for Australian mathematicians, including students and early career researchers, to present their work in front of leading specialists in their field.

The event proved an effective research launch pad with a number of collaborative projects initiated and progressed during the week, including one between Dr Alexander Fish (The University of Sydney) and Sweden's Assistant Professor Michael Bjorklund (Chalmers University).

Setting the future research agenda, new and previously unpublished results on topics including ergodic theory, number theory, Ramsey theory, Diophantine approximation, fractal geometry and random walks featured in many of the headline talks. The keynote presentation on the divisibility properties of higher rank lattices by Professor Shahar Mozes (The Hebrew University of Jerusalem), focusing on his work with Swiss mathematician Professor Manfred Einsiedler, attracted a lot of attention from number theorists at the conference. The results of Einsiedler-Mozes are number theoretic, but using a dynamical approach, and some quantitative analogues of these results may be able to be proved analytically.

Other keynote speakers included The University of New South Wales' Professor Michael Cowling, Associate Professor Nikos Frantzikinakis (University of Crete), and Professor Alexander Gorodnik (Bristol University).

Local research community representation reflected the event's timing and the

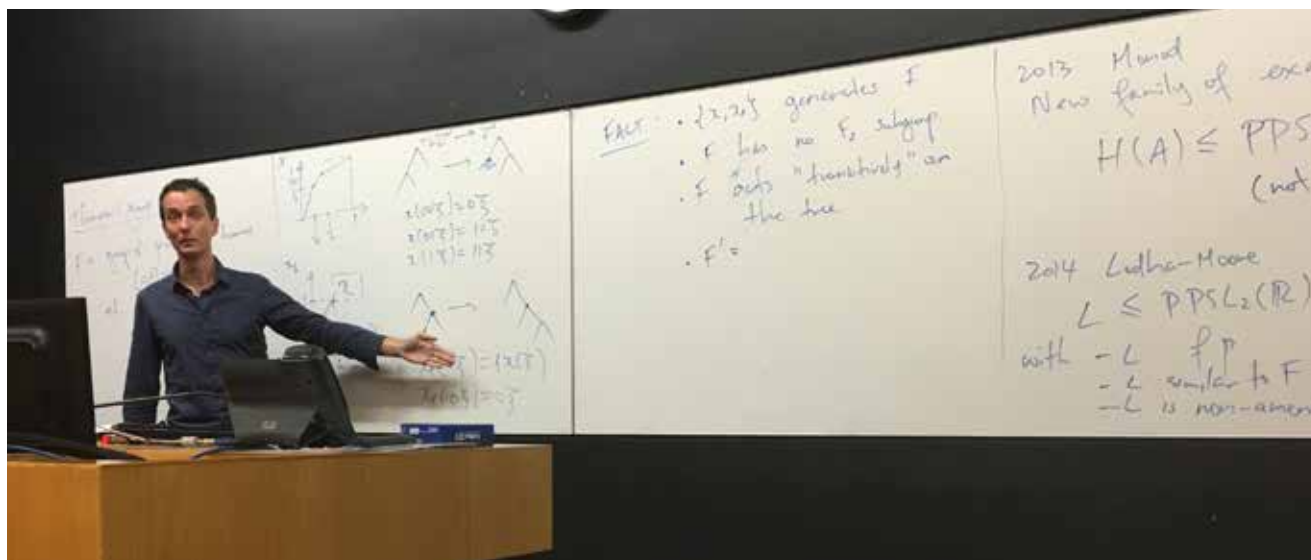
relative under-representation of ergodic theory as a field of research in Australia. The organisers are hoping that future events on ergodic theory and related fields will attract more participants.

"Many thanks for organising a conference in Ergodic Theory in Sydney, Australia. It was excellent, and I will definitely take part in the future similar events."

Assoc. Prof. Nikos Frantzikinakis,
University of Crete

WORKSHOP PARTICIPATION

- 44** Attendees
- 6** Postgraduate students
- 8** Early career researchers
- 4** Women
- 14** International participants



Organisers

Dr Alexander Fish, The University of Sydney
Dr Mumtaz Hussain, The University of Newcastle

Special Presenters

Prof. Michael Cowling,
The University of New South Wales
Research interests: harmonic analysis and geometry of Lie groups
Assoc. Prof. Nikos Frantzikinakis,
University of Crete, Greece
Research interests: ergodic theory and connections

to combinatorics and number theory

Prof. Alexander Gorodnik, Bristol University, UK
Research interests: theory of dynamical systems, number theory, geometry and representation theory
Prof. Shahar Mozes, Einstein Institute for Mathematics, The Hebrew University of Jerusalem, Israel
Research interests: Lie groups, discrete subgroups, geometric group theory and ergodic theory

MathSciNet Classification

19D06, 19E08, 19L10

Web Links

maths.usyd.edu.au/ET2016/

Other Sponsors

The University of Sydney

Key Contact

Dr Alexander Fish, The University of Sydney,
alexander.fish@sydney.edu.au

1.02 MODU2016

RMIT University, 18–22 July 2016

Optimisation in the modern world faces many challenges, from the rise of big data to the realisation that increased numerical precision does not always improve the accuracy of computation. These require new insights and deeper structural understanding of the underlying problems. This workshop focused on recent developments and challenges in optimisation theory.

MODU2016 provided a platform for key national and international field leaders to disseminate their most recent advances in optimisation theory and algorithmic development. In planning the program of this workshop, the priority was to maintain balance between the generality and depth of the topics. Most talks focused on the general theory of optimisation, with just a few presentations dedicated to modelling.

A key focus was the event's deliberate intention to bring people together who would not have much chance to meet and collaborate otherwise. Some participants commented that "this was not a usual crowd", and all coffee breaks were bustling with discussions. The approach paid off with new ideas and collaborations arising from the event.

In a powerful overlap, two participants (Dr Yalçın Kaya and David Kirszenblat) spoke about almost identical problems, but with entirely different approaches to their solution (optimal control versus geometric approach). This resulted in sustained discussion between project participants, and they all admitted that this was a fascinating coincidence. The Demyanov-Ryabova conjecture presented by Tian Sang (who recently solved a special case) got other participants interested in this area. Later on, keynote speaker Professor Aris Daniilidis solved another special case of this problem in collaboration with his student Colin Petitjean.

The conference also exposed early career researchers to both local and international experts. Several international participants took deep interest in the problems presented by local (and junior)

participants. In particular, AD DR Robert Baier and Professor Constantin Zalinescu engaged in active research discussions with Dr Nadezda Sukhorukova (Swinburne University) and Dr Julien Ugon (Federation University) after attending their talks, providing valuable and useful feedback.

The conference was well attended by junior researchers (more than 20 per cent were postgraduate and early career researchers), while female researchers accounted for 16 percent, including two keynote speakers.

WORKSHOP PARTICIPATION

- 51 Attendees**
- 8 Postgraduate students**
- 3 Early career researchers**
- 8 Women**
- 12 International participants**

"One of the finest workshops I've ever attended. Great format, good diversity of talks. I am leaving full of ideas and very stimulated."

Prof. Heinz Bauschke, University of British Columbia

Organisers

Prof. Jonathan Borwein, The University of Newcastle

Assoc. Prof. Regina Burachik, University of South Australia

Prof. Andrew Eberhard, RMIT University

Dr Vera Roshchina, RMIT University

Special Presenters

Prof. Heinz Bauschke, University of British Columbia, Canada

Research interests: convex analysis and optimisation, monotone operator theory, projection methods, and applications

Prof. Jonathan Borwein, The University of Newcastle
Research interests: computer assisted mathematical research, high performance computing, applied mathematics, functional and numerical analysis, data mining, discrete mathematics, dynamical systems, machine learning

Prof. Xiaojun Chen, The Hong Kong Polytechnic University, Hong Kong

Research interests: stochastic equilibrium problems, iterative methods for nonlinear/singular/nonsmooth equations, complementarity problems and applications, nondifferentiable optimisation, verification methods, spherical t-designs

Prof. Aris Daniilidis, University of Chile, Chile

Research interests: optimisation and equilibrium
Prof. Gabriele Eichfelder, Technische Universität Ilmenau, Germany

Research interests: optimisation

Prof. Jeya Jeyakumar, The University of New South Wales

Research interests: mathematical optimisation

Dr Guoyin Li, The University of New South Wales

Research interests: optimisation under uncertainty, numerical optimisation, semidefinite programming, nonsmooth analysis and variational analysis, convex analysis and functional analysis, global optimisation

Prof. Jeff Linderoth, University of Wisconsin-Madison, USA

Research interests: high performance and grid computing, numerical optimisation—integer

programming and stochastic programming

Prof. Pablo Parrilo, Massachusetts Institute of Technology, USA

Research interests: convex optimisation, semidefinite programming, systems and control, applied mathematics

Prof. Jie Sun, Curtin University of Technology

Research interests: operations research, optimisation, applied mathematics

MathSciNet Classification

90C25, 41A10, 90C60

Web Links

modu2016.org

Other Sponsors

CARMA, RMIT University, AustMS

Key Contact

Dr Vera Roshchina, RMIT University,
vera.roshchina@rmit.edu.au

1.03 WINTER OF DISCONNECTEDNESS

The University of Newcastle, 25 July – 5 August 2016

Structured as a mixture of mini-courses and lectures, this two-week workshop fostered exploration of Australian and international advances in our understanding of totally disconnected, locally compact groups.

Totally disconnected, locally compact (t.d.l.c.) groups are studied for two main reasons: on one hand, important classes of t.d.l.c. groups arise in particular contexts in geometry and algebra and, on the other, half the task of describing the structure of general locally compact groups is understanding the totally disconnected case.

Program contributors included mathematicians at the forefront of current international developments, attracting researchers and students, with courses covering totally disconnected groups specifically and in group theory and combinatorics more generally. A number of instructional lectures on recently developed techniques were offered. Individual lectures discussed work currently in progress and surveyed recent advances.

There were several highlights among the lectures. One was work in progress described by Dr Adrien Le Boudec, Dr Colin Reid and Professor Pierre-Emmanuel Caprace in their well-presented series of lectures. Each of them described important new work, at the time still unpublished,

that was new to almost all other audience members. Professor Pierre-Emmanuel Caprace in particular gave a masterly series of lectures informed by the overview he had given in his invited lecture at the European Mathematical Congress just two weeks before. Another highlight was the insights given by Professor Marc Burger into his influential paper with Professor Shahar Mozes on groups acting on trees.

A new collaboration between two research students, Tim Bywaters and Stephan Tornier, was initiated during the program and their work is to be published in a combined paper with another participant, Professor Dr Helge Glöckner. Lecture notes of the courses by Drs Reid and Le Boudec will also be published together with notes from lectures given at an earlier MATRIX workshop, in the 2016 MATRIX Annals (prepublication versions available at www.matrix-inst.org.au/2016-matrix-annals/)

In addition to the workshop program, a public forum on *Creativity and Mathematics* featured workshop participants Professor John Wilson and Professor George Willis, and the University of Newcastle academics in architecture, psychology and creative industries. Each panellist spoke briefly before responding to questions from the audience. About 90 members of the public attended.

The desirability of a future event on this topic was discussed. However, key participants from this workshop are involved in a number of related events in North America and Europe over the next two years and so it is most likely that this event will be in 2019 or 2020.

WORKSHOP PARTICIPATION

- 28 Attendees**
- 2 Postgraduate students**
- 3 Early career researchers**
- 3 Women**
- 21 International participants**

“The conference over two weeks turned out to be very productive for me and important for my students. All the mini courses were of an outstanding quality and I am going back with several notepads full of questions and projects.”

Professor Marc Burger,
ETH Zürich, Switzerland

Organisers

Prof. Pierre-Emmanuel Caprace, Université catholique de Louvain, Belgium

Assoc. Prof. Murray Elder, The University of Newcastle

Prof. Jacqui Ramagge, The University of Sydney

Dr Colin Reid, The University of Newcastle

Assoc. Prof. Simon Smith, City University of New York, USA

Dr Anne Thomas, The University of Sydney

Prof. George Willis, The University of Newcastle

Special Presenters

Prof. Dr Marc Burger, ETH Zurich, Switzerland
Research interests: algebra, geometry and topology, number theory

Prof. Pierre-Emmanuel Caprace, Université catholique de Louvain, Belgium
Research interests: locally normal subgroups and local decomposition theory

Dr Elisabeth Fink, University of Ottawa, Canada

Research interests: geometric group theory, asymptotic cones, quasi-isometry rigidity, hyperbolic and relatively hyperbolic groups

Assoc. Prof. Michael Giudici,

The University of Western Australia

Research interests: permutation groups and their action on various combinatorial, locally s-arc transitive graphs, fixed point free elements of prime order and graph decompositions

Prof. Dr Helge Glöckner, Paderborn University, Germany

Research interests: infinite-dimensional calculus and Lie groups, Lie groups over local fields

Prof. Dr Alessandra Iozzi, ETH Zurich, Switzerland

Research interests: geometric group theory

Dr Adrien Le Boudec, Université catholique de Louvain, Belgium

Research interests: simple groups of almost automorphisms of trees

Prof. Shahar Mozes, Hebrew University of Jerusalem, Israel

Research interests: Lie groups, discrete subgroups, geometric group theory and ergodic theory

Dr Uri Onn, Ben-Gurion University of the Negev, Israel/The Australian National University

Research interests: algebra, group theory and generalisations, topological groups, Lie groups

Dr C. R. E. Raja, ISI Bangalore, India

Research interests: probability theory and stochastic processes, topological groups, Lie groups

Dr Colin Reid, The University of Newcastle

Research interests: profinite and totally disconnected locally compact groups.

Prof. Riddhi Shah, Jawaharlal Nehru University, India

Research interests: dynamics of group actions, probabilities on groups, structure of groups

Dr Thiery Stulemeijer, Université catholique de Louvain, Belgium

Research interests: topological groups, Lie groups

Prof. John Wilson, University of Oxford, UK
Research interests: profinite groups, finite and infinite soluble groups, model theory of groups, branch groups, word growth of groups, finitely presented groups, generation problems for finite simple groups.

MathSciNet Classification

22 Topological Groups, Lie Groups

Web Links

carma.newcastle.edu.au/meetings/
winterofdisconnectedness/

Other Sponsors

CARMA, MATRIX

Key Contact

Prof. George Willis, CARMA, The University of Newcastle, george.willis@newcastle.edu.au

1.04 INTERNATIONAL CONFERENCE IN K-THEORY

Western Sydney University, 1–5 August 2016

Attended by mathematicians from a broad swathe of mathematical disciplines, this conference showcased significant advances in the mathematical sciences related to K-theory.

K-Theory is a discipline of mathematics that has embraced concepts and problems central to many other major disciplines of mathematics. Expert talks included algebraic geometry, algebraic and differential topology, noncommutative geometry, number theory, operator algebras and quadratic form theory. A common thread is that all these subjects have employed K-theoretic methodologies.

The conference provided Australian early career, postdoc and established researchers with a chance to network with some of the world's best in this area. The conference schedule allowed plenty of time for discussion and interaction, and speakers were chosen keeping in mind their track records of interaction with junior researchers and students. A total of 23 talks were delivered, including 6 by Australian mathematicians and 2 female speakers.

Among the highlights were talks by the keynote speakers, including Professor Dr Joseph Ayoub's presentation on P1, δ -localisation and the conservativity conjecture, Professor Thomas Geisser's talk on Etale motivic cohomology, Professor Lars Hesselholt on topological Hochschild homology and the Hasse-Weil zeta function, Professor Shoji Saito on purity of reciprocity sheaves and Professor Chuck Weibel on the K-theory of toric varieties in mixed characteristic.

There were 47 participants, 35 of them overseas participants from China,

Denmark, Germany, India, Japan, Mexico, Singapore, Switzerland, Thailand, the UK and USA. With networking opportunities between the talks many new links have been established.

WORKSHOP PARTICIPATION

47 Attendees
12 Early career researchers
3 Women
35 International participants

“Coming from the US, this was a valuable opportunity for me to interact with mathematicians from the region that I rarely get a chance to work with. Mathematicians not just from Australia but also from Singapore, Thailand, China and Japan.”

Professor Chuck Weibel, Rutgers University

Organisers

Prof. Christian Haesemeyer,
The University of Melbourne
Assoc. Prof. Roozbeh Hazrat,
Western Sydney University
Dr Daniel Murfet,
The University of Melbourne
Prof. Amnon Neeman,
The Australian National University

Special Presenters

Prof. Dr Joseph Ayoub,
Institute for Mathematics, Zürich
University, Switzerland
Research interests: algebraic geometry and motives

Prof. Thomas Geisser, Rikkyo University, Japan
Research interests: arithmetic algebraic geometry, algebraic K-theory, motivic cohomology

Prof. Lars Hesselholt,
University of Copenhagen, Denmark
Research interests: homotopy theory, algebraic K-theory and arithmetic algebraic geometry.

Prof. Shuji Saito,
Tokyo Institute of Technology, Japan
Research interests: geometry and topology, number theory

Prof. Chuck Weibel, Rutgers University, USA
Research interests: algebraic K-theory, motivic cohomology, motivic homotopy theory, cyclic homology, algebraic geometry, homological algebra

MathSciNet Classification

19D06, 19E08, 19L10

Web Links

sites.google.com/site/interconfonktheory2016/home

Other Sponsors

The University of Melbourne, Western Sydney University, Australian National University, AustMS

Key Contact

Assoc. Prof. Roozbeh Hazrat, Western Sydney University r.hazrat@westernsydney.edu.au

1.05 GEOMETRY AT ANU

The Australian National University, 15–26 August 2016

Geometry at ANU connected central algebraic geometry topics with many other areas of mathematics. The event targeted both early career and established researchers and attracted many international participants.

This workshop brought together a large group of world experts to discuss current progress in algebraic geometry. The two-week event started with a week-long workshop for postgraduate students and postdocs, which led into the conference itself. The format prepared the students to fully and productively participate in the research conference.

This was a truly international event, with about half the speakers taken from Australian universities and half the speakers coming from Europe and the US. For many speakers, this was their first time in Australia, and hopefully will serve as a starting point for longer-term collaboration between mathematical communities here and abroad. It was also wonderful to see graduate students from Europe and the US interacting with Australian PhD students during and after the workshop. The conference covered a broad range

of topics, and featured talks connecting algebraic geometry to representation theory, combinatorics, and dynamical systems. There was certainly no shortage of questions and comments from the strong representation theory contingent after Professor Alexeev's talk on modular interpretations of root systems! Furthermore, a beautiful and fruitful interplay between algebraic and dynamical ideas emerged in the talks of Associate Professor Dawei Chen and Dr Tuyen Truong, and interesting, new combinatorial problems arose from Dr David Jensen's talk on topical approaches to the classical theory of algebraic curves.

Two specific highlights from early career participants stood out. First, Assistant Professor Ben Bakker presented some amazingly original ideas for proving general type results for complex ball quotients. One of the major themes in algebraic geometry is to understand the birational geometry of various moduli spaces of interest, which has typically proceeded by means of understanding the divisor theory of the space, and applying theorems of higher-dimensional algebraic geometry. Bakker's approach is completely different,

relying on the hyperbolic geometry of the uniforming group, yet he was able to obtain significant results on several moduli spaces of interest, including moduli spaces of curves, Del Pezzo surfaces, and K3 surfaces. There was significant interest from members of the audience to develop these ideas further and apply them in a broader range of settings.

Second, Professor Jochen Heinloth presented some new ideas for a completely stack-theoretic approach to Geometric Invariant Theory. There was a strong overlap with his work and recent work of Associate Professor Jarod Alper and Assistant Professor Jack Hall, and it seems likely that by synthesising these ideas, new, more streamlined approaches for the construction of moduli spaces may be available in the near future.

WORKSHOP PARTICIPATION

77 Attendees
19 Postgraduate students
8 Early career researchers
9 Women
43 International participants

“This was a very good conference with high-level speakers that represented well many recent developments in algebraic geometry. The mix of the participants and topics was very good, I thought. I especially appreciated the talks by Claire Voisin (College de France), Klaus Hulek (Hanover), and Michel Brion (Grenoble). Seeing them all in one place was a special treat. I also appreciated the chance to meet Australian mathematicians, from Canberra and Sydney, and to make new mathematical connections which I hope will continue. This was well worth a long trip!”

Prof. Valery Alexeev, University of Georgia, USA

Organisers

Dr Jarod Alper,
The Australian National University
Dr James Borger,
The Australian National University
Assoc. Prof. Scott Morrison,
The Australian National University
Dr Daniel Murfet,
The University of Melbourne
Prof. Amnon Neeman,
The Australian National University
Dr David Smyth,
The Australian National University

Special Presenters

Prof. Valery Alexeev, University of Georgia, USA
 Research interests: algebraic geometry, moduli of surfaces, moduli of abelian varieties
Prof. Michel Brion, University of Grenoble, France
 Research interests: algebraic groups, algebraic geometry
Prof. Burt Totaro, UCLA, USA
 Research interests: algebraic geometry, topology, lie groups
Prof. Claire Voisin, University of Paris, France
 Research interests: algebraic geometry, as pertains to Hodge theory and the Hodge Conjecture

MathSciNet Classification

14H10, 14J10, 14C25

Web Links

maths-people.anu.edu.au/~alperj/geometry-at-the-anu

Other Sponsors

The Australian National University, AustMS

Key Contact

Prof. Amnon Neeman, The Australian National University, amnon.neeman@anu.edu.au

1.06 ANIMAL, VEGETAL, MINERAL? EMERGENCE AND FUNCTION OF COMPLEX SHAPES IN SELF-ASSEMBLY

Cave House Hotel, WA, 19–23 September 2016

Selected by the Australian Academy of Sciences as the 2016 Boden Research Conference, Australian and international researchers gathered for a multi-discipline discussion on structure and geometry in living and dead systems. As well as successfully creating synergies between the biological and natural sciences, this event opened new research directions.

Animal, Vegetal, Mineral encouraged open and broad discussion between biologists, physicists, mathematicians, chemists and materials scientists. Exploring the divide between the biological and the natural sciences, the conference drew out common features and essential differences of living and dead systems.

Structure and pattern formation in both biological and synthetic systems and on the nanoscale was the key focus, as well as the role of structure and geometry in physical properties and evolutionary function. While such nanoscale geometries are found ubiquitously both in biological systems and synthetic self-assembly, it is becoming increasingly clear that fundamental differences in the formation mechanisms of the biotic and abiotic systems exist. Our understanding of these formation processes hinges on geometric concepts—from differential and hyperbolic geometry to computational and stochastic geometry. It is for this reason that this interdisciplinary event's engagement of the Australian applied maths community is so important.

This workshop was a bold and successful attempt to encourage nearly 80 Australian, European, Asian and American scientists

to think more fundamentally about their connections to the broader community of scientists. Through this lens they were encouraged to look in detail “over the fence” that usually divides life scientists from natural scientists and mathematicians from lab- and field-based researchers.

Topics covered by speakers included:

- Pattern and structure formation in biology and synthetic self-assembly
- Relationships between geometry and function/properties
- Geometric methods and concepts for applied and life sciences
- Nanostructures and biomimetic approaches
- Geometry, including hyperbolic, computational and stochastic geometry
- Protein and lipid assemblies in natural and synthetic membrane systems

Exceeding expectations, conference attendance included 49 international participants and 78 in total. Significantly, Fellows of the Royal Society and the Australian Academy of Sciences were among this year's delegates.

The Royal Society journal *Interface Focus* dedicated a special issue to the meeting (*Growth and function of complex forms in biological tissue and synthetic self-assembly: Theme issue* organised by Stephen T. Hyde, Gerd E. Schröder-Turk, Myfanwy E. Evans and Bodo D. Wilts, *Interface Focus* Vol 7:4 6 August 2017) featuring articles by conference attendees.

As well as providing the springboard for several collaborations, new links and synergies between disjoint research communities at the conference opened avenues for future research. Organisers

believe the roundtable discussion forum for nanostructure formation in biology and chemistry was central to achieving this goal, emphasising the essential role that geometric mathematical approaches and modelling play in this field.

With 11 keynote lectures from global field leaders, 10 invited talks, 27 contributed talks and 23 poster presentations, *Animal, Vegetal, Mineral* was a major event within the 2016 Australian and West Australian science calendar.

“...a superb and stimulating conference. The ‘cross-cultural’ aspect of getting biologists, physicists, mathematicians, chemists and engineers together made it particularly powerful in finding ways forward. It showed the power of mixing it up—something we should do more.”

Prof. Justin Marshall, The University of Queensland

WORKSHOP PARTICIPATION

- 78** Attendees
- 15** Postgraduate students
- 8** Early career researchers
- 17** Women
- 49** International participants

Organisers

Dr Gerd Schröder-Turk, Murdoch University

Prof. Stephen Hyde, The Australian National University

Dr Myfanwy Evans, Technical University of Berlin, Germany

Dr Charlotte Conn, RMIT University

Dr Bodo Wilts, Fribourg University, Switzerland

Special Presenters

Prof. George Attard, University of Southampton, UK
Research interests: synthesis of novel nanostructured metals and oxides using lyotropic liquid crystalline phases as templates data-driven

modelling to lipidomic studies of prokaryotes as well as single-celled eukaryotes (marine diatoms)

Prof. Yuru Deng, Changzhou University, China

Research interests: cubic membranes in inner-cellular cell organelles, biological membranes based on triply-periodic minimal surface geometries in nature, physiological structure-function relationships in amoeba inner-cellular membranes

Prof. Leslie Dutton, University of Pennsylvania, USA
Research interests: elementary processes of oxidation-reduction and related biological events, mechanisms of electron transfer

Prof. Neil Hunter FRS, University of Sheffield, UK
Research interests: photosynthesis, microbiology,

chlorophyll, phototrophic bacteria, cyanobacteria, carotenoids, light-harvesting complexes, reaction centres, membrane proteins, biochemistry, enzymology, nanotechnology, atomic force microscopy

Prof. Poul Erik Jensen, University of Copenhagen, Denmark

Research interests: molecular plant biology, specifically photosynthesis research and chloroplast biology, and light harvesting

Prof. Justin Marshall, The University of Queensland
Research interests: photoreceptor physiology & biophotonics of crustaceans, colour vision, photoreceptor physiology and biophotonics of marine life forms

Prof. Konrad Polthier, Free University Berlin, Germany

Research interests: geometry and topology of minimal surfaces, discrete geometry and visualisation approaches for complex geometries

Prof. Richard Prum, Yale University, USA

Research interests: cell biological formation and evolutionary purpose of nanostructured biophotonic crystals in birds and insects

Prof. John Seddon, Imperial College London, UK

Research interests: physical chemistry of bicontinuous phases (modelled by triply-periodic minimal surfaces), and applications of lipid polymorphism, including pharmaceutical applications

Prof. Mohan Srinivasarao, Georgia Tech, Atlanta, USA

Research interests: cholesteric liquid crystal phases and chiral Bouligand structures in beetle cuticles

Prof. Peter Vukusic, University of Exeter, UK

Research interests: biophotonic nanostructured materials in insects, and in particular also their benefits for industrial or biomimetic applications.

MathSciNet Classification

92C15, 51M10, 53A10

Web Links

amsi.org.au/animal-vegetal-mineral-workshop

Other Sponsors

Australian Academy of Sciences, AustMS/ANZIAM, Murdoch University, RMIT University, The Australian National University, Ian Potter Foundation, Perth Conference Bureau

Key Contact

Dr Gerd Schröder-Turk, Murdoch University,
G.Schroeder-Turk@murdoch.edu.au

1.07 NUMBER THEORY DOWN UNDER 4

The University of Newcastle, 23–26 September 2016

The fourth annual installment of this popular meeting was dedicated to the celebration of Professor Richard Brent's 70th birthday. An exploration of number theory, the event fostered critical discussion between Australian and international mathematicians.

This workshop highlighted number theory's linkages with a number of other mathematical disciplines. Sessions explored the many open problems lying at the intersection of number theory and harmonic analysis, measure theory, computation, and algebra.

Many of Professor Richard Brent's collaborators and colleagues delivered lectures in his honour. A mathematician and computer scientist, his contributions have spanned number theory, random number generators, numerical analysis, computer arithmetic, algorithmics, analysis and combinatorics. During his long career,

Professor Brent has supervised nineteen PhD students to completion, taught undergraduate and postgraduate courses in mathematics and computer science across five universities, and shown himself an able administrator in his stints as a Head of Department at ANU and Oxford. He is currently a Fellow of the Australian Academy of Science, an Emeritus Professor at ANU, and a Conjoint Professor at the University of Newcastle.

Four questions were addressed at this conference:

- Diophantine approximation and its applications — bringing together Diophantine approximation, probabilistic number theory, measure theory and conformal dynamical systems. The main research question focused on different complexities was “how well can a real number be approximated by rational numbers quantitatively?”; or in other words the focus was on shrinking

target problems. Speakers presented state-of-the-art research in these areas, shedding light on their connections with each other.

- Special values of L -series and questions of transcendence, including Apéry's proof that $\zeta(3)$ is irrational, the most well-known example of this topic. One question that is receiving more attention in recent years is “What role can computation play in predicting and verifying the irrationality or transcendence of a special value?” Results were presented on both theoretical and computational approaches to irrationality.
- Zeroes of the zeta-function and of L -functions — a fruitful approach to understanding the analytic properties of the Riemann zeta-function has been to examine L -functions in more exotic settings. For example, the Riemann hypothesis has been proved over finite



fields. Our speakers addressed the current gaps in the literature — between easy settings, such as finite fields, and *hard* settings, such as Hecke L -functions.

- Computational Number Theory, in particular related to the works of Professor Brent. Talks covered probabilistic bounds on maximal determinants of binary matrices, computer algebra algorithms, and multiple precision arithmetic related to the MP package in Fortran introduced by Professor Brent.

With a focus on the use of computational techniques for exact problem solving, this event stimulated robust discussion, opening avenues for national and international collaboration. There were 24 talks spanned equally over 4 days, including 11 talks given by distinguished overseas speakers. The conference's 50 participants included a substantial proportion of postgraduate students and early career researchers who benefited from substantial networking opportunities.

Postgraduate students and early career researchers welcomed the opportunity to

present and discuss their research in a collaborative and stimulating environment. They additionally benefited from engagement with national and international field leaders and new academic networks.

WORKSHOP PARTICIPATION

- 50 Attendees**
- 6 Postgraduate students**
- 8 Early career researchers**
- 8 Women**
- 16 International participants**

Organisers

Dr Michael Coons, The University of Newcastle
Dr Alex Ghitza, The University of Melbourne
Dr Mumtaz Hussain, La Trobe University
Dr Tim Trudgian, The University of New South Wales, Canberra, Australian Defence Force Academy

Special Presenters

Dr Shi Bai, ENS Lyon, France
 Research interests: cryptography, computational number theory
Dr David H. Bailey, University of California, Davis, USA
 Research interests: parallel computing, number theory
Prof. YoungJu Choie, Pohang University of Science and Technology, Korea
 Research interests: number theory, modular forms
Assoc. Prof. Shaun Cooper, Massey University, NZ
 Research interests: number theory, analysis
Dr Lassina Dembélé, University of Warwick, UK
 Research interests: algebraic number theory,

computational number theory, Hilbert modular forms, automorphic forms, mod and p -adic Langlands programme

Prof. Karl Dilcher, Dalhousie University, Canada
 Research interests: number theory, combinatorial number theory, computational number theory, classical analysis, Bernoulli and Euler numbers, sequences of polynomials, zeros of polynomials, graph-theoretic polynomials

Prof. Hidenori Katsurada, Muroran Institute of Technology, Japan
 Research interests: analysis, applied mathematics, algebra

Assoc. Prof. Simon Kristensen, Aarhus University, Denmark
 Research interests: arithmetic, ergodic theory, small denominator problems, Diophantine approximation, metric number theory

Assoc. Prof. Yohei Tachiya, Hiroshima University, Japan
 Research interests: algebra

Dr Bao-Wei Wang, Huazhong University of Science and Technology, China

Research interests: number theory

Dr Paul Zimmermann, INRIA, France
 Research interests: asymptotically fast arithmetic, computational number theory

MathSciNet Classification

Not listed

Web Links

carma.newcastle.edu.au/meetings/ntdu4

Other Sponsors

CARMA

Key Contact

Dr Mumtaz Hussain, La Trobe University,
m.hussain@latrobe.edu.au

1.08 TOPOLOGICAL MATTER, STRINGS, K-THEORY AND RELATED AREAS

The University of Adelaide, 26–30 September 2016

This workshop stimulated interdisciplinary research collaboration in topological aspects of condensed matter physics, showcasing research from prominent international and Australian researchers.

There has been a significant surge of interest in topological aspects of condensed matter physics over the last decade. This reflects its underlying mathematical commonalities with string theory. In particular, techniques from geometry, topology, index theory, noncommutative geometry and T-duality. Having previously played fundamental roles in the study of D-branes and high-energy

physics, these are now being applied to matter at ordinary energy scales.

Mathematicians, mathematical physicists, string theorists and condensed matter physicists from 10 countries including Australia presented their best research at the workshop. The workshop's timing — it ran a week prior to the announcement of the 2016 Nobel Prize in Physics for *theoretical discoveries of topological phase transitions and topological phases of matter* — highlighted the workshop's timeliness and the need to establish Australia as a centre for research in this field.

The workshop kicked off with a talk by Professor Motoko Kotani, who shared

many fascinating ideas for the realisation of topological phenomena in materials. As the Director of the Advanced Institute of Materials Research, a unique multi-disciplinary institute in Sendai, Japan, Professor Kotani was able to provide a fascinating overview of the country's state-of-the-art in topological materials research. This was followed by Professor Stephen Bartlett's general talk. A researcher with the University of Sydney and Chief Investigator at the ARC Centre of Excellence for Engineered Quantum Systems, he explored topological phases in quantum information.

This set the tone for the rest of the workshop, comprising talks that were

mathematically more technical. Speakers included prominent overseas researchers Professor Krzysztof Gawedzki (ENS, Lyon, France, managing editor of *Annales Henri Poincaré*), Professor Gian Michele Graf (ETH, Switzerland), Professor Ugo Bruzzo (SISSA, Italy, managing editor of *Journal of Geometry and Physics*), Professor Hermann Schulz-Baldes (Germany), Assistant Professor Emil Prodan (USA), Dr Keith Hannabuss (University of Oxford, UK), and Assistant Professor Giuseppe De Nittis

(Chile). New ARC Future Fellow Associate Professor Paul Zinn-Justin (University of Melbourne) also gave a talk on K-theory and quantum integrable systems, as well as a Colloquium talk at the Mathematics department. There was also a session of short talks by PhD students on their thesis research. All in all, a large range of topics was covered, unified by the theme of applications to topological matter.

The Australian Institute of Physics newsletter promoted the workshop to the

broader Australian physics community. (aip.org.au/nobel-winning-topology-and-your-chance-to-get-involved-physics-in-november/#more-368.) In addition, the speakers contributed to the workshop proceedings, which were published in a Virtual Special Issue of the *Journal of Geometry and Physics*, entitled *String Geometry, Dualities and Topological Matter* in October 2017 (sciencedirect.com/science/journal/03930440/vsi?sdc=1).

“The workshop has been very valuable to me because it exposed me to quite different and new perspectives on a subject I am working on. In particular it allowed me to appreciate first hand some of the research being done in Australia, which I more rarely get to see at workshops in Europe.”

Prof. Gian Michele Graf, ETH Zurich

WORKSHOP PARTICIPATION

32 Attendees
8 Postgraduate students
2 Early career researchers
3 Women
10 International Participants

Organisers

Dr David Baraglia, The University of Adelaide

Prof. Peter Bouwknegt, The Australian National University

Dr Guo Chuan Thiang, The University of Adelaide

Prof. Mathai Varghese, The University of Adelaide

Special Presenters

Prof. Ugo Bruzzo, International School for Advanced Studies (SISSA), Trieste, Italy

Research interests: geometry, topology, mathematical physics

Prof. Krzysztof Gawedzki, ENS de Lyon, France

Research interests: mathematical physics, theoretical physics

Prof. Gian Michele Graf, ETH Zürich, Switzerland

Research interests: mathematical physics

Prof. Motoko Kotani, Tohoku University, Japan

Research interests: geometry, topology

Asst. Prof. Emil Prodan, Yeshiva University, USA

Research interests: mathematical physics, condensed matter physics

Prof. Hermann Schulz-Baldes, Friedrich-Alexander Universität Erlangen-Nürnberg, Germany

Research interests: mathematical physics, functional analysis, condensed matter physics

MathSciNet Classification

19M05, 46L90, 58Z05

Web Links

iga.adelaide.edu.au/workshops/WorkshopSep2016/

Other Sponsors

Institute for Geometry and its Applications/The University of Adelaide, AustMS

Key Contact

Dr Guo Chuan Thiang, The University of Adelaide, guochuan.thiang@adelaide.edu.au

1.09 WORKSHOP ON LOW-DIMENSIONAL TOPOLOGY AND QUANTUM ALGEBRA

The Australian National University, 31 October – 4 November 2016

Focusing on recent advances in low-dimensional topology and quantum algebra, this workshop fostered collaboration between research leaders across all areas of this vibrant field. The diverse program highlighted the work of both established experts and exceptional Australian and global early career researchers.

Although historically viewed as separate fields, the development of new topological invariants deeply linked to quantum groups and category theory has created surprising interactions between low-dimensional topology and quantum algebra. These invariants have proven to be effective

tools for tackling fundamental problems in manifold and link theory. They have also generated new algebra research activity due to their compelling internal structure and close connections to higher categories and higher representation theory.

The first day of the workshop was devoted to introductory talks on the major research areas in an effort to reach across disciplinary boundaries and maximise accessibility to student participants. Key themes included link homologies, hyperbolic and computational topology of 3-manifolds, finite-type invariants and contact geometry. The next four days of the conference were devoted to research talks with sufficient time allowed for

“The conference gathered a great collection of researchers from Australia and abroad. The schedule and environment allowed for quality research collaboration.”

Dr Norman Do, Monash University

collaboration outside the formal program.

The event increased the global visibility of Australian mathematical programs

and successes. It highlighted existing collaborations between Australian and international researchers with several of the international speakers marking their first visits to the country. The talks were well executed and speakers were successful in communicating with both specialists and the general audience. Multiple attendees

reported plans for new collaborative research projects, while another attendee sees the potential to apply material (finite-type invariants) discussed in some of the talks in their own work. Several attendees also praised the value of gathering the majority of the Australian topology community in one place.

WORKSHOP PARTICIPATION

- 36 Attendees**
- 8 Postgraduate students**
- 6 Early career researchers**
- 6 Women**
- 9 International participants**

Organisers

Dr Joan Licata, The Australian National University

Assoc. Prof. Jessica Purcell, Monash University

Dr Zsuzsanna Dancso, The University of Sydney

Assoc. Prof. Scott Morrison, The Australian National University

Special Presenters

Assoc. Prof. Benjamin Burton,

The University of Queensland

Research interests: computational geometry and topology, 3-manifold topology

Dr Baptiste Chantraine, Université de Nantes, France

Research interests: algebraic invariants of Legendrian sub-manifolds of contact manifolds

Assoc. Prof. Zsuzsanna Dancso,

The University of Sydney

Research interests: quantum algebra, geometry, topology, knot theory

Dr Norman Do, Monash University

Research interests: geometry and topology, mathematical physics

Assoc. Prof. Craig Hodgson,

The University of Melbourne

Research interests: geometry and topology, low-dimensional topology

Dr Neil R. Hoffman, The University of Melbourne

Research interests: hyperbolic geometry, low-dimensional topology

Dr Joshua Howie, Monash University

Research interests: low-dimensional topology

Assoc. Prof. Anthony Licata,

The Australian National University

Research interests: geometric representation theory, categorification

Dr Joan Licata, The Australian National University

Research interests: low-dimensional topology and contact geometry

Dr Gwénaél Massuyeau,

Université de Strasbourg, France

Research interests: quantum topology, finite type invariants, 3-manifolds and quantum algebra

Dr Daniel Mathews, Monash University

Research interests: geometry and topology, contact topology, symplectic topology, hyperbolic geometry, Heegaard Floer homology and topological quantum field theory

Dr Yoav Moriah, Israel Institute of Technology, Israel

Research interests: geometric and low dimensional topology, analysis, algebra, number theory

Assoc. Prof. Jessica Purcell, Monash University

Research interests: low-dimensional topology

Dr Hoel Queffelec, Université de Montpellier, France

Research interests: algebraic topology, knot theory, representation theory of quantum groups

Prof. J. Hyam Rubinstein, The University of Melbourne

Research interests: low dimensional topology, minimal surfaces (combinatorial and smooth), differential geometry and shortest network design, especially applied to underground mining

Assoc. Prof. Scott Morrison, The Australian

National University

Research interests: Khovanov homology, derived topological quantum field theories, and small examples of subfactors and singly generated tensor categories

Asst. Prof. Radmila Sazdanovic, North Carolina State University, USA

Research interests: topology, geometry, categorification, mathematical physics

Dr Jonathan Spreer, The University of Queensland

Research interests: combinatorics, geometry, topology

Assoc. Prof. Stephan Tillmann,

The University of Sydney

Research interests: geometry and topology, combinatorial topology

MathSciNet Classification

57M27, 57R56

Web Links

tqft.net/web/conferences/Topology2016/

Other Sponsors

AustMS, Mathematical Sciences Institute/The Australian National University

Key Contact

Dr Joan Licata, The Australian National University, joan.licata@anu.edu.au



1.10 MATHEMATICAL METHODS FOR APPLICATIONS: ANZIAM-ZPAMS JOINT MEETING

Hangzhou, Zhejiang Province, China, 11–14 November 2016

Exploring synergies between the Chinese and Australian applied mathematics cultures, this event strengthened ANZIAM's alliance with Chinese counterpart ZPAMS.

This meeting was designed as a platform to forge collaboration between ANZIAM and the Zhejiang Provincial Applied Mathematics Society. In many Chinese institutions, the disciplines of mathematics and computer science occupy a single unit, with research interests in areas such as machine learning. Conversely, our applications tend to be more in biological and environmental science. However, commonalities in numerical analysis and approximation theory methods were used as a bridge between the two areas, each expanding the range of interests.

Key research themes included machine learning, modelling of biological systems and numerical analysis. Speakers included:

- Professor Ian Sloan (UNSW) spoke on high-dimensional integration rules, with the main illustrative application being flow through randomly heterogeneous porous media. The improved quasi-Monte Carlo approach was shown to be amazingly efficient, suggesting that some very challenging emerging applications may be handled in future.
- Dr Alona Ben-Tal (Massey University, New Zealand) used three very interesting examples to show how systematic model reduction in physiology can help to explain puzzling dynamical phenomena. These examples included respiration systems in birds, which are quite different from those

in mammals, previously unexplained coupling between heart rate and breathing rate, and bursting phenomena in neural networks.

- Academician Professor Zongben Xu (Vice President of X'ian Jiaotong University, China) spoke on the emphases of a national project on *big data analytics*. The required analytic tools related to Prof Sloan's talk. The main advances shown were in "communication-efficient distributed kernel regression" which aims for distributed machine learning from distributed data sets, using limited rounds of communication.
- Professor Jin Cheng (Fudan University, and Vice President of the Chinese Mathematical Society) gave a very clear and motivational talk on how much boundary data can be removed from an elliptic PDE problem, while maintaining uniqueness of solutions. This is an intrinsically elegant problem that has clear applications to remote sensing.

The event succeeded in its aim of improving cultural and scientific understanding with many animated good-humoured exchanges between sessions, during meal breaks and during social events. Many of the side discussions included workplace challenges (e.g. language, geographic and political isolation, government directives, interactions between theorists and practitioners, the balance between pragmatism and ethical practice). The interaction was facilitated by the two host universities (Zhejiang Sci-Tech University and China Jiliang University) contributing approximately \$16,000 above

budget to freely provide all high-quality meals. The process was also aided by the talks overall being of a higher standard than we had anticipated. Many of the delegates requested specific international collaborations in the future.

The resulting special issue of the *ANZIAM Journal* (paper version), has provided the broader ANZIAM membership with a good overview of activity in Zhejiang Province. The Chinese response to this issue was strong, with many more contributed papers than anticipated. In the end, the special issue included more than 30 papers, all with authors from East Asia (China or Japan or Australian-Chinese ex-pats). At the same time, our small ANZ contingent still provided a broad cross section of ANZIAM activity, covering biological and environmental modelling, numerical analysis, fluid mechanics, mathematical finance and image analysis. (*The ANZIAM Journal*, Volume 58, Issue 3–4, January–April 2017)

Requests for future collaboration have come from several universities, including China Jiliang University, Ningbo University and Fudan University. Several Chinese delegates expressed interest in attending ANZIAM and APCfMI conferences in future. Several first-time visitors to China expressed interest in returning for scientific collaboration in future.

While attendance by Australian and New Zealand delegates was not as high as originally anticipated, the Chinese delegation exceeded expectations.

"I will continue to collaborate with China Jiliang University. Thank you to the organisers for a superb effort and for looking after us so well."

Prof. Ian Sloan, The University of New South Wales

WORKSHOP PARTICIPATION

107 Attendees
14 Postgraduate students
25 Early career researchers
18 Women
87 International participants

Organisers

Prof. Philip Broadbridge, La Trobe University, Chair
Prof. Song-Liang Qiu, Zhejiang Sci-Tech University, Chair
Prof. Feilong Cao, China Jiliang University
Prof. Zuohua Ding, Zhejiang Sci-Tech University
Prof. Jueliang Hu, Zhejiang Sci-Tech University
Prof. Tim Marchant, University of Wollongong

Assoc. Prof. Mark Nelson, University of Wollongong
Dr Julia Piantadosi, University of South Australia
Assoc. Prof. Dianhui (Justin) Wang, La Trobe University

Special Presenters

Dr Alona Ben-Tal, Massey University, NZ
 Research interests: physiological modelling,

including complexity reduction in neural networks, dynamical systems, mathematical modelling, numerical methods

Prof. Philip Broadbridge, La Trobe University
 Research interests: integrable systems, mathematical foundations of physics, hydraulics and water resources

Prof. Jin Cheng, Shanghai University of Finance and Economics, Fudan University, China
Research interests: inverse problems for boundary value problems with PDEs, also with some experience in numerical differentiation

Prof. Song-Liang Qiu, Zhejiang Sci-Tech University, China
Research interests: applied mathematics, analysis

Prof. Changzheng Qu, Ningbo University, China
Research interests: applied mathematics

Prof. Ian Sloan, The University of New South Wales
Research interests: computation mathematics,

numerical analysis and approximation theory
Prof. Zongben Xu, Xi'an Jiaotong University, China
Research interests: intelligent information processing, data mining, neural nets, machine learning, general applied mathematics

MathSciNet Classification

68T05, 65D18, 92B20

Web Links

anziam.org.au/ZPAMS

Other Sponsors

ANZIAM, SIAM, Zhejiang Provincial Applied Mathematics Society (ZPAMS), La Trobe University, University of Wollongong, University of South Australia, Zhejiang Sci-Tech University and China Jiliang University

Key Contact

Prof. Philip Broadbridge, La Trobe University,
P.Broadbridge@latrobe.edu.au

1.11 INTERNATIONAL CONFERENCE ON NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS

University of New England, 21–25 November 2016

In honour of Professor Norm Dancer's 70th birthday, this conference brought together leading international and Australian nonlinear partial differential equation research experts. As well as reporting and discussing recent developments, delegates exchanged ideas and explored opportunities for collaboration.

This conference focused on new developments in several themes of nonlinear partial differential equations (PDEs) and their applications, especially those on which Professor Dancer has made significant contributions. The program included nonlinear elliptic and parabolic equations, the calculus of variations, and applications in physics, biology and geometry.

Presenters included a number of international leaders on nonlinear PDEs, including Professors Neil Trudinger (Australia), Xu-Jia Wang (Australia), Francois Hamel (France), Angela Pistoia (Italy), Changfeng Gui (USA), and Michel Chipot (Switzerland). Fittingly, many attendees were former postdocs and collaborators of Professor Dancer.

The talks provided a nice overview of the current research status of several important topics in nonlinear PDEs. One highlight was Professor Neil Trudinger's account of the evolution of the old Yamabe problem to some of the current questions in optical transport problems.

The event resulted in the initiation and extension of several collaborations between attendees. Professor Guo's talk on weighted elliptic equations led to a new joint investigation into unsolved problems in fourth order elliptic PDEs with Australian colleagues, while Professor Hamel and Australian colleagues established a new collaboration on some open problems regarding spreading speed in heterogeneous media. In a continuing collaboration, Professor Gui and his Australian colleagues extended their work on travelling wave solutions with curved fronts.

In addition, several overseas participants stayed beyond the conference to collaborate with their Australian colleagues, and gave talks in Sydney.

Well attended by early career researchers, the atmosphere during the conference was stimulating yet relaxed.

This providing an excellent chance for young researchers to discuss research with leading figures in their field.

A women's luncheon held during the conference, featuring talks by UNE's Vice Chancellor Professor Annabelle Duncan and Professor Angela Pistoia, from the University of Rome, attracted both conference attendees and local academics.

"It was a great pleasure ... to attend the conference with all the other colleagues. It was a great success, congratulations!"

Prof. François Hamel,
University of Aix-Marseille, France

WORKSHOP PARTICIPATION

- 47** Attendees
- 6** Postgraduate students
- 8** Early career researchers
- 8** Women
- 17** International participants

Organisers

Assoc. Prof. Florica Cirstea,
The University of Sydney
Assoc. Prof. Daniel Daners,
The University of Sydney (Co-Chair)
Prof. Yihong Du, University of New England (Co-Chair)
Dr Daniel Hauer, The University of Sydney
Prof. Aron Murphy, University of New England
Assoc. Prof. Shusen Yan, University of New England
Kate Daly, University of New England (Admin)

Special Presenters

Prof. Dr Michel Chipot, University of Zürich, Switzerland
Research interests: applied mathematics, variational inequalities, nonlinear problems, elliptic equations and systems, parabolic equations, calculus of variations, applications, numerical analysis
Assoc. Prof. Elaine Crooks, Swansea University, UK
Research interests: nonlinear PDEs, singular limits of elliptic and parabolic systems, reaction-diffusion-convection systems and travelling waves,

applications of PDE to biology, geometric methods for image processing

Dr Jérôme Droniou, Monash University
Research interests: numerical schemes for diffusion equations, scalar conservation laws, elliptic and parabolic equations

Assoc. Prof. Massimo Grossi, Sapienza University of Rome, Italy

Research interests: nonlinear PDEs

Prof. Changfeng Gui, University of Texas at San Antonio, USA

Research interests: nonlinear PDEs and applied mathematics, image analysis and processing
Prof. Zongming Guo, Henan Normal University, China
 Research interests: nonlinear PDEs
Prof. François Hamel, University of Aix-Marseille, France
 Research interests: elliptic and parabolic non-linear PDEs, travelling waves, propagation phenomena
Prof. Xijun Hu, Shandong University, China
 Research interests: geometry and topology, analysis, applied mathematics
Dr Jiakun Liu, University of Wollongong
 Research interests: nonlinear elliptic and parabolic PDEs and applications in geometry and optimal transportation
Prof. Yuan Lou, Renmin University of China/Ohio State University, USA
 Research interests: PDEs, applications in population biology, nonlinear elliptic and parabolic systems
Prof. Julián López Gómez, Universidad Complutense de Madrid, Spain
 Research interests: PDEs and reaction-diffusion systems, spatial ecology and population dynamics, spectral theory on Banach spaces, topological degree and abstract nonlinear analysis
Assoc. Prof. James McCoy, University of Wollongong
 Research interests: differential geometry, PDEs,

functional analysis and topology
Prof. Angela Pistoia, Sapienza University of Rome, Italy
 Research interests: nonlinear PDEs, variational and topological methods, conformal geometry
Prof. Frédéric Robert, Université de Lorraine, France
 Research interests: nonlinear analysis on manifolds, elliptic equations of high order
Prof. Dr Guido Sweets, University of Cologne, Germany
 Research interests: analysis, applied mathematics, PDEs
Dr Melissa Tacy, University of Otago, NZ
 Research interests: microlocal analysis, semiclassical analysis and harmonic analysis
Prof. Tom ter Elst, University of Auckland, NZ
 Research interests: harmonic analysis, operator theory, geometric analysis, subelliptic and degenerate operators, PDEs
Prof. Neil Trudinger, The Australian National University and University of Wollongong
 Research interests: applied and nonlinear analysis
Dr Leo Tzou, The University of Sydney
 Research interests: nonlinear analysis
Assist. Prof. Jérôme Vétois, McGill University, Canada
 Research interests: nonlinear PDEs, nonlinear

analysis on manifolds
Dr Kelei Wang, Wuhan University, China
 Research interests: nonlinear PDEs, analysis, mathematical analysis, differential geometry, system modelling
Prof. Xu-Jia Wang, The Australian National University
 Research interests: elliptic and parabolic PDEs and applications in geometry and physics
Prof. Zhitao Zhang, Chinese Academy of Sciences, China
 Research interests: applied mathematics, analysis, algebra,

MathSciNet Classification

35J, 35K, 37B, 47A, 47H, 47J, 58E, 92D

Web Links

sydney.edu.au/science/math/su/PDESeminar/nlpde2016

Other Sponsors

University of New England, The University of Sydney, AustMS

Key Contact

Prof. Yihong Du, University of New England, ydu@une.edu.au

1.12 INTERACTIONS BETWEEN TOPOLOGICAL RECURSION, MODULARITY, QUANTUM INVARIANTS AND LOW-DIMENSIONAL TOPOLOGY

MATRIX, Creswick, 28 November – 23 December 2016

This event provided a powerful platform to foster international collaboration in the areas of mathematical physics, topological recursion and low-dimensional topology. Recent advances and connections between these fields were explored in a stimulating environment that led to several new collaborations and published results.

Recent quantum invariants in low-dimensional topology have arisen out of mathematical physics at the same time that the field of topological recursion is making rapid advances. This international conference was an ideal conclusion to the four-week MATRIX program investigating interactions between topological recursion, modularity, quantum invariants and low-dimensional topology. Connections between these fields are apparent from the physics perspective and research is now under way to make rigorous sense of these relationships.

A majority of the 33 talks were delivered by international visitors, with the program providing an excellent mix of expertise and shared interest in applications to different mathematical areas including algebraic geometry, conformal field theory, knot theory, representation theory, quantum invariants and combinatorics.

Highlights included headline talks by Professor Jørgen Andersen on the Verlinde formula for Higgs bundles, Professor Feng Luo on discrete uniformisation for polyhedral surfaces and its convergence, Associate Professor Rinat Kashaev on Pachner moves and Hopf algebras, Associate Professor Scott Morrison on Modular data for Drinfeld doubles, and two lectures by Professor Hyam Rubinstein and Associate Professor Craig Hodgson on counting genus 2 surfaces in 3-manifolds. Talks by Dr Gaetan Borot on initial conditions for topological recursion and Professor Tudor Dimofte on counting vortices in the 3d Index were also well received along with Professor George

Shabat's talk on counting Belyi pairs over finite fields, Dr Leonid Chekhov's talk on abstract topological recursion and Givental decomposition, and Assistant Professor Piotr Sulkowski's lectures on knots and BPS states and super-quantum curves.

There were many other sessions exploring connections between mathematical physics and low-dimensional topology, particularly regarding quantum invariants of knots, as well as computational and algorithmic issues. It was agreed by all participants that the environment at Creswick was intellectual and stimulating and led to new collaborations.

Significantly, the conference and MATRIX short courses have resulted in several research papers and course notes published in the 2016 MATRIX annals (matrix-inst.org.au/2016-matrix-annals/).

Note: AMSI sponsored the 28 November – 23 December workshop held during the second half of this four-week MATRIX event

“Several years ago, my collaborators and I proposed a new quantum invariant of 3-manifolds called the “3D Index.” Its definition was inspired by the physics of supersymmetric quantum field theories. Several of the participants at the MATRIX workshop (Craig Hodgson, Norman Do, Neil Hoffman, Hyam Rubinstein) have since studied this invariant, establishing its mathematical properties and discovering deep connections with 3-dimensional hyperbolic geometry and the theory of normal/minimal surfaces in 3-manifolds.

I had very productive interactions with these participants, joining our perspectives on the 3D Index to further develop its properties. I also continued discussions about number theory and physics with a long-time collaborator of mine, Roland van der Veen. Finally, it was a pleasure to meet several new senior mathematicians and grad students and to learn about their research; conversations with Henry Segerman, Andrew Cricker, and Rafael Siejakowski were particularly enlightening.”

Prof. Tudor Dimofte, University of California, Davis, USA

WORKSHOP PARTICIPATION

79 Attendees
23 Postgraduate students
10 Early career researchers
10 Women
46 International participants

Organisers

Dr Norman Do, Monash University

Assoc. Prof. Craig Hodgson,

The University of Melbourne

Asst. Prof. Neil Hoffman,

Oklahoma State University, USA

Prof. Motohico Mulase,

University of California, Davis, USA

Prof. Paul Norbury, The University of Melbourne

Special Presenters

Prof. Jørgen Andersen, Aarhus University, Denmark

Research interests: knot theory, topology, algebraic topology, differential geometry, mathematical physics, moduli spaces

Dr Gaëtan Borot, Max Planck Institute for

Mathematics, Germany

Research interests: mathematical physics, geometry and physics, combinatorics of surfaces, random matrix theory, statistical physics, integrable systems, quantum topology, moduli spaces, topological recursion

Dr Leonid Chekhov, Steklov Mathematical Institute, Russia

Research interests: theoretical physics, geometry and topology, mathematical physics, combinatorics, topology, quantum field theory, differential geometry

Prof. Tudor Dimofte, University of California, Davis, USA

Research interests: quantum fields and strings, algebraic geometry, knot theory

Assoc. Prof. Rinat Kashaev,

University of Geneva, Switzerland

Research interests: knot theory, hyperbolic geometry, mathematical physics

Prof. Sergey Matveev, Chelyabinsk State University

and Russian Science Academy, Russia

Research interests: geometry and topology

Assoc. Prof. Todor Milanov,

University of Tokyo, Japan

Research interests: symplectic topology, complex geometry, representations of infinite-dimensional Lie algebras

Prof. Hyam Rubinstein, The University of Melbourne

Research interests: low dimensional topology, minimal surfaces (combinatorial and smooth), differential geometry, shortest network design

Asst. Prof. Piotr Sulkowski, University of Warsaw,

Poland and Caltech, USA

Research interests: mathematical physics, string theory, gauge theory

Asst. Prof. Roland van der Veen,

Leiden University, Netherlands

Research interests: (low-dimensional) geometry/topology, representation theory, mathematical physics

MathSciNet Classification

57R56, 57M27, 58D29

Web Links

matrix-inst.org.au/events/interactions-between-topological-recursion-modularity-quantum-invariants-and-low-dimensional-topology/

Other Sponsors

NSF

Key Contact

Prof. Paul Norbury, The University of Melbourne, norbury@unimelb.edu.au

INTERACTIONS BETWEEN TOPOLOGICAL RECURSION, MODULARITY, QUANTUM INVARIANTS AND LOW-DIMENSIONAL TOPOLOGY

By Professor Paul Norbury

THE INTERPLAY BETWEEN PHYSICS AND GEOMETRY IS FUNDAMENTAL TO OUR UNDERSTANDING OF REAL world phenomena such as the Global Positioning System which uses Einstein's geometric theory of general relativity. Turning this around, physics uncovers beautiful and unexpected structures underlying highly abstract ideas from pure mathematics and geometry.

Quantum field theory, which is in some ways complementary to Einstein's theory of relativity, is required in solid state physics to produce semi-conductors used in the architecture of computers. It is also applied to geometry to uncover deep structures.

Some geometric structures are extremely complicated, much more so than say, a square. Fortuitously, physically observable quantities in a physical theory can sometimes be adapted to produce *measurable quantities* out of geometric structures from pure mathematics. These measurable quantities give a partial description of complicated geometric structures. Quantum field theory is an excellent source of so-called quantum invariants of geometric structures.

In quantum field theory, physically observable quantities are computed as statistical averages using a path integral. While powerful, the path integral is usually not defined in a mathematically precise manner. To make sense of it, there are a number of approaches, including perturbative methods or replacing the path integral with integration over a finite-dimensional space known as a moduli space. The perturbative approach appears in many forms in mathematics; for example, it can produce invariants of three-dimensional geometric structures that take the form of q -series, such as

$$1 - q - 2q^2 - 2q^3 - 2q^4 + q^6 + 5q^7 + \dots$$

which is a quantum invariant of the tetrahedron—a basic building block of three-dimensional spaces. These geometric structures inherit deep properties from physics, and conversely supply ideal testing grounds for new ideas in the field.

Integration over finite-dimensional moduli spaces introduces extremely rich geometric structure in mathematics and leads to the study of deep and longstanding mathematical problems in many fields, such as algebraic geometry. Integration over spaces of $N \times N$ matrices in the limit $N \rightarrow \infty$, known as matrix models, are basic examples of path integrals in quantum field theory. The integrals cannot be calculated exactly, so instead one uses a perturbative expansion, i.e. a formal Taylor series, which is organised using combinatorics and graphs. The graphs naturally fatten to surfaces. This appearance of surfaces beginning from a quantum field theory viewpoint has huge significance! From it an important alternative view emerges: the idea of strings moving through space and tracing out surfaces. This leads to the study of moduli spaces of surfaces mapping to target varieties and in particular the theory of Gromov-Witten invariants.

A recent tool arising out of matrix models to study moduli problems is *topological recursion*, which is a universal recursive structure applicable to a wide range of problems in geometry and mathematical physics. It is fast becoming a fundamental tool in enumerative geometry as well as mathematical physics and is the basis of an actively developing field. It is related naturally to quantum invariants such as the quantum curve, and to non-perturbative invariants, with applications to geometry. Topological recursion produces a vast set of examples of mirror symmetry, which is currently one of the most important and influential problems at the confluence of mathematics and physics.

Topological recursion takes as input a dimension-one variety C inside a symplectic surface, known as a *spectral curve*, and produces a collection of differentials $\omega_n^g(p_1, \dots, p_n)$ on C , for integers $g \geq 0$, $n \geq 1$. Pictorially, ω_n^g is defined recursively from $\omega_{n'}^{g'}$ for $2g' - 2 + n' < 2g - 2 + n$ by:

$$\omega_n^g = \omega_{n+1}^{g-1} + \sum \omega_{n_1+1}^{g_1} \omega_{n_2+1}^{g_2}$$

Heuristically $\omega_n^{(g)}(p_1, p_2, \dots, p_n) = \left\langle \text{Tr} \frac{1}{x(p_1) - A} \dots \text{Tr} \frac{1}{x(p_n) - A} \right\rangle_c$ is the expected value of a resolvent in a matrix model.

Closely related to topological recursion is an old idea, currently seeing renewed interest, of replacing commuting objects, such as functions on a surface with non-commuting functions, in analogy with momentum and position operators in quantum mechanics. This leads to the idea of a quantum curve. A quantum curve of a dimension-one variety $C = \{(x, y) \in \mathbb{C}^2\} \mid P(x, y) = 0\}$ is a Schrödinger-type linear differential equation

$$\hat{P}(\hat{x}, \hat{y}) \psi(p, \hbar) = 0, \quad [\hat{x}, \hat{y}] = \hbar$$

where $p \in C$, \hbar is a formal parameter, and $\hat{P}(\hat{x}, \hat{y})$ is a differential operator-valued non-commutative quantisation of C with $x = x \cdot$ and $y = \hbar \frac{d}{dx}$, e.g. $\hbar^2 \frac{d^2}{dx^2} - x$ is a quantisation of the variety $y^2 = x$.

The conference featured many lectures reporting on connections between mathematical physics and low-dimensional topology—including lectures by Hyam Rubinstein and Craig Hodgson on counting genus 2 surfaces in 3-manifolds and Tudor Dimofte on counting vortices in the 3d index—quantum invariants of knots including computational and algorithmic issues by Ben Burton, and recent results in topological recursion—including lectures by Jørgen Andersen on the Verlinde formula for Higgs bundles, Gaëtan Borot and Leonid Chekhov on abstract topological recursion following recent ideas of Kontsevich and Soibelman.

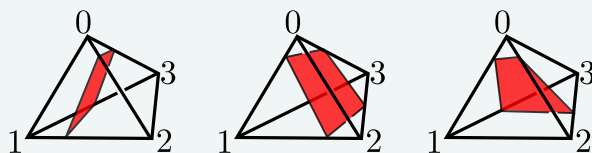
The (still unproven) Volume Conjecture of Kashaev, relates the asymptotic behaviour of the coloured Jones polynomials of a knot to the hyperbolic volume of its complement. Higher order terms in the asymptotic expansion of the coloured Jones polynomials are conjectured in work of Dijkgraaf, Fuji and Manabe to be related via topological recursion to the A-polynomial of a knot, another classical invariant arising from hyperbolic geometry. The work of Futer, Kalfagianni and Purcell gives other important relationships between the geometry of knot complements and the colored Jones polynomials, including partial results toward the Jones slope conjecture of Garoufalidis. The AJ-Conjecture of Garoufalidis suggest other important connections between the quantum and geometric approaches, relating the quantum A-polynomials that arise from the recurrence relations for the coloured Jones polynomials to the classical A-polynomial.

This is an exciting area of geometry full of conjectures and deep relationships with physics. Over the next ten years we would expect to see many of these conjectures resolved and a deeper picture emerging where geometry and physics are fundamentally connected and mutually beneficial.

Leading researchers

Professor Tudor Dimofte

Tudor Dimofte received his PhD at Caltech then spent five years at the Institute for Advanced Study in Princeton before taking up a position at UC Davis. In 2011, together with the physicists Gaiotto and Gukov, Dimofte introduced a powerful new invariant of cusped 3-manifolds called the *3D index*. This is a collection of q -series, defined using the combinatorics of an ideal triangulation, which seems to contain a great deal of information about the geometry and topology of the manifold. Conjecturally, there are many connections between the 3D index, hyperbolic geometry, incompressible surfaces and the quantum A-polynomials, but little is proved so far. Recent work of Australians and collaborators—Garoufalidis, Hodgson, Hoffman, Rubinstein and Segerman—show rigorously that the 3D index of a triangulation gives a topological invariant of hyperbolic 3-manifolds, and gives a generating function for counting discrete surfaces, known as normal surfaces, in discrete models of hyperbolic 3-manifolds, as in the diagram.



Associate Professor Rinat Kashaev

Rinat Kashaev received his PhD at IHEP in Russia, and now has a position at the University of Geneva and the Steklov Institute in St Petersburg. Kashaev is one of the world leaders in quantum and state sum invariants. He has proven fundamental results relating the quantum dilogarithm to geometry. In 1997 Kashaev related Chern-Simons gauge theory to hyperbolic geometry to produce his famous volume conjecture

$$\frac{1}{\pi} \lim_{n \rightarrow \infty} \frac{|\log J_n(K; q = e^{2\pi i/n})|}{n} = \text{Vol}(S^3 \setminus K)$$

relating the hyperbolic volume of the complement of a knot $K \subset S^3$ to its coloured Jones polynomial $J_n(K; q)$. Kashaev is also one of the pioneers developing *quantum Teichmüller theory* which promotes combinatorial structure due to Robert Penner, fundamental to the description of geometric surfaces, to quantum non-commutative structure.

1.13 HYPERGEOMETRIC MOTIVES AND CALABI-YAU DIFFERENTIAL EQUATIONS

MATRIX, Creswick, 8–28 January 2017

Over three weeks, international and Australian arithmetic algebraic geometry experts expanded their knowledge while seeding collaborative investigation of current problems in the field.

One of the key goals of arithmetic algebraic geometry is to understand L -functions of algebraic varieties including in the context of computing and relationship to other objects. A product of the influential Langlands program, it is expected that these L -functions will coincide with L -functions arising from automorphic forms, consequently satisfying functional equations and analytic continuation. Recent work is targeted at investigating and explicitly computing L -functions of the so-called hypergeometric motives. These families of motives are characterised by the fact that their periods are given by generalised hypergeometric functions.

L -functions form an important class of special functions, playing a crucial role in parts of physics such as conformal field theory and quantum mechanics. The L -functions of the hypergeometric motives cover a wide range (if not all) of known L -functions. The hypergeometric data allow us to efficiently compute parameters — degrees, Hodge numbers etc. — associated with the (sometimes unknown) algebraic structures. These data also provide us with a way to test

conjectures on special values and the distribution of zeroes, while simultaneously verifying numerically standard conjectures on analytic continuation and functional equations for these L -functions. Many algorithms for computing the hypergeometric motives are now implemented in mathematical software.

Along with development of new methods to establish modularity of L -functions of Calabi-Yau manifolds, this MATRIX event focused on analysing the integrality phenomenon in mirror symmetry from the arithmetic point of view and various applications of finite hypergeometric functions and Calabi-Yau differential equations. It provided an exceptional opportunity to unite international experts in two related areas of number theory and to expose Australian mathematicians with expertise in neighbouring topics to this exciting field.

The full MATRIX program was divided into one-week blocks, with the first and third week providing seminars and mini-courses on hypergeometric motives and Calabi-Yau differential equations respectively, and the middle week featuring this workshop combining both topics.

Keynote speaker Professor Fernando Rodriguez-Villegas explored p -adic hypergeometric sums in his opening section. He also gave a lecture later in the workshop detailing his collaborative work

with Professor David Roberts and Dr Mark Watkins on motivic supercongruences. Other keynote lectures included Associate Professor Robert Osburn's talk dedicated to modular forms and cellular integrals and Professor Duco van Straten's lecture on Calabi-Yau equations and L -functions. These talks received enthusiastic responses from participants and led to much discussion over the ensuing days.

The program included several lectures on open problems in Dwork cohomology. With ample time for networking and collaboration built into the schedule, this led to remarkable progress on solving these problems. Preprints and preliminary reports on these achievements are already available in the 2017 MATRIX proceedings published by Springer and accessible online through the MATRIX website (matrix-inst.org.au/book-series/).

Note: AMSI sponsored the 16–20 January workshop held during the second week of this three-week MATRIX event

WORKSHOP PARTICIPATION

- 25 Attendees**
- 3 Early career researchers**
- 6 Women**
- 19 International participants**



Organisers

Prof. Ling Long, Louisiana State University, USA
Dr Masha Vlasenko, Institute of Mathematics of the Polish Academy of Sciences, Poland
Prof. Wadim Zudilin, The University of Newcastle

Special Presenters

Dr Piotr Achinger, Institut des Hautes Études Scientifiques, Université Paris-Saclay, France
 Research interests: algebraic geometry in characteristic p , Frobenius splittings, étale fundamental group, deformation theory, Calabi-Yau varieties, logarithmic geometry
Prof. Frits Beukers, Utrecht University, Netherlands
 Research interests: Diophantine equations, hypergeometric functions, number theory
Prof. David Broadhurst, Open University, UK
 Research interests: theoretical high energy physics, evaluations of multi-loop Feynman diagrams by computer algebra and high-precision numerical techniques, connections between knot theory, number theory and field theory
Dr Eric Delaygue, Institut Camille Jordan, Lyon, France
 Research interests: number theory, combinatorics
Assoc. Prof. Sharon Frechette, College of the Holy Cross, USA
 Research interests: number theory, modular forms
Assoc. Prof. Robert Osburn, University College Dublin, Ireland
 Research interests: number theory, special functions, modular forms, combinatorics, algebraic K -theory

Prof. Ravi Ramakrishna, Cornell University, USA
 Research interests: algebraic number theory
Prof. David Roberts, University of Minnesota, USA
 Research interests: algebraic geometry, game theory, group theory, number theory
Prof. Fernando Rodriguez Villegas, ICTP, Trieste
 Research interests: number theory, representation theory, combinatorics, symmetric functions
Assoc. Prof. Adriana Salerno, Bates College, USA
 Research interests: number theory, arithmetic geometry
Prof. Abdellah Sebbar, University of Ottawa, Canada
 Research interests: number theory, algebraic geometry, moonshine, quantum groups
Assoc. Prof. Holly Swisher, Oregon State University, USA
 Research interests: number theory, combinatorics, modular forms, integer partitions, hypergeometric series, supercongruences
Asst. Prof. Fang-Ting Tu, Louisiana State University, USA
 Research interests: number theory
Prof. Duco van Straten, Johannes Gutenberg University, Mainz, Germany
 Research interests: mirror symmetry, algebraic geometry, Picard-Fuchs differential equations
Dr Masha Vlasenko, Institute of Mathematics of the Polish Academy of Sciences, Warsaw, Poland
 Research interests: number theory, particularly in automorphic forms, L -functions, periods and p -adic cohomology

Assoc. Prof. John Voight, Dartmouth College, USA
 Research interests: arithmetic algebraic geometry, number theory
Dr Mark Watkins, The University of Sydney
 Research interests: computational and analytic number theory
Asst. Prof. James Wan, Singapore University of Technology and Design, Singapore
 Research interests: applied mathematics, computing
Prof. Yi-Fan Yang, National Chiao Tung University, Taiwan
 Research interests: number theory

MathSciNet Classification

11 Number Theory, 14 Algebraic Geometry, 33 Special Functions

Web Links

matrix-inst.org.au/events/hypergeometric-motives-and-calabi-yau-differential-equations

Other Sponsors

Foundation Compositio Mathematica, Number Theory Foundation, AustMS

Key Contact

Prof. Wadim Zudilin, The University of Newcastle, wadim.zudilin@newcastle.edu.au

1.14 INTERNATIONAL CONFERENCE IN PDE, GEOMETRIC ANALYSIS AND FUNCTIONAL INEQUALITIES

The University of Sydney, 7–10 March 2017

Bringing together experts in three approaches to non-linear analysis, this conference identified new field connections and opportunities for collaboration.

The International Conference in PDE, Geometric Analysis and Functional Inequalities aimed to demonstrate and strengthen connections between partial differential equations, geometry and functional inequalities. Bridges between these fields have classically been forged through the calculus of variations. In recent times, such connections have yielded new exciting results for example, the existence and classification of extremals in geometric variational problems and their stability, bringing into focus the benefit of further exploration.

With over forty participants, the spread of experience was excellent. Notable attendees included Professors Hiroshi Matano (University of Tokyo), Takayoshi Ogawa (Tohoku University), Andrea Cianchi (University of Florence) and Neil Trudinger (The Australian National University). These world leaders were joined by a number of established mid career and rising early career researchers who benefited greatly from this opportunity. During the four-day conference, talks were intertwined from all three focus areas, identifying avenues for new connections and collaborative work.

Kicking off the program, Professors Ogawa and Cianchi explored fundamental new results on PDE covering both the role of dimensionality in global analysis of drift-diffusion systems (Ogawa), and L^2 regularity theory for nonlinear elliptic equations

(Cianchi). Professor Norman Dancer led another notable session, speaking on limits of systems with a large parameter, and Japanese early career researcher Professor Norisuke Ioku, described fascinating new work on non-existence for the classical nonlinear heat equation. Associate Professor Nelia Charalambous and Dr Serena DiPierro respectively presented new results in the spectral theory of the Laplacian on forms and a fractional PDE model for dislocation in crystals.

Professor Neil Trudinger received a standing ovation for his session on a novel direction for fully nonlinear PDE, the generated Jacobian equations. During the conference we also heard of several new results about inequalities named after participants, in particular Professor Futoshi Takahashi spoke about the Trudinger-Moser

inequalities and Professor Carlo Nitsch discussed the Bossel-Daners inequality. There was a charged mathematical atmosphere throughout the conference, sparking fruitful and provocative discussions in tea breaks and during social activities.

The conference had two secondary aims: to deepen and invigorate the Japanese-Australian partnership in mathematics, especially in nonlinear analysis, and to promote gender equity in the mathematical sciences. On both counts the conference was a resounding success. New collaborative ties have been built, and the fine history of Australian-Japanese collaboration and support in mathematics is set to continue. We expect that this will in turn serve to produce excellent outcomes.

The conference made several inroads on gender equity. By design, we promoted equity at all levels in participants of the conference, from students through to

our most senior presenters. Through the support of Professor Nalini Joshi's ARC Georgina Sweet Laureate Fellowship, we were able to invite two influential and inspiring female mid career researchers, Associate Professors Nelia Charalambous and Julie Rowlett. Not only this, but our support from The University of Sydney made it possible to offer a Travel Award. This was given by competitive process to Robin Neumayer, a promising PhD candidate. The conference and this award enabled Neumayer to present her work to leaders in the field, making connections with them and encouraging further fruitful interaction.

We additionally held a Diversity Dinner on the evening of the first day, with Associate Professor Julie Clutterbuck (Future Fellow, Monash University) as our MC. The panel for our evening included Professors Neil Trudinger, Yihong Du,

Associate Professors Nelia Charalambous, Julie Rowlett, Florica Cirstea, as well as Dr Serena DiPierro, and Robin Neumayer. We held extensive discussions on issues around diversity and inclusion in mathematics, especially on structural changes. Feedback and engagement from the evening was uniformly positive. We hope that there are more such events at future international conferences.

WORKSHOP PARTICIPATION

- 40** Attendees
- 8** Postgraduate students
- 2** Early career researchers
- 12** Women
- 16** International participants

“This has been a wonderful conference! Excellent speakers, the talks covered a wide range of topics which was sufficiently broad to provide variety, yet sufficiently related so that all audience members could understand all talks. ‘Extra-curricular’ activities, the panel discussion and dinner cruise were a great added bonus! Thank you.”

Workshop participant

Organisers

Assoc. Prof. Daniel Daners,

The University of Sydney

Dr Daniel Hauer, The University of Sydney

Dr Glen Wheeler, University of Wollongong

Dr Valentina Wheeler, University of Wollongong

Special Presenters

Assoc. Prof. Nelia Charalambous, University of Cyprus, Cyprus

Research interests: global analysis, PDEs on manifolds, mathematical physics

Prof. Andrea Cianchi, University of Florence, Italy
Research interests: analysis

Assoc. Prof. Florica-Corina Cirstea,

The University of Sydney

Research interests: nonlinear equations, nonlinear analysis

Prof. E. Norman Dancer, The University of Sydney
Research interests: nonlinear analysis, degree theory, Morse theory, Conley index

Dr Serena DiPierro, The University of Melbourne
Research interests: analysis, applied mathematics

Prof. Yihong Du, University of New England
Research interests: nonlinear elliptic and parabolic differential equations, nonlinear functional analysis

Assoc. Prof. Yoshihito Kohsaka, Graduate School of Maritime Sciences, Kobe University, Japan
Research interests: mathematical analysis of nonlinear PDEs, free boundary problems, geometric evolution equations

Prof. Hiroshi Matano, University of Tokyo, Japan
Research interests: qualitative theory of nonlinear equations, structure of singularities, travelling waves, dynamical systems

Tatsuya Miura, The University of Tokyo, Japan
Research interests: mathematical analysis

Robin Neumayer, University of Texas at Austin, USA

Research interests: calculus of variations, elliptic PDEs

Assoc. Prof. Carlo Nitsch, University of Naples Federico II, Italy

Research interests: elliptic PDEs, geometric inequalities, parabolic PDEs

Prof. Takayoshi Ogawa, Tohoku University, Japan
Research interests: nonlinear PDEs, real analysis, functional analysis, applied analysis

Dr Artem Pulemotov, The University of Queensland
Research interests: geometric analysis

Assoc. Prof. Julie Rowlett, Chalmers University and the University of Gothenburg, Sweden
Research interests: geometric analysis, PDEs

Prof. Futoshi Takahashi, Osaka City University and OCAMI, Japan

Research interests: nonlinear PDEs

Prof. Neil Trudinger, The Australian National University and University of Wollongong

Research interests: applied and nonlinear analysis

Prof. Sumio Yamada, Gakushuin University, Japan
Research interests: geometry and topology

MathSciNet Classification

35A, 53C, 39B

Web Links

maths.usyd.edu.au/u/PDESeminar/ga2017

Other Sponsors

AustMS, University of Wollongong, The University of Sydney

Key Contact

Dr Glen Wheeler, University of Wollongong,
glenw@uow.edu.au

1.15 APPLIED PROBABILITY AT THE ROCK

Ayers Rock Resort, NT, 17–21 April 2017

An in-depth exploration of applied probability, this workshop encouraged Australian and international field leaders to share recent discoveries and seed new collaborations. It also provided an opportunity to celebrate prominent Australian applied probabilist Professor Phil Pollett's 60th birthday.

Applied probability deals with the modelling and understanding of randomly-varying systems such as healthcare systems; infectious disease spread; and telecommunication systems and the Internet, all of which are ubiquitous in our communities.

More than 70 Australian and international researchers helped showcase the full breadth of applied probability, including

three major themes of *Networks in Queueing and Telecommunications*, *Stochastic Models in Biology* and *Limits and Approximation*. These themes were chosen to both reflect important areas of research in applied probability and also areas of interest to guest of honour Professor Phil Pollett.

Event highlights included Professor Frank Kelly's (University of Cambridge) keynote lecture on a Markov model of a limit order book: thresholds, recurrence, and trading strategies, and Professor Ruth J. Williams' (University of California, San Diego) talk covering diffusion approximations and reflecting boundaries.

Also notable, Prof. Erik van Doorn (University of Twente) spoke on the strong

ratio limit property of discrete-time Markov chains, and Prof. Andrew Barbour (The University of Melbourne) on his work on convergence to equilibrium in Markov population processes.

The conference was well attended by researchers of all levels, including postgraduate students and early career researchers. Plenty of breaks in the schedule provided ample time for discussions and socialising between delegates.

WORKSHOP PARTICIPATION

- 71** Attendees
- 11** Postgraduate students
- 10** Early career researchers
- 16** Women
- 26** International participants

“For me, one of the most notable aspects of the conference was the breadth and quality of the contributions from younger participants. This attests to the encouragement and mentoring provided in the Applied Probability field, and to the general environment provided through the discipline’s leadership in Australia. Phil can be proud, amongst much else, in this legacy.”

Prof. Frank Kelly, University of Cambridge

Organisers

Assoc. Prof. Joshua Ross, The University of Adelaide (Chair)

Prof. Nigel Bean, The University of Adelaide

Dr Giang Nguyen, The University of Adelaide

Dr Leonardo Rojas-Nandayapa, University of Liverpool, UK

Dr David Sirl, University of Nottingham, UK

Special Presenters

Prof. Andrew Barbour, The University of Melbourne/ University of Zürich, Australia, Switzerland
Research interests: applied probability, biomathematics and statistics

Prof. Erik van Doorn, University of Twente,

Netherlands

Research interests: applied mathematics, probability theory, analysis

Prof. Frank Kelly, University of Cambridge, UK

Research interests: random processes, networks and optimisation

Prof. Ruth Williams, University of California, San Diego, USA

Research interests: probability theory, stochastic processes and their applications

MathSciNet Classification

60J20, 60J28, 60K20

Web Links

maths.adelaide.edu.au/APatR

Other Sponsors

The University of Queensland, The University of Adelaide, ACEMS, AustMS

Key Contact

Assoc. Prof. Joshua Ross, The University of Adelaide, joshua.ross@adelaide.edu.au

APPLIED PROBABILITY AT THE ROCK

By Professor Joshua Ross, Dr Andrew Black, Dr Giang Nguyen, and Professor Nigel Bean

APPLIED PROBABILITY IS THE FIELD OF MATHEMATICS THAT seeks to understand processes in which chance plays a key role. Its origins can be traced to the study of *games of chance* in the 15th century, but it was the 18th century that witnessed the first applications to scientific problems. In the past century, it has made significant contributions to many areas, such as the provisioning and operation of telecommunication networks, the modelling and control of epidemics, the pricing of derivatives in finance, and throughout optimisation and Bayesian statistics.

The scientific side of this workshop focused on mainstream applied probability. We heard from world-leading experts on applications to financial markets and the analysis of trading strategies, improved approximation methods for stochastic systems with reflecting boundaries, traffic modelling, Bitcoin, epidemics in structured populations, and efficient rare-event estimation, amongst many other topics. The vibrant interactions amongst researchers resulted in new research ideas and collaborations. Another key success of the workshop was in acknowledging the contributions of Professor Phil Pollett, on the occasion of his 60th birthday. This was not only in recognition of his many scientific contributions, including to the topics of quasi-stationary distributions and asymptotic approximations, but his tremendous skills as a mentor for young applied probabilists in Australia.

New applications in applied probability in this decade have included healthcare systems, vehicle sharing, machine learning, and energy, to name a few. Recent breakthroughs include multilevel Monte Carlo methods, which allow for the estimation of a large class of expectations at an optimal convergence rate.

The recent trend in applied probability is the development of closer ties with data and algorithms/computation, in particular for statistical applications such as Markov Chain Monte Carlo. Further, these links between statistics and applied probability are also a consequence of the complexity of the processes being analysed. For example, in the more traditional industrial applications of queueing theory, it was obvious how many servers there were, and it was easy to fit distributions to the clearly defined service and arrival processes. Recent moves into healthcare, for example, challenge these basic assumptions. In a hospital, it is clear that the patients are the customers. But, are the beds, the doctors, the nurses or the treatments the servers? How many servers are there, and how do they interact? Together, these mean that novel and sophisticated statistical techniques are required.

With applied probability informing and exploiting developments in statistics and computation, and also with strong links to the burgeoning field of machine learning, this trend is likely to continue. Also, the rapid advances in biology, in particular in the field of genetics, suggests that more biological applications will arise in the future. See *Stochastic Models of Major Transitions* for a recent biological case study.

Professor Phil Pollett

As a Professor of Mathematics at The University of Queensland and a Chief Investigator at the ARC Centre of Excellence for Mathematical and Statistical Frontiers, Phil Pollett is a leader in the field of applied probability in Australia.

Phil holds an honours degree in applied mathematics from the University of Adelaide, and a PhD degree in applied probability from the University of Cambridge, where he was a student under Professor Frank Kelly, FRS, CBE. Following positions at The University of Adelaide, Murdoch University and the University of Wales College of Cardiff, he joined The University of Queensland as a Senior Lecturer in 1987, and became a full Professor there in 2004.

His research is recognized internationally for significant contributions to Markov process theory, and mathematical modelling of complex systems in population biology, ecology, chemical kinetics and telecommunications. This research has been supported by twelve ARC Discovery/Linkage grants. In 1993 he was awarded the Moran Medal by the Australian Academy of Science for distinguished research in applied probability.

Phil conceived of and developed the Probability Web, recognized as the main web resource for probabilists throughout the world, and one of the first academic websites. He has published more than 150 journal articles and technical reports, and has guided the development of many honours students, postgraduate students and postdoctoral fellows through supervision and collaboration.



"I was quite taken aback by the apparent influence I have had on people. I didn't quite realise it until I heard the words that were said about me and what an impact I have made. Since the conference I've been reflecting quite a lot on that."

Prof. Phil Pollett, The University of Queensland

CASE STUDY: STOCHASTIC MODELS OF MAJOR TRANSITIONS

Applied probability and stochastic modelling has a long history of applications in ecology and evolution. Indeed, Darwinian natural selection can only be understood properly as a process driven by randomness.

One current application of stochastic modelling is to understand the evolution of early multicellular entities from unicellular ancestors. This is known as a *major transition*, a process that leads to the creation of a new level of biological organisation. The fundamental problem is to understand how the earliest groups of cells came to possess the properties needed for them to take part in the process of Darwinian evolution by natural selection. Unlike in more standard evolutionary models, we cannot just assume that the groups already have these properties, as this would be invoking the very things we need to explain.

One particular model assumes the environment plays a key role in starting this process. In effect, a very particular ecological environment can lead to groups forming with Darwinian properties. For example, the environment might be divided into patches, and individual cells reproduce and die within a patch, while regular dispersal events create new generations of patches. From a modelling perspective, this is a difficult problem because it is a multi-level process, with three corresponding distinct time-scales: at the cell level, the patch/group level, and finally the level of the population of patches. The evolutionary dynamics that we wish to study happen over the longest time-scale, or many generations of patches. We can exploit separation in time-scales between individual cell growth and mutation events to derive an approximation for the within-patch dynamics that allows us to make some progress.

We employ a piece-wise deterministic approximation; this means that the time of mutation events is stochastic, but the growth dynamics within the patch are deterministic. This allows us to model the process of generating mutants as a non-homogeneous Poisson process (the rate depends on time, rather than being constant). This model can be solved via a set of ordinary differential equations, which is much more efficient than estimating the full stochastic dynamics via simulation. The figure below shows a sample genealogy that can be computed with this model. Because the model is mechanistic we can track both the cell and patch genealogies and track how the fitness of both evolve with time.

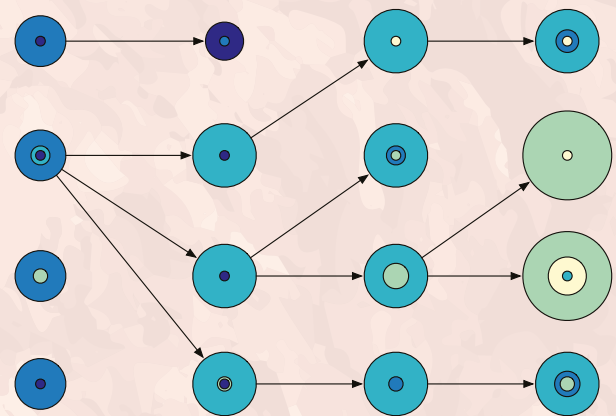


Figure 1 shows part of a genealogy that results from this process. The areas of the circles represent the proportion of cells of different types and lighter colours indicate slower growth rates.

KEYNOTE SPEAKERS

Professor Frank Kelly

Frank Kelly is Professor of the Mathematics of Systems at the University of Cambridge. Elected a Fellow of the Royal Society in 1989, and a Foreign Member of the National Academy of Engineering in 2012, he was awarded a CBE for services to mathematical sciences in 2013.

His main research interests are in random processes, networks and optimization. He is especially interested in applications to the design and control of networks, and to the understanding of self-regulation in large-scale systems.

Professor Andrew Barbour

Andrew Barbour is a Professor of Mathematics at the University of Zurich's Institute for Mathematics, and holds an Honorary Professorship at The University of Melbourne. He is internationally renowned for his contributions to applied probability, in particular in asymptotic approximations, approximation by Stein's method, combinatorial probability, and applications in mathematical biology, in particular epidemiology and ecology.

Professor Ruth Williams

Ruth Williams holds the Charles Lee Powell Chair in Mathematics at the University of California, San Diego. An inaugural Fellow of the American Mathematical Society, she has received many honours over the course of her career. Most recently, in 2016, Williams was awarded the John von Neumann Theory Prize by the Institute for Operations Research and the Management Sciences, jointly with Martin I. Reiman.

Her current research includes the study of stochastic models of complex networks, for example, those arising in Internet congestion control and systems biology.

Professor Erik van Doorn

Erik van Doorn, a Professor at the University of Twente in the Netherlands, has made significant contributions in stochastic processes. He is world-renowned for his work on quasi-stationary distributions and birth-death processes, often involving orthogonal polynomials.

1.16 CHINA-AUSTRALIA JOINT CONFERENCE ON PDE AND RELATED TOPICS

Mission Beach Resort, Qld, 1–6 May, 2017

This conference drew some of the top researchers in this field, building on Australia's strong record of productive collaboration with China in the area of partial differential equations. A chance to explore recent discovery, the conference furthered this partnership and enhanced this powerful relationship.

A central and highly applicable field of modern mathematical analysis, partial differential equations (PDEs) appear naturally in many applications from physics to finance. Possessing a deep and highly developed underlying mathematical theory, they play an important role in driving the development of many related areas of analysis. While not a new area of mathematics, the subject has recently seen exciting new developments, including applications to fundamental problems such as optimal transport, new interpretations and extensions to very irregular domains (metric measure spaces and Alexandrov spaces, or even fractals), fascinating new directions involving non-locally defined equations, and far-reaching applications in geometric and topological contexts (most obviously the success of the Ricci flow in proving the Poincaré conjecture and Thurston's geometrisation conjecture).

Interactions between Australian and Chinese researchers in the field have been deepening since the 1980s. Most recently, joint research efforts have produced substantial advances in the theory of optimal transport (such as the Ma-Trudinger-Wang results on the regularity of the optimal transport map), semi-linear equations with critical exponents and multiple solutions (exemplified by the

extensive collaborations involving Professor Norman Dancer, Dr Shusen Yan, Professor Daomin Cao, Professor Juncheng Wei and others), geometric PDE problems (such as the proof by Professor Ben Andrews and Professor Haizhong Li of the Pinkall-Sterling conjecture). These collaborations have helped to raise the profile of this area of mathematics in both countries, and have resulted in particular in increased recruitment of graduate students, postdocs and researchers at all levels from China to Australia in recent years.

This conference was particularly successful in its intention to build on interactions and collaborations between Australian and Chinese PDE researchers. As well as furthering existing collaboration, the program seeded new discussions between researchers yet to join forces.

The event covered a wide range of PDE theory, particularly on themes of common interest to the Australian and Chinese delegations. These ranged from geometric variational problems (e.g. minimal surfaces, eigenvalues) and geometric flows, through to vortex patches and nonlinear hyperbolic problems (e.g. fluid jets).

Highlights of the conference included the opening talk by Professor Zhouping Xin (CUHK), a world leader in nonlinear hyperbolic PDE. He presented a beautiful talk on the analysis of subsonic jets, a problem which arises naturally in important applications but which is technically very difficult, characterised by the absence of variational structure and the difficulty that it cannot be treated as a perturbation from a solvable background problem. He presented fundamental new results on the solution of this problem.

Professor Xi-Ping Zhu's (Sun Yat-sen University) keynote was also very well received. Known for his work on Ricci flow and related topics, he spoke on recent work on Einstein's field equations of general relativity, in particular a recent breakthrough towards the famous cosmic censorship hypothesis.

Professor Haizhong Li (Tsinghua University) sparked discussion with a presentation on a remarkable new result classifying the possible limiting shapes under flows by a wide range of geometric evolution equations. This cutting edge work has opened up a new direction of research in the field.

Highlights from Australian researchers included Dr Emma Carberry's (The University of Sydney) new results on the structure of moduli space of constant mean curvature tori and planes in space-forms, Monash University's Associate Professor Julie Clutterbuck's counterexample to the widely conjectured concavity result for the first Robin eigenfunction on convex domains and Dr Paul Bryan's (The University of Queensland) new work on ancient solutions and Harnack inequalities for a class of geometric parabolic equations. Several shorter talks were given by early career researchers.

The workshop included plenty of time for discussion and research collaboration, especially in the afternoons. Organisers expect China to host a follow-up conference in two–three years.

WORKSHOP PARTICIPATION

- 45 Attendees**
- 9 Postgraduate students**
- 8 Early career researchers**
- 8 Women**
- 14 International participants**

Organisers

Prof. Ben Andrews, The Australian National University

Prof. Yihong Du, University of New England

Assoc. Prof. Florica Cirstea, The University of Sydney

Prof. Joseph Grotowski, The University of Queensland

Prof. Neil Trudinger, The Australian National University

Special Presenters

Dr Paul Bryan, The University of Queensland

Research interests: geometric analysis, hypersurface flows

Prof. Daomin Cao, University of Chinese Academy of Sciences

Research interests: PDEs, calculus of variations

Dr Emma Carberry, The University of Sydney

Research interests: differential geometry, geometric applications of integrable systems

Prof. Xuan Duong, Macquarie University

Research interests: harmonic analysis, PDEs, singular integrals and function spaces

Assoc. Prof. Xiaoli Han, Tsinghua University

Research interests: PDEs

Dr Min-Chun Hong, The University of Queensland

Research interests: non-linear PDEs, geometric analysis and calculus of variations

Prof. Huaiyu Jian, Tsinghua University

Research interests: PDEs, calculus of variations, geometric analysis

Dr Feida Jiang, Nanjing University

Research interests: PDEs

Prof. Haizhong Li, Tsinghua University

Research interests: geometry of submanifolds, Riemannian geometry, affine differential geometry, variational problems for submanifolds and Riemannian manifolds

Prof. Jiayu Li, University of Science and Technology of China

Research interests: geometric analysis,

Prof. Yachun Li, Shanghai Jiaotong University
Research interests: nonlinear PDEs and related applications

Prof. Xinan Ma, University of Science and Technology of China

Research interests: geometry and topology, differential geometry, mathematical analysis

Assoc. Prof. Todd Oliynyk, Monash University
Research interests: PDEs: singular limits of symmetric hyperbolic systems, geometric PDEs, general relativity: Newtonian limit, post-Newtonian expansions, Einstein-Yang-Mills, gravitating perfect

fluids and elastic bodies, geometric flows: Ricci flow, renormalisation group flow

Prof. Xu-Jia Wang, The Australian National University
Research interests: elliptic and parabolic PDEs, applications in geometry and physics

Dr Valentina Wheeler, University of Wollongong
Research interests: analysis, geometry, topology

Prof. Zhouping Xin, Chinese University of Hong Kong
Research interests: PDEs, Fluid Dynamics and Nonlinear Waves

Prof. Xiaohua Zhu, Beijing University
Research interests: geometric analysis

Prof. Xiping Zhu, Sun-Yat Sen University
Research interests: geometry and topology

MathSciNet Classification

35 Partial Differential Equations

Web Links

maths.anu.edu.au/events/china-australia-joint-conference-partial-differential-equations

Other Sponsors

The Australian National University Mathematical Sciences Institute, The University of Queensland

Key Contact

Prof. Ben Andrews, The Australian National University, ben.andrews@maths.anu.edu.au

1.17 TOPOLOGY IN AUSTRALIA AND SOUTH KOREA 2017

The University of Melbourne, 1–5 May 2017

A platform to foster Australian research collaboration with the Republic of South Korea, this conference was attended by global and local experts in algebraic topology.

A central field in mathematics, algebraic topology has deep connections and applications to other fields. Historically under-represented in the Asia-Pacific region, the field has a strong presence in research agendas at world-class universities such as Harvard (Hopkins, Lurie), MIT (Miller, Barwick), Bonn (Schwede, Lueck, Kreck, Teichner), Oxford (Tillman) and more. There are indications this trend is changing with the subject growing in Australia and Korea: with new appointments at the IBS Center for Geometry and Physics (South Korea), the University of Melbourne, the University of Queensland and Macquarie University complementing the established groups at ANU and Melbourne. A new wave

of recruitment in Australia and at other Asia-Pacific universities — especially in Japan and Korea — has provided the kind of critical mass that makes community-building timely.

The event featured four to five talks each day, concentrated in the afternoons, mixing the keynote lecture series with one-hour research talks. The research talks were split between Korean, Australian and other international speakers with emphasis on diversity of gender, career-stage and unique contributions to the program. This was designed to maximize attendance and to encourage the audience that was drawn to the key note speakers to participate in the related research talks. Having the mornings free allowed substantial time for discussion and collaboration.

The two keynote lecture series each featured three lectures centred on topological approaches to physical problems. Professor Mike Hopkins discussed key results in algebraic topology as they

“This was one of the more interesting topology conferences I’ve attended.”

Assoc. Prof. David Gepner,
Purdue University

relate to condensed matter physics, and Professor Yong-Geun Oh described the construction of a fundamental object in symplectic topology and its relationship to problems in mirror symmetry. The first lecture from each of the keynote speakers was aimed at a public audience and attracted additional participants to each talk from the local mathematics community.

Accompanying the 2 lecture series were 11 additional research talks by a mix of local and international speakers. Highlights included research collaborations emerging between speakers Associate Professor Craig Westerland (University of Minnesota) and Dr TriThang Tran (Monash University/Trinity College); and Dr Daniel Murfet (The University of Melbourne) and Professor Calin Lazaroiu (IBS-CGP).

Considered by all a great success, the event will continue next year in Korea strengthening efforts to establish this workshop and conference as a fixture in the annual research calendars of both countries.



WORKSHOP PARTICIPATION

- 43** Attendees
- 5** Postgraduate students
- 2** Early career researchers
- 9** Women
- 17** International participants

Organisers

Dr Vigleik Angeltveit, The Australian National University
Dr Gabriel C. Drummond-Cole, IBS Centre for Geometry and Physics, Korea
Dr Philip Hackney, Macquarie University
Dr Marcy Robertson, The University of Melbourne

Special Presenters

Prof. Mike Hopkins, Harvard University, USA
 Research interests: algebraic topology, stable

homotopy theory

Prof. Yong-Geun Oh, IBS Center for Geometry and Physics, Pohang University of Science and Technology, Korea
 Research interests: symplectic geometry, hamiltonian dynamical systems, mirror symmetry

MathSciNet Classification

55 Algebraic Topology, 18 Category Theory;
 Homological Algebra, 19 K-Theory

Web Links

phck.net/task17

Other Sponsors

Institute for Basic Science, The University of Melbourne

Key Contact

Dr Marcy Robertson, The University of Melbourne,
marcy.robertson@unimelb.edu.au

1.18 TENSOR CATEGORIES AND FIELD THEORY

The University of Melbourne, 5–9 June 2017

Attracting a dynamic mix of international and Australian tensor categories and field theory experts, this workshop provided a platform to explore recent field developments and new collaborations.

Recent years have seen a rich cross-fertilisation of ideas between physics and mathematics that has led to fantastic advances in each field. A prominent example of this is the notion of a tensor category. These abstract structures have a depth and ubiquity that has made them indispensable knowledge for many modern research fields including conformal field theory and vertex algebras, knot theory, operator algebras and subfactors, quantum groups, representation theory, topological quantum field theory and, more recently, applied fields such as condensed matter physics.

Providing both an introduction to the topic and exposure to the cutting edge of current research, the conference was comprised a mixture of plenary talks and

lectures. This year's program covered a broad range of mathematical topics, resulting in an accurate impression of the important open problems of the field and their relationships with several branches of fundamental pure and applied research. In particular, this was very useful for students and early career researchers.

During their visits for the conference, Associate Professor Eric Rowell and Professor Dmitri Nikshych, along with organiser Associate Professor Scott Morrison and postdoc Corey Jones, proved the rank-finiteness conjecture for premodular categories, a significant achievement. This result used an unexpectedly simple application of a previous result of Rowell's on centres of supermodular categories that had been missed for several years.

The visit of Dr Shashank Kanade also led directly to a significant new result, showing that the constructive approach to fusion favoured by physicists (the Nahm-Gaberdiel-Kausch algorithm) can

be directly deduced from the rigorous, but non-constructive, theory developed by mathematicians (Huang-Lepowsky-Zhang). This work is a joint collaboration with Professor Arun Ram and Dr David Ridout.

Despite differences in the core problems being tackled, the international speaker panel's use of similar tools served to emphasise the importance of the underlying abstract mathematics. Strong global attendance also provided a fantastic networking opportunity with many participants quick to seed new collaborations. Feedback from attendees was unanimously glowing. Based on this feedback, they went away excited by what they'd heard and keen to learn more.

WORKSHOP PARTICIPATION

- 46 Attendees**
- 19 Postgraduate students**
- 3 Early career researchers**
- 6 Women**
- 8 International participants**

"It was a great idea to bring together some of the experts from a variety of backgrounds, both domestic and international, and explore synergies in the different aspects of the fast-emerging topic of categorical approaches to field theory. I learned a lot."

Prof. Peter Bouwknegt, The Australian National University



Organisers

Dr Nora Ganter,

The University of Melbourne

Dr Pinhas Grossman,

The University of New South Wales

Assoc. Prof. Scott Morrison,

The Australian National University

Dr Thomas Quella,

The University of Melbourne

Assoc. Prof. Jorgen Rasmussen, The University of Queensland

Dr David Ridout,

The University of Melbourne (Chair)

Special Presenters

Assoc. Prof. Gavin Brennen, Macquarie University

Research interests: quantum simulation and computation, topological quantum science

Adj. Prof. Bianca Dittrich,

Perimeter Institute, Canada

Research interests: mathematical physics, quantum gravity

Dr Shashank Kanade,

University of Alberta, Canada

Research interests: vertex operator algebras, tensor categories, integer partition identities and q -series

Dr Liang Kong,

University of New Hampshire, USA

Research interests: vertex operator algebras, category theory, representation theory, string theory, quantum field theories, topological orders in condensed matter physics

Prof. Dmitri Nikshych,

University of New Hampshire, USA

Research interests: Hopf algebras and quantum groups, tensor categories and module categories over them

Assoc. Prof. Eric Rowell,

Texas A&M University, USA

Research interests: mathematical foundations of

topological phases of matter

Dr Simon Wood, Cardiff University, UK

Research interests: algebra and mathematical physics, quantum field theory

MathSciNet Classification

18D10, 81T40, 81T45, 46L37

Web Links

sites.google.com/view/tensorcategories2017/home

Other Sponsors

The University of Melbourne, AustMS

Key Contact

Dr David Ridout,

The University of Melbourne,
david.ridout@unimelb.edu.au

1.19 COMPUTATIONAL INVERSE PROBLEMS

MATRIX, Creswick, 13–23 June 2017

This combined conference provided an opportunity for leading experts in computational inverse problems to discuss open challenges and recent advances.

The integration of complex data sets into large-scale computational models is one of the central challenges of modern applied mathematics, present in almost every application area within science and engineering including geosciences, biological systems, astrophysics, meteorology, aerospace and subsurface flow. At its heart often lies an inverse problem: converting indirect data into useful characterisations of the unknown model parameters including source terms, initial or boundary conditions, model structure and physical coefficients.

Traditionally, solving statistical inverse problems for systems governed by large-scale, complex computational models has been intractable. Such models are complicated and computationally expensive to evaluate, with available indirect data often limited, noisy and subject to natural variation. As a result, inversion algorithms often scale poorly to high-dimensional (or in principle infinite-dimensional) model parameters.

Assembling a strong field of mathematicians leading research on computational inverse problems and related areas, this event aimed to advance and identify

new and promising research directions. Successful realisation of these new opportunities may make a critical impact on applications of great current interest to the Australian and international research communities, including mathematical biology, flows in porous media, computational finance and meteorology. Some of these applications may also have substantial industrial impacts.

The program covered a wide range of relevant topics in computational inverse problems, including:

- New connections between Markov chain Monte Carlo (MCMC) and Sequential Monte Carlo (SMC) methods and high-dimensional approximation techniques (e.g. Quasi Monte Carlo (QMC) and sparse grids), in the context of computational inverse problems
- New insight into the role of projection-based model reduction in multi-scale modelling
- Integration of model reduction techniques and high-dimensional approximation techniques to reduce the variance in computing posterior expectations
- Investigation on the role of stochastic optimisation and distributed optimisation methods in PDE-constrained inverse problems, as well as the development of relevant algorithms
- Applications to different areas of applied mathematics, including additive

manufacturing, computational finance and flow in porous media

The conference and workshop was a springboard for new collaborations between Australian and international researchers, while existing research partnerships were reinvigorated, with new ideas and potential teams for attracting ARC funding initiated and discussed. In addition, there are plans for a series of book chapters in the MATRIX book series published by Springer.

The significant number of students and early career researchers who attended this year's event benefited greatly from the engagement with the international participants.

Note: AMSI sponsored both the conference and workshop during this two-week long MATRIX event.

WORKSHOP PARTICIPATION

47 Attendees

11 Postgraduate students

9 Early career researchers

6 Women

28 International participants

Organisers

Dr Tiangang Cui, Monash University

Prof. Hans De Sterck, Monash University

Prof. Markus Hegland, The Australian National University

Assoc. Prof. Youssef Marzouk, Massachusetts Institute of Technology

Prof. Ian Turner, Queensland University of Technology

Prof. Karen Willcox, Massachusetts Institute of Technology

Special Presenters

Prof. Johnathan Bardsley, University of Montana, USA

Research interests: inverse problems, uncertainty quantification, computational mathematics, computational statistics

Assoc. Prof. Josef Dick, The University of New South Wales

Research interests: numerical integration, quasi-Monte Carlo rules

Assoc. Prof. Colin Fox, University of Otago, NZ
Research interests: Bayesian inference, inverse problems, acoustics, semi-analytic methods

Assoc. Prof. Tim Garoni, Monash University
Research interests: statistical mechanics, Markov-chain Monte Carlo methods

Prof. Omar Ghattas, University of Texas at Austin, USA
Research interests: simulation and modelling of complex geophysical, mechanical and biological systems on supercomputers, inverse problems and associated uncertainty quantification for large-scale systems

Prof. Heikki Haario, Lappeenranta University of Technology, Finland

Research interests: computing in mathematics, natural science, engineering and medicine, artificial intelligence, theory of computation

Prof. Markus Hegland, The Australian National University

Research interests: computational mathematics, data mining

Dr Qinian Jin, The Australian National University
Research interests: numerical analysis, inverse problems, PDEs, geometric analysis

Prof. Marko Laine, Finnish Meteorological Institute, Finland

Research interests: statistical post-processing for numerical weather prediction, uncertainty quantification, mathematical and statistical methods, Markov chain Monte Carlo (MCMC) methods

Assoc. Prof. Youssef Marzouk, Massachusetts Institute of Technology, USA

Research interests: computational science and engineering, computational statistics, uncertainty quantification, inverse problems, data assimilation, energy and geophysics applications

Dr Habib Najm, Sandia National Laboratory, USA
Research interests: Combustion, computational reacting flow, computational modelling, uncertainty quantification, stochastic modelling, data assimilation, inverse problems

Dr Fred Roosta, The University of Queensland
Research interests: big data and machine learning, randomised algorithms, mathematical statistics, numerical optimisation, numerical analysis and scientific computing, numerical linear algebra,

image processing, inverse problems

Prof. Hans De Sterck, Monash University

Research interests: numerical methods for scientific computing, data science

Prof. Ian Turner, Queensland University of Technology

Research interests: computational electromagnetics, computational mathematics, computational modelling of porous media, drying process-modelling, linear algebra, numerical analysis, salinity modelling, scientific computation, supercomputing

Prof. Karen Willcox, Massachusetts Institute of Technology, USA

Research interests: Multi-fidelity uncertainty quantification, multi-fidelity optimisation under uncertainty, adaptive reduced models, data to decisions in aerospace engineering

MathSciNet Classification

65 Numerical analysis, 60 Probability Theory and Stochastic Processes, 62 Statistics

Web Links

www.matrix-inst.org.au/events/computational-inverse-problems/

Other Sponsors

AustMS (ANZIAM), MATRIX, Monash University

Key Contact

Dr Tiangang Cui, Monash University, tiangang.cui@monash.edu

1.20 INTEGRABILITY IN LOW-DIMENSIONAL QUANTUM SYSTEMS

MATRIX, Creswick, 26 June – 21 July, 2017

Focusing on the mathematical aspects of integrability in low-dimensional quantum systems, this conference seeded new global collaborations to advance the frontiers of knowledge.

Classical integrability of two-dimensional systems and the related quantum integrability of one-dimensional systems are finding areas of application in statistical physics, condensed matter physics and particle physics in addition to contributing to highly mathematical topics such as Yang-Baxter algebras, quantum groups, cluster algebras, affine Lie algebras and combinatorial representation theory. Furthermore, results from exactly integrable systems also continue to provide an invaluable testing ground for

important approximation schemes and numerical simulations.

The impact of this workshop will be of long-lasting benefit to the community in mathematical and theoretical physics in Australia and the region. The conference was preceded by a series of introductory lectures on hot topics and advanced seminars, offering extensive training to postgraduate students and early career researchers working in integrability and related topics.

Conference attendees included 15 global field specialists, with each presenting recent work and discoveries. Given its core aims, organisers built significant networking opportunities into the event structure. This strengthened existing and early-stage collaborations,

work expected to lead to significant advances in the discipline.

Conference highlights included the announcement of the analytic calculation of the conformal partition functions of two-dimensional critical percolation, the demonstration of the quantum toroidal integrability behind the AGT correspondence, and some striking progress on the mathematical

WORKSHOP PARTICIPATION

- 59** Attendees
- 8** Postgraduate students
- 10** Early career researchers
- 7** Women
- 40** International participants

description of fusion within the affine Temperley-Lieb algebra.

Rapid progress was made on a number of fronts, including collaborations explaining the mysteries of Baxter's Q-matrix for $sl(2)$ models at roots of unity and an analytical derivation of the correlation functions and conformal weights of critical dense polymers. Many physical applications to quantum quenches, ultracold atoms and matter-

light interaction were also showcased during the meeting.

Several of the conference presentations will be included in a forthcoming volume of the MATRIX Proceedings published by Springer.

Note: AMSI sponsored the 10–14 July workshop held during the third week of this four-week long MATRIX event.

“I initiated two new projects project with different colleagues. Moreover, I learned a great deal from the talks and from discussions with many of the participants.”

Workshop participant



Organisers

Prof. Murray Batchelor,

The Australian National University

Prof. Patrick Dorey,

Durham University, UK

Dr Clare Dunning, Kent University, UK

Prof. Giuseppe Mussardo,

SISSA, Trieste, Italy, (not participating)

Prof. Paul Pearce,

The University of Melbourne

Prof. Chaiho Rim,

Sogang University, Korea

Special Presenters

Prof. Zoltan Bajnok,

Wigner Research Center for Physics, Hungary

Research interests: conformal field theory including boundaries and defects, spin chains, AdS/CFT correspondence, finite size effects

Prof. Ed Corrigan, University of York, UK

Research interests: mathematical physics, classical and quantum field theory, two-dimensional integrable quantum field theories with boundaries and defects

Prof. Patrick Dorey,

Durham University, UK

Research interests: integrable quantum field theory, statistical mechanics

Dr Clare Dunning, Kent University, UK

Research interests: exactly solvable models, integrable quantum field theory, spectral theory of ordinary differential equations

Prof. Angela Foerster,

Federal University of Rio Grande do Sul, Brazil

Research interests: condensed matter physics, quantum physics, theoretical physics

Prof. Dr Holger Frahm,

Leibniz University of Hanover, Germany

Research interests: quantum spin chains and non-Abelian anyons, supersymmetric vertex models, quantum impurities, strongly correlated electron systems

Prof. Dr Andreas Klümper,

University of Wuppertal, Germany

Research interests: mathematical physics, quantum physics, condensed matter physics, multi-particle quantum systems, exactly solvable models

Dr Alexi Morin-Duchesne,

Université catholique de Louvain, Belgium

Research interests: mathematical physics

Prof. Rafael Nepomechie,

University of Miami, USA

Research interests: integrable quantum spin chains, integrable quantum field theories, integrability in string theory

Prof. Dr Kareljan Schoutens,

University of Amsterdam, Netherlands

Research interests: low-dimensional quantum field theories, the quantum Hall effects, condensed matter theory, quantum information

MathSciNet Classification

82A15, 82B23, 81T40

Web Links

matrix-inst.org.au/events/integrability-in-low-%C2%AD%E2%80%90dimensional-quantum-systems/

Other Sponsors

MATRIX, Asia Pacific Center for Theoretical Physics, AustMS

Key Contact

Prof. Paul Pearce,

The University of Melbourne,
papearce@unimelb.edu.au

1.21 CATS 2017: COMPUTATIONAL AND ALGORITHMIC TOPOLOGY, SYDNEY

The University of Sydney, 27 June – 1 July, 2017

Bringing together Australian and international experts and emerging researchers, this interdisciplinary workshop provided the opportunity to examine recent results in computational and algorithmic topology and set future research directions.

A rapidly growing interdisciplinary research area, computational topology uses computers to apply innovative algorithms to complex and fundamental mathematical problems. This powerful combination has already proven to have remarkable real-world applications. While largely independent, the emerging branches of computational topology have much to offer each other.

The popular introductory lecture series took an interdisciplinary exploration of key computational geometry and low-dimensional topology techniques, including motivation, key examples and applications. A number of computational geometry themes were on the agenda including parameterised complexity, Delaunay triangulations and discrete Morse theory, while low-dimensional topology topics included sweep-outs and thin position.

With a broad focus, this year's research talks covered computational geometry and low-dimensional topology. Spanning the whole spectrum, speakers included

graduate students, early and mid career researchers and established experts.

Long lunch breaks ensured ample time for discussion and knowledge transfer between participants.

Highlights included:

- A presentation from Associate Professor Erin Wolf Chambers exploring a new computational method to measure on the medial axis, demonstrating its significance in extracting clean, shape-revealing and topology-preserving skeletons which are robust to noise on the boundary
- Associate Professor Murray Elder's explanation of how to decide the solvability of and expressed the set of all solutions to an equation in a free or virtually free group in PSPACE
- An application of the method of comparing shapes based on finding an optimal conformal diffeomorphism between two surfaces given by Professor Joel Hass
- Associate Professor Dave Letscher's report on an application of normal surface theory to remove topological noise from a dataset
- A description by Dr Clément Maria of a polynomial time algorithm to compute quantum invariants of 3-manifolds with bounded first Betti number
- The introduction of a new decomposition

result for 3-manifolds and its applications by Associate Professor Jessica Purcell

- Professor Hyam Rubinstein gave an application of normal surface theory to the study of the 3D index of a hyperbolic 3-manifold
- Dr Hubert Wagner spoke on an extension of topological data analysis to the setting of information spaces
- Professor Yusu Wang reported on recent work addressing the issue of size and the issue of noise associated with modern data

A calendar fixture for many, the event attracted a sizable contingent of international researchers and postgraduate students. Female participation was also high, comprising half of the speakers and 28 per cent of the total conference attendees.

WORKSHOP PARTICIPATION

- 49** Attendees
- 15** Postgraduate students
- 12** Early career researchers
- 13** Women
- 26** International participants

"I particularly liked the combination of tutorial-like lectures in the first couple of days combined with talks in the remaining. I also liked the diverse topics of the conference, which covers some aspects of computational topology that I am not familiar with and learned a lot about this time."

Prof. Yusu Wang, Ohio State University, USA



Organisers

Dr Robert C. Haraway III,

The University of Sydney

Dr Joshua Howie, Monash University

Assoc. Prof. Stephan Tillmann,

The University of Sydney

Special Presenters

Assoc. Prof. Erin Wolf Chambers,

Saint Louis University, USA

Research interests: computational topology and geometry, combinatorics, combinatorial algorithms

Assoc. Prof. Murray Elder,

University of Technology Sydney

Research interests: geometric group theory, complexity theory, automata and formal language theory, enumerative combinatorics, pattern-avoiding permutations

Dr Serge Gaspers,

The University of New South Wales

Research interests: algorithms and complexity, combinatorics, satisfiability and constraints, intractable computational problems

Prof. Joel Hass, University of California Davis, USA

Research interests: low-dimensional topology and geometry

Assoc. Prof. Dave Letscher,

Saint Louis University, USA

Research interests: computational topology, computational geometry, algorithms, algorithmic questions in 3-manifold topology

Dr Clément Maria,

The University of Queensland

Research interests: computational geometry and topology, persistent homology, low-dimensional topology

Assoc. Prof. Jessica Purcell, Monash University

Research interests:

low-dimensional topology

Dr Vanessa Robins,

The Australian National University

Research interests: computational topology and geometry

Prof. Hyam Rubinstein,

The University of Melbourne

Research interests: low dimensional topology, minimal surfaces (combinatorial and smooth), differential geometry, shortest network design

Dr Monique Teillaud,

INRIA Nancy, France

Research interests: computational geometry

Prof. Abby Thompson,

University of California Davis, USA

Research interests: knot theory, 3-fold manifolds

Dr Hubert Wagner, Institute of Science and Technology, Austria

Research interests: computational geometry and topology, scientific computing, pattern recognition, algorithms

Prof. Yusu Wang, Ohio State University, USA

Research interests: computational geometry, computational and applied topology

MathSciNet Classification

57M27, 68Q25

Web Links

maths.usyd.edu.au/u/tillmann/cats2017/

Other Sponsors

The University of Sydney

Key Contact

Assoc. Prof. Stephan Tillmann,

The University of Sydney,

stephan.tillmann@sydney.edu.au



MATHSFEST AUSTRALIA 2016

Australian National University, 28 November – 13 December, 2016

A three-week long multi-event created by attaching an international workshop to each side of the 60th Annual Meeting of the Australian Mathematical Society, MathsFest attracted considerable international interest.

MathsFest is a new initiative of the Australian Mathematical Society and the Australian Mathematical Sciences Institute, with the aim of boosting the international presence of Australia's mathematical sciences.

The idea was simple: put one full-blown, well-funded workshop on either side of the AustMS meeting, connected to it through overlapping plenaries and themes. The goal: to build connections between Australian mathematicians and international researchers, encouraging collaboration and highlighting Australian capabilities.

While MathsFest will not accompany the 2017 AustMS conference, there are plans to revisit it in future years.

MathsFest Committee

Prof. Ben Andrews,

The Australian National University

Mari Ericksen, AMSI

Prof. Gary Froyland,

The University of New South Wales

Prof. Vladimir Gaitsgory, Macquarie University

Prof. Tim Marchant, AustMS

Anne Nuguid, AMSI **Prof. Geoff Prince,** AMSI

Prof. John Urbas, The Australian National University

Liam Williamson, AMSI

“With an overall attendance pushing 500 and with twenty-five of the world’s leading mathematicians delivering plenary lectures, MathsFest will have a lasting impact on our international collaborations,”

Prof. Geoff Prince, AMSI Director

“...an important platform to open new opportunities for future international research collaborations with members.”

Prof. Tim Marchant, President, AustMS

1.22 MATHSFEST: ADVANCES IN ERGODIC THEORY, HYPERBOLIC DYNAMICS AND STATISTICAL LAWS

Australian National University, 28 November – 2 December, 2016

The opening event of MathsFest 2016, this workshop was one of the largest on dynamical systems ever held in Australia. With a strong national and international presence, field leaders used this rare platform to set the research agenda for ergodic theory for the coming years.

Over the past five decades, advances in statistical mechanics and thermodynamics, ergodic theory and probability theory have had profound effects on mathematics, physics, engineering and biology. From the 1990s, probability theory tools have enabled major successes in understanding statistical correlation decay rates and more general statistical properties of non-uniformly hyperbolic dynamical systems. These refined statistics have improved prediction of the behaviour of complex physical systems. In a related direction, progress has been made on determining rates of convergence to limiting behaviour for a variety of quantities of physical relevance such as Lyapunov exponents, equilibrium measures, and ergodic sums amongst many others.

These developments have had applications in homogenisation theory, the modelling of weather and ocean systems, extreme value theory, and development of efficient numerical codes to model phenomena ranging from fluid flow to space missions. More recently we have seen important advances in the rigorous analysis of emergent stochastic behaviour of deterministic chaotic dynamical systems with often unexpected and practically relevant results.

The first of two MathsFest workshops, the event preceded the 2016 annual meeting of the Australian Mathematical Society. The opportunity to explore theoretical and applied areas of dynamical systems, ergodic theory and probability drew a number of international invited speakers. This breadth of expertise enabled participants to immerse themselves a week of in-depth sessions covering topics such as hyperbolic dynamics, thermodynamic formalism, statistical properties of dynamical systems, quantum ergodicity, infinite-dimensional ergodic theory, stochastic processes, data assimilation and

computational dynamics. This paved the way for critical discussion exploring recent advances and future directions in the field.

Importantly, the event met a significant need for international engagement in this growing area with many international speakers in Australia for the first time. Highlights of the program included:

- Presentations on The Weil-Petersson geodesic flow by Professor Keith Burns
- The approximation of invariant sets for delay and partial differential equations by Professor Michael Dellnitz
- Some ergodic problems for stochastic PDEs by Professor Benjamin Goldys
- Ergodic theory in data assimilation by Professor David Kelly
- Dynamical systems theory applied to eigenfunction estimates by Professor Andrew Hassell
- Local limit theorem in negative curvature by Professor François Ledrappier
- Lagrange and Markov dynamical spectra of Lorenz-like attractors by Local Limit Theorem Maria José Pacifico
- Hyperbolic billiards by Professor Carlangelo Liverani

- Quantitative recurrence for slowly mixing hyperbolic systems by Professor Françoise Pène
- Rigorous estimates for the Lanford map by Professor Mark Pollicott
- Decay of correlations in various hard-core models by Professor Kavita Ramanan
- Gibbs-Markov-Young structures for partially hyperbolic attractors by Dr José F. Alves
- Hyperbolic neighbourhoods in nonautonomous flows by Associate Professor Sanjeeva Balasuriya
- Functional networks by Professor Mike Field

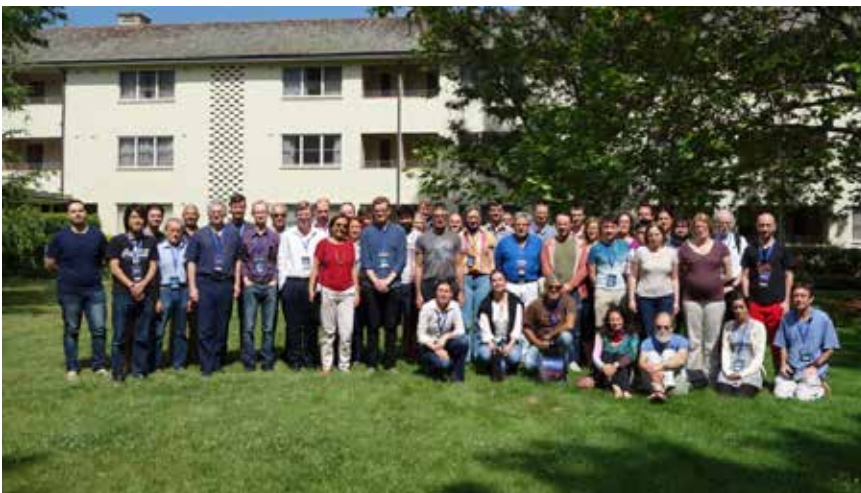
- Random group actions by Professor Anthony Dooley
 - Intrinsic excitability and the role of saddle slow manifolds by Professor Hinke Osinga
 - Decreasing entropy in the destruction of horseshoes via internal tangencies by Dr Isabel Rios
 - Equilibrium states on noncommutative solenoids by Professor Aidan Sims
- Furthermore, engaging talks by early career researchers and a lively PhD student poster session were vital parts of the workshop.
- The event coincided with the 60th birthday of Canberra-born invited speaker Professor Keith Burns. An evening was

devoted to the occasion, including sharing memorable stories and pictures of Keith and, of course, a birthday cake!

With a mix of established academics, early career researchers, and students attending, the program included vital openings for networking. In all, 11 AMSI member organisations were represented in the collection of participants.

WORKSHOP PARTICIPATION

- 58** Attendees
- 14** Postgraduate students
- 8** Early Career Researchers
- 17** Women
- 29** International participants



“Thank you so much for the discussions and for organising such an entertaining and enlightening conference!”

Dr Alex Blumenthal, University of Maryland College Park

Organisers

Prof. Gary Froyland, The University of New South Wales
Dr Cecilia González-Tokman, The University of Queensland
Prof. Georg Gottwald, The University of Sydney
Dr Andy Hammerlindl, Monash University
Prof. Matthew Nicol, University of Houston, USA
Prof. Luchezar Stoyanov, The University of Western Australia

Special Presenters

Prof. Keith Burns, Northwestern University, USA
 Research interests: Dynamical systems and ergodic theory
Prof. Dr Michael Dellnitz, Paderborn University, Germany
 Research interests: dynamical systems, multiobjective optimisation
Prof. Benjamin Goldys, The University of Sydney
 Research interests: stochastic PDEs, ergodic theory of infinite-dimensional diffusions, applications of stochastic control and Hamilton-Jacobi equations in finance
Prof. Andrew Hassell, The Australian National University
 Research interests: spectral and scattering theory,

PDEs, microlocal analysis and semiclassical analysis
Asst. Prof. David Kelly, Courant Institute of Mathematical Sciences, New York University, USA
 Research interests: probability and applied mathematics, including data assimilation, multiscale modelling, SPDEs and rough path theory
Prof. Francois Ledrappier, University of Notre Dame, USA
 Research interests: dynamical systems theory, geometry of compact negatively curved manifolds, geometric measure theory
Prof. Carlangelo Liverani, University of Rome Tor Vergata, Italy
 Research interests: ergodic theory, dynamical systems, mathematical physics, statistical mechanics, mathematics
Prof. Maria Jose Pacifico, Universidade Federal do Rio de Janeiro, Brazil
 Research interests: dynamical systems and applications
Prof. Françoise Pène, Université de Bretagne Occidentale, France
 Research interests: probability theory, geometry and topology, statistics
Prof. Mark Pollicott, Warwick University, UK
 Research interests: thermodynamic formalism and applications, including geometry, number theory,

dimension theory and analysis
Prof. Kavita Ramanan, Brown University, USA
 Research interests: probability theory, stochastic processes and their applications
Prof. Amie Wilkinson, University of Chicago, USA
 Research interests: ergodic theory and smooth dynamical systems

Web Links

mathsfest.amsi.org.au/

Other Sponsors

The Australian National University, The University of New South Wales, The University of Western Australia, The University of Sydney, The University of Queensland, Monash University, the Australian Research Council

Key Contact

Prof. Gary Froyland, The University of New South Wales, g.froyland@unsw.edu.au

MATHSFEST: ADVANCES IN ERGODIC THEORY, HYPERBOLIC DYNAMICS AND STATISTICAL LAWS

By Professor Gary Froyland and Dr Cecilia González-Tokman

A RELATIVELY YOUNG MATHEMATICAL DISCIPLINE, DYNAMICAL SYSTEMS ORIGINATED IN THE LATE 19th century with the works of Henri Poincaré around the question of stability of the solar system. When trying to figure out whether the gravitational forces would constrain planet Earth to remain revolving around the Sun forever, Poincaré discovered what in his time were unimaginable complications within solutions of relatively simple ordinary differential equations.

Ergodic theory attempts to describe dynamical systems from a global probabilistic perspective. For example, it aims to answer questions such as “How often do most trajectories visit a region of interest?” Poincaré’s recurrence theorem was the first result in this direction, and is applicable to dynamical systems $T: X \rightarrow X$ having a T -invariant probability measure μ (a measure μ on X such that, for every measurable $A \subset X$, $\mu(A) = \mu(T^{-1}(A))$; in words, the probability of an event A occurring in the present is the same as the probability of this event occurring one time step in the future). This striking result states that if $\mu(A) > 0$, then for μ almost every $x \in A$, the trajectory $\{T^j(x)\}_{j \geq 0}$ returns infinitely many times to A . This result is associated with some surprising, even seemingly paradoxical facts. For example, the combination of digits 31415926535 is found infinitely many times in the decimal expansion of almost every number within 10^{-12} of π . More strikingly, if a billiard game took place on a frictionless table, then for almost every starting position and velocity configuration of the billiard balls, the billiard flow would, after many collisions, go back arbitrarily close to its initial layout after the cue ball is hit.

Classical results in ergodic theory relate so-called time averages, $\frac{1}{n} \sum_{j=0}^{n-1} \phi(T^j(x))$, with space averages $\int_X \phi(y) d\mu(y)$, where $\phi: X \rightarrow \mathbb{R}$ is an observable of interest, and μ is a T -invariant probability measure for the system. The famous Birkhoff ergodic theorem shows that when ϕ is integrable and μ is *ergodic*; that is, when all T -invariant sets have either full or null μ measure, then for μ almost every $x \in X$,

$$(1) \quad \lim_{n \rightarrow \infty} \frac{1}{n} \sum_{j=0}^{n-1} \phi(T^j x) = \int_X \phi(y) d\mu(y).$$

This fact is informally phrased as *time averages equal space averages*.

Recently, research efforts have focused on understanding several aspects related to the convergence in (1). Model systems under intensive investigation include various types of billiard systems, as well as other systems with complementary *expanding* and *contracting* directions—called hyperbolic systems. Other models incorporate external factors into the dynamics, to account for noise and/or external forces.

In fact, for many systems, even finding an ergodic invariant measure μ is a difficult question. When such a measure is available, one may study conditions leading to decay of correlations, limit theorems, large deviations, linear response and more. These refined statistics have improved prediction of the behaviour of complex physical systems. Topics related to these lines of research were addressed at this MathsFest workshop in the invited talks of world experts Keith Burns, François Ledrappier, Carlangelo Liverani, Maria José Pacifico, Françoise Pène, Mark Pollicott, Kavita Ramanan and Amie Wilkinson.

Over the past five decades, theoretical and computational advances in statistical mechanics and thermodynamics, ergodic theory and probability theory have had profound effects on mathematics, physics, engineering and biology. Ergodic theory and dynamical systems also have by now numerous connections with other areas of mathematics. In this direction, Michael Dellnitz presented a novel numerical framework for the computation of finite-dimensional invariant sets for infinite-dimensional dynamical systems, and illustrated this approach by computing attractors both for delay differential equations and for partial differential equations. David Kelly talked about ergodic theory in the modern field of data assimilation. Ben Goldys discussed properties of the long-term behaviour of systems evolving randomly in space and time using stochastic evolution equations. Andrew Hassell showed how results from dynamical systems have been used to prove estimates for high-energy eigenfunctions on Riemannian manifolds.

1.23 MATHSFEST: NONLINEAR AND GEOMETRIC PARTIAL DIFFERENTIAL EQUATIONS

Australian National University, 9–13 December 2016

Running as part of MathsFest, this satellite workshop to the 2016 Annual AustMS meeting explored global advancements in geometric analysis, and geometric and nonlinear partial differential equations.

Geometric analysis combines methods from analysis (including ordinary and partial differential equations, calculus of variations, measure theory and functional analysis) with differential geometry. Examples of the use of geometric analysis methods include general relativity, where the structure of space-time is determined by a system of geometric partial differential equations (the Einstein equations); minimal surface theory, where the shapes of minimal surfaces (soap bubbles) are the solutions of nonlinear partial differential equations; and the Ricci flow of Riemannian metrics, which was used by Hamilton and Perelman to solve the Poincaré conjecture and Thurston's geometrisation conjecture.

Australia is well represented in geometric analysis and this workshop aimed to build on this profile by bringing a number of international experts in the field to Australia to interact with local researchers.

In addition to this satellite workshop, the AustMS 2016 conference included several related talks and special sessions, including plenary speaker Professor André Neves, who spoke about the geometric analysis of minimal hypersurfaces in Riemannian manifolds. There were special sessions in geometry partial differential equations, and harmonic analysis, all of which had significant overlap with the workshop theme.

An interesting mix of talks and interactive networking sessions ensured the success of the workshop program. Highlights included:

- Professor Duong Phong's (Columbia) talk on a novel fully nonlinear geometric flow arising in complex geometry;
- a report by Professor Guofang Wei

(UCSB) on her recent work with Professor Seto and Professor Wang on the fundamental gap for convex domains in the sphere

- talks by Professor Pavel Exner (Prague) on singular Schrödinger operators and by Professor Xianzhe Dai (UCSB) on conical degenerations and Eguchi-Hanson instantons
- and Professor Gerhard Huisken's (Tübingen/Oberwolfach) lecture on a fully nonlinear flow of hypersurfaces with surgery

WORKSHOP PARTICIPATION

54	Attendees
12	Postgraduate students
14	Early Career Researchers
8	Women
10	International participants

“The level of the talks was very high and followed by inspiring questions and remarks of the audience. Beside the regular schedule, participants used the occasion to start new collaborations and discussing mathematics with each other.

From my point of view, it was a very well organised and successful satellite conference of MathsFest. The support by AMSI was certainly at the right place.”

Dr Daniel Hauer, The University of Sydney

Organisers

Prof. Ben Andrews, The Australian National University

Prof. Xu-Jia Wang, The Australian National University

Dr Julie Clutterbuck, Monash University

Dr Huy Nguyen, The University of Queensland

Dr Valentina Wheeler, University of Wollongong

Special Presenters

Prof. Dr Gerhard Huisken, University of Tübingen Mathematical Research Institute of Oberwolfach
Research interests: analysis, differential geometry, mathematical relativity

Prof. Yoshihiro Tonegawa, Tokyo Institute of Technology, Japan
Research interests: PDEs of elliptic and parabolic

types, geometric measure theory and its applications, calculus of variations, minimal surface, mean curvature flow

Prof. André Arroja Neves, Imperial College London, UK/University of Chicago, USA

Research interests: differential geometry and analysis of PDEs

Prof. Duong Phong, Columbia University, USA

Research interests: geometry and analysis

Prof. Jaigyoung Choe, Korea Institute for Advanced Study, South Korea

Research interests: differential geometry, geometric analysis,

Prof. Guofang Wei, University of California, Santa Barbara, USA

Research interests: differential geometry

Web Links

mathsfest.amsi.org.au/nonlinear-geometric-partial-differential-equations/

Other Sponsors

The Australian National University, University of Wollongong, The University of New South Wales, The University of Western Australia, The University of Sydney, The University of Queensland, Monash University. Australian Research Council

Key Contact

Prof. Ben Andrews, The Australian National University, Ben.Andrews@anu.edu.au

MATHSFEST: NONLINEAR AND GEOMETRIC PARTIAL DIFFERENTIAL EQUATIONS

By Professor Ben Andrews

PARABOLIC EQUATIONS ARE ONE OF THE FUNDAMENTAL TYPES of naturally arising partial differential equations. The simplest example is the heat equation or diffusion equation, in which a function $u(x,t)$, maybe representing a temperature or a concentration of some chemical at a point x at each time t , moves with time at a rate proportional to the second derivatives:

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2}.$$

In this simple case, the equation is linear and the solution for given initial data $u(x,0)=u_0(x)$ can be written as a supersolution of Gaussian *fundamental solutions*, each representing heat diffusing from a point source:

$$u(x,t) = \frac{1}{\sqrt{4\pi t}} \int u_0(y) e^{-\frac{|y-x|^2}{4t}} dy.$$

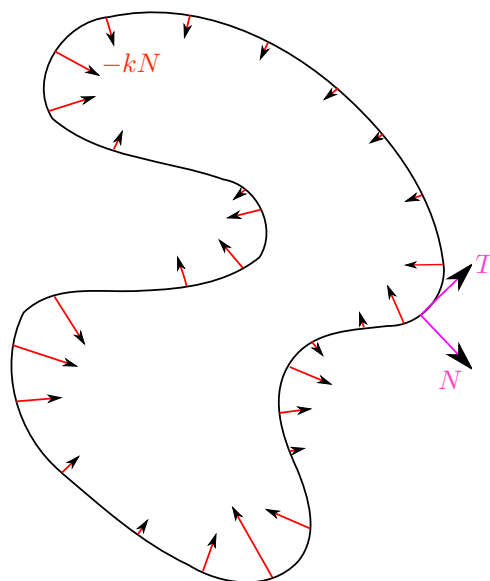
We can read off several simple but interesting properties of the solution from this:

- For $t > 0$, we can differentiate $u(x,t)$ as many times as we like with respect to y , since the derivatives fall on the Gaussian and not on u_0 . Thus, even if u_0 is highly irregular, the solution is immediately infinitely many times differentiable.
- The formula gives $u(x,t)$ as a weighted average of the initial data u_0 . This implies in particular that if the initial temperature is positive everywhere, then it will never fall below freezing, and if the initial temperature is below boiling point then it will never increase above it at any point. This is an instance of the *parabolic maximum principle*.
- As t approaches infinity, the gradient of the solution settles down to zero (if u_0 is bounded, then the formula gives that $|\frac{\partial u}{\partial x}| \leq \frac{C}{\sqrt{t}}$). That is, even if the initial temperature is wildly fluctuating, it eventually settles down to become constant.

These properties are shared to a large degree with other kinds of parabolic equations. Each is characterised by immediate smoothing of solutions, maximum principles implying that maximum values cannot increase, and a tendency for solutions to settle down to *steady states* which are solutions of partial differential equations of elliptic type, and in some cases are relatively simple to classify or describe.

All of the above properties are desirable for applications in differential geometry. Ideally one could take a complicated geometric object (even one lacking regularity), and apply a heat flow to deform it, producing a time-dependent geometric object. The heat flow should immediately smooth the object, overcoming any problems with lack of regularity, and the long term behaviour should be relatively simple, satisfying an elliptic equation corresponding to the steady state of the flow. The maximum principle means that inequalities on geometric quantities could be preserved throughout the process.

A simple (and easy to visualise) example of how this ideal is put into practice is in the *curve shortening flow*: This is a heat equation which takes a smooth curve and deforms it in the direction of the curvature vector:



A beautiful theorem of Matt Grayson says if the initial curve is a simple closed curve in the plane, then the curve shortening flow evolves it smoothly to a point in finite time, and the shape of the curve is circular as the final time is approached (more precisely, rescaling about the final point to keep the enclosed area constant gives smooth convergence to a circle). In the special case where the initial curve is convex, a maximum principle applies to say that it remains convex throughout the process.

A more spectacular example concerns the Ricci flow, a heat equation for deforming a metric on an abstract manifold, where the metric tensor moves in the direction opposite to the Ricci curvature tensor. Richard Hamilton introduced this flow in his celebrated 1982 paper where he used it to prove that any metric with positive Ricci curvature on a compact three-dimensional manifold can be deformed to one with constant sectional curvatures (it follows that the manifold itself is a lens space i.e. quotient of the three-dimensional sphere by a finite group of isometries acting totally (discontinuously)). The Ricci flow has since been used to prove several other big theorems in differential geometry, including Böhm and Wilking's assertion that a simply connected compact manifold that carrying a metric with a positive curvature operator is diffeomorphic to a standard sphere, and that a simply connected compact manifold, which carries a metric for which the ratio of sectional curvatures at any point is less than 4, must be diffeomorphic to a sphere (Brendle and Schoen's *differentiable 1/4-pinching theorem*).

In another famous result of this type Gerhard Huisken, then at the Centre for Mathematical Analysis at ANU in the early 1980s, proved that a convex surface in space (or hypersurface in a higher-dimensional space) can be deformed in the direction of its mean curvature vector (the *mean curvature flow*) to shrink to a point in finite time, asymptotically approaching a shrinking standard sphere near the final time.

The ideal situation described above is the best of all possible worlds, but things do not always work out quite so simply: in some situations the geometric object can evolve to develop singularities, rather than evolving to a simple final state. This happens, for example, in both the mean, where a surface with a thin neck joining two larger regions will have the neck *pinch off* and form a singularity, and in the Ricci flow of Riemannian metrics (in dimensions 3 and higher) where similar ‘neck-pinching’ and more complicated singularities can arise.

A lot of recent work has been devoted to understanding situations where such singularities arise. Inspired by Richard Hamilton, Grisha Perelman applied the Ricci flow to an arbitrary metric on a compact three-dimensional manifold, and showed how to perform *surgery* to remove regions of high curvature before singularities form, and then continue the Ricci flow while still understanding the topological changes that have taken place. This *Ricci flow with surgery*, through Perelman’s remarkable contributions, resulted in the proof of the Poincaré conjecture, and also a much broader conjecture of Thurston (known as the geometrization conjecture) which essentially classifies all compact three-dimensional manifolds.

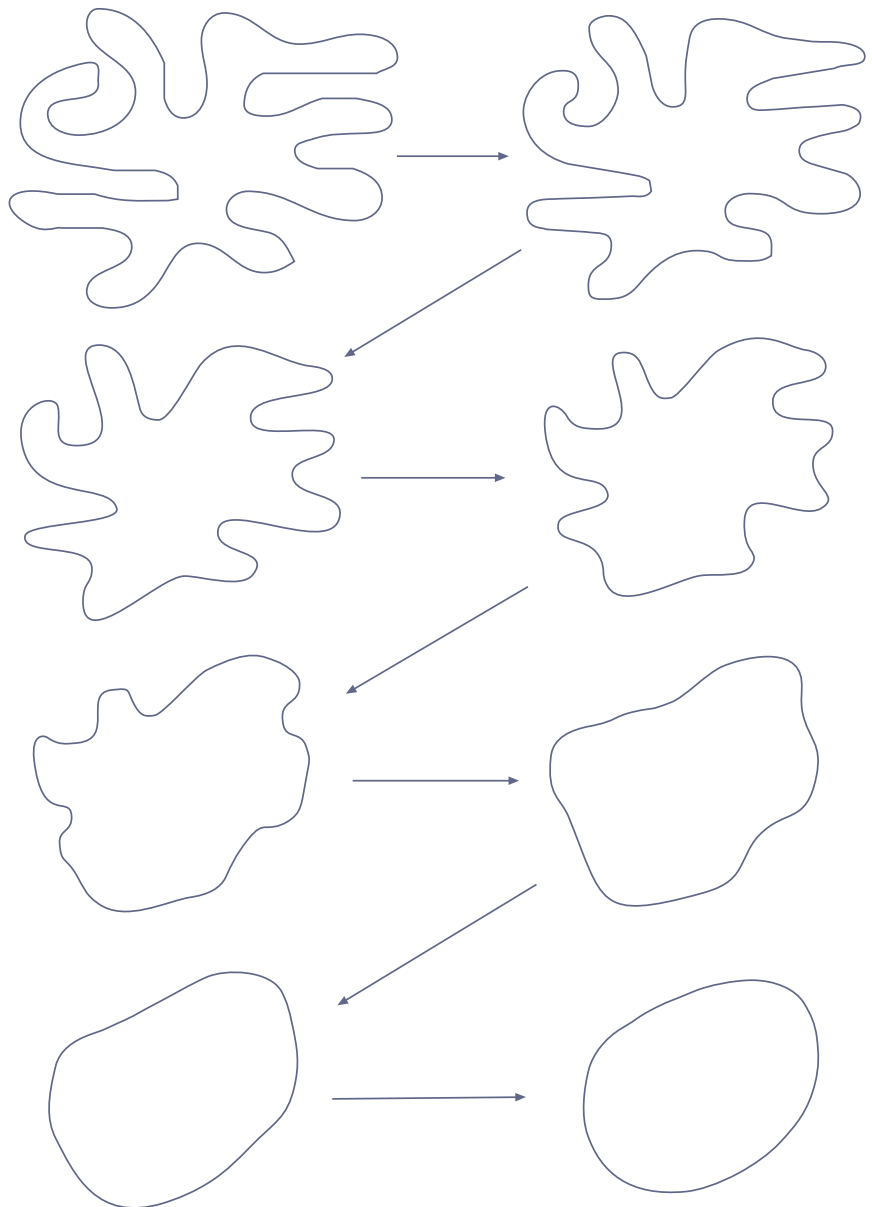
A corresponding result for mean curvature flow of hypersurfaces with positive mean curvature in spaces of dimension at least 4 was proved in a series of papers by Huisken and Sinestrari. Their technique does not apply for surfaces in space, but a new breakthrough was recently made by Brendle and Huisken, allowing the mean curvature flow with surgery for embedded compact surfaces with positive mean curvature in three-

dimensional space to be understood.

While the workshop discussed many other areas of research as well, quite a few talks were devoted to geometric heat equations: these included talks by Yoshi Tonegawa (Tokyo Tech), Duong Phong (Columbia), Haotian Wu (Sydney), Hayk Mikayelyan (Ningbo) and Frederick Tsz-Ho Fong (Hong Kong).

In particular, Gerhard Huisken’s talk at the conference described his recent breakthrough with Simon Brendle. They consider hypersurfaces in Riemannian manifolds, satisfying a natural curvature inequality. In the simplest case, one assumes that the sectional curvatures

of the background are non-negative, and that the sum of any two principal curvatures of the hypersurface are positive at any point. They define a fully nonlinear heat equation with surgery, which deforms the hypersurface through a sequence of neck-pinching singularities, ending up with a collection of spheres and tori. This is a remarkable result. They are forced to work with a fully nonlinear heat equation by the geometric requirements of the problem, but still manage to derive strong enough estimates to control the solution through the surgery process.



A photograph of Professor Maria Vlasίου, a woman with dark hair and glasses, wearing a blue and green patterned top. She is standing behind a podium, gesturing with her right hand while speaking. A laptop is open on the podium in front of her. The background is a plain, light-colored wall.

Lecture Series 2

2017 AMSI-ANZIAM Lecturer Professor Maria Vlasίου

PHOTO: MICHAEL SHAW

2 | LECTURE SERIES

Our compelling outreach program continues to foster critical engagement and discussion to build the profile and impact of Australia's mathematical sciences. National tours and specialist lectures provide powerful opportunities for students, emerging and established researchers and the community to engage with cutting edge scientific discovery and emerging ideas.

In 2016 and 2017 AMSI sponsored **8** specialist talks and **7** public lectures through the AMSI-SSA and AMSI-ANZIAM Lecture series

“An essential platform to strengthen research ties, these events highlight mathematics and statistics as an innovation driver.”

Professor Geoff Prince, AMSI Director

Lecture Series

2.1	AMSI-SSA Lecturer.....	48
	Interview: Encounters with Randomness.....	49
2.2	2017 AMSI-ANZIAM Lecturer.....	50
	Interview: Making Decisions in the Face of Uncertainty	51
2.3	ACE Short Courses and Seminars	52

2.1 AMSI-SSA LECTURER

Professor Jeffrey Rosenthal, University of Toronto, Canada
28 November – 15 December 2016

Co-sponsored with SSA, the bi-annual sponsorship of this Lecture Tour provides the research and general communities with an opportunity to hear from top international statisticians.

Taking in the best of Australia and the Statistical Society of Australia's annual conference, Canadian statistician Professor Jeffrey Rosenthal shared his work with technical and general audiences in Queensland, NSW, Victoria, ACT and South Australia. Attended by all ages, his four popular public lectures took an entertaining look at the daily impact of randomness, probability and statistics on our lives.

The tour attracted significant national and local media coverage including radio interviews in Sydney and Melbourne as well as on ABC Radio National, and articles in newspapers, including *The Australian Financial Review* (national), the *Herald Sun* (Melbourne) and *The Advertiser* (Adelaide) and online.

Biography

Jeffrey Rosenthal is a professor in the University of Toronto's Department of Statistics. He received his BSc from the University of Toronto at the age of 20, his PhD in Mathematics from Harvard University at the age of 24, and tenure at the University of Toronto at the age of 29. He received the 2006 CRM-SSC Prize, the 2007 COPSS Presidents' Award, the 2013 SSC Gold Medal, and teaching awards at both Harvard and Toronto. He is a fellow of the Institute of Mathematical Statistics and of the Royal Society of Canada.

Professor Rosenthal's book for the general public, *Struck by Lightning: The Curious World of Probabilities*, was published in 16 editions and 10 languages, and was a bestseller in Canada, leading to numerous media and public appearances, and to his work exposing the Ontario lottery retailer scandal. He has also dabbled as a computer game programmer, musical performer, and improvisational comedy performer, and is fluent in French. His web site is www.probability.ca.

2016 AMSI-SSA LECTURER

JEFFREY ROSENTHAL
 Professor of Statistics, University of Toronto

TOURING IN AUSTRALIA 28 NOV – 16 DEC 2016

SPECIALIST LECTURES	PUBLIC LECTURES
THE MATHEMATICS OF MARKOV CHAIN MONTE CARLO	FROM LOTTERIES TO POLLS TO MONTE CARLO
11.30–12.30PM MON 28 NOV QUEENSLAND UNIVERSITY OF TECHNOLOGY	6–7PM MON 28 NOV THE UNIVERSITY OF QUEENSLAND & QUEENSLAND UNIVERSITY OF TECHNOLOGY
2–3PM TUES 29 NOV MACQUARIE UNIVERSITY	6–7PM WED 30 NOV THE UNIVERSITY OF NEW SOUTH WALES
11.30–12.30PM WED 30 NOV UNIVERSITY OF TECHNOLOGY SYDNEY	6–7PM TUES 13 DEC UNIVERSITY OF ADELAIDE & THE STATISTICAL SOCIETY OF AUSTRALIA
2.30–3.30PM THURS 1 DEC UNIVERSITY OF WOLLONGONG	6–7PM THURS 15 DEC AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE
11.30–12.30PM THURS 15 DEC LA TROBE UNIVERSITY	

RESEARCH.AMSI.ORG.AU/AMSI-LECTURER

AMSI RESEARCH

Specialist Lecture

The Mathematics of MCMC

This talk explored Markov chain Monte Carlo (MCMC) algorithms, such as the Metropolis Algorithm and the Gibbs Sampler, which are extremely useful and popular for approximately sampling from complicated probability distributions through repeated randomness. Frequent applications include such diverse subjects as Bayesian statistics, physical chemistry, medical research, financial modelling, numerical integration, and more. Drawing on simple graphical simulations, Professor Rosenthal demonstrated how these algorithms work, why they are so useful and how mathematical analysis provides deeper insights into their implementation, optimisation, and convergence times and ability to *adapt* algorithms to improve their performance on the fly.

Public Lecture

From Lotteries to Polls to Monte Carlo

Professor Rosenthal took Australian audiences on an engaging exploration of randomness and probability and how they help us answer fascinating and often important questions. How unlikely is it to win a lottery jackpot? If you flip 100 coins, how close will the number of heads be to 50? How many dying patients must be saved to demonstrate that a new medical drug is effective? Why

do strange coincidences occur so often? If a poll samples 1,000 people, how accurate are the results? How did statistics help to expose the Ontario Lottery Retailer Scandal? If two babies die in the same family without apparent cause, should the parents be convicted of murder? Why do casinos always make money, even though gamblers sometimes win and sometimes lose? And how is all of this related to Monte Carlo Algorithms, an extremely popular and effective method for scientific computing?

SSA Conference Plenary Talk

Adaptive MCMC for Everyone

Markov chain Monte Carlo (MCMC) algorithms, such as the Metropolis Algorithm and the Gibbs Sampler, are an extremely useful and popular method of approximately sampling from complicated probability distributions. Adaptive MCMC attempts to automatically modify the algorithm while it runs, to improve its performance on the fly. However, such adaptation often destroys the ergodicity properties necessary for the algorithm to be valid. In this talk, we first illustrated MCMC algorithms using simple graphical Java applets. Addressing the SSA annual conference, Professor Rosenthal explored adaptive MCMC, and presented examples and theorems concerning its ergodicity and efficiency and explored recent ideas to make adaptive MCMC more widely applicable in broader contexts.

Encounters with Randomness

An interview with Jeffrey Rosenthal, University of Toronto

Can you tell me a little about yourself? Was mathematics a natural curiosity for you or did you have key mentors who shaped your interest along the way?

Actually, I had a lot of mathematical people in my family: both of my parents, one grandfather and one uncle taught math, while another grandfather was an accountant. So, this made it seem “natural” to me to study math, whereas many other people think studying math is “weird”, even if they are good at it. Then, of course, I had lots of good math teachers along the way, in high school and undergraduate studies and doctoral studies, who all taught me lots of things.

Your research focuses on statistics and probability. Can you tell me a little about this area and why it interests you?

I think statistics and probability are fascinating subjects. Not only are they interesting mathematically, they also have applications to almost every aspect of our lives—whenever we're not sure what will happen next. And in the modern computer age, there is more data available to analyse than ever before.

What are you currently working on? Do you have any new research such as recent papers, books or articles?

I continue to be actively engaged in research. Much of my work is about “Markov chain Monte Carlo algorithms”, which are special computer algorithms, which use randomness to help us compute difficult quantities. They are extremely popular in many sciences, with applications to medical research, economics and finance, genetics, computer science, chemical physics and many other areas. I also continue to work with researchers in other fields, most recently about game theory voter models. Plus I still write articles about mathematical ideas for a general audience; in recent years I have written articles about probability and justice, the mathematics of scaling, pi instant, the lottery retailer scandal, the mathematics of music and the Monty Hall problem.

There has been a strong response to your public appearances and your book *Struck by Lightning: Curious World of Probabilities*. Why

do you think statistics and probability resonates so strongly with general audiences? What can they tell us about the world?

Everyone has encounters with randomness and uncertainty, from coincidences to gambling, from crime rates to medical decisions, from lottery jackpots to terrorist attacks to opinion polls and so much more. The stories are easily relatable and of obvious importance, even if they also connect to mathematical formulas.

You are known for your work exposing the Ontario lottery retailer scandal. Can you tell us a little about this and how your involvement in this came about?

A Canadian investigative news television program, the Fifth Estate, asked me to look into whether people who sold lottery tickets were winning more often than could be explained by chance. So, I did some calculations, and it turned out that they were! I was amazed that the resulting story quickly became major front-page news in Canada and lead to numerous consequences including legislative debate, the firing of two CEOs, several criminal charges, jail time and payouts totalling over twenty million dollars.

As the 2016 AMSI-SSA Lecturer, what was the most important message you wanted people to take away from these events?

Randomness and uncertainty surround us everywhere, but through simple logical thinking and the understanding of a few easy principles, we can better understand the randomness, and thus make better decisions and avoid unnecessary fears.

What engagement have you had with industry, how are statistics applied to drive innovation and optimisation?

Statistics are extremely popular in industry right now. Loads of companies, from medical researchers to financial institutions to software developers to marketing analysts to computer innovators, are all looking for “data scientists”, i.e. people who understand and can apply statistics to diverse data using computer analysis.

“I have done consulting work for various industries helping them to analyse data and develop new probabilistic models. More importantly, I see that they are always trying to hire our best students!”

PHOTO: MICHAEL SHAW

2.2 2017 AMSI-ANZIAM LECTURER

Professor Maria Vlasiou, Eindhoven University of Technology, Netherlands 13–22 February 2017

Co-sponsored with ANZIAM, this bi-annual Lecture Tour brings eminent international researchers to Australia, giving the research community and general public an opportunity to hear from top mathematical scientists.

Associate Professor Maria Vlasiou's 2017 AMSI-ANZIAM Lecturer tour included universities in Adelaide, Perth, Melbourne and Sydney. With research interests spanning stochastic processes and operations research, and a focus on practical problems in industrial settings, she explored the analysis of non-traditional stochastic models, such as healthcare logistics, warehouse systems and traffic control.

This series was well attended, including audiences of more than 60 in Adelaide and more than 80 in Melbourne.

Biography

Maria Vlasiou is an Associate Professor in the Department of Mathematics and Computer Science at the Eindhoven University of Technology (TU/e), a Research Fellow of the European research institute Eurandom, and a Scientific Staff member of CWI. Born in Greece in 1980, she received her B.Sc. (2002, Hons.) and Ph.D. (2006) from the Aristotle University of Thessaloniki and TU/e, respectively. In 2006, she moved to the H. Milton Stewart School of Industrial and Systems Engineering at the Georgia Institute of Technology (USA), where she first worked as a Research Engineer and later on as a Postdoctoral Fellow. She joined the Eindhoven University of Technology in 2008.

Her research interests centre on stochastic processes and stochastic operations research, with a focus on the performance of stochastic processing networks with layered architectures and on perturbation analysis for heavy-tailed risk models. Other interests include Lévy processes, large deviations for non-monotone stochastic recursions, and proportional fairness in heavy traffic for bandwidth-sharing networks. She has supervised four PhD theses on these topics that have received the Willem van Zwet runner-up award and a Stieltjes-prize finalist position.

Associate Professor Vlasiou has been invited to more than 20 foreign universities for collaboration and seminars. She has been associate editor in 2 journals and has refereed for about 45 international journals, conferences and national science foundations. Associate Professor Vlasiou's research so far has been funded by grants from more than 10 science foundations, universities, societies, and organisations. She is the co-author of more than 30 refereed papers, the co-recipient of the best paper award in ICORES 2013, the Marcel Neuts student paper award in MAM8, and the 3rd prize of the 8th conference in Actuarial Science.

2017 AMSI-ANZIAM LECTURER
MARIA VLASIOU
ASSOCIATE PROFESSOR, EINDHOVEN UNIVERSITY OF TECHNOLOGY

**TOURING IN AUSTRALIA
13–22 FEBRUARY 2017**

PUBLIC LECTURES
QUEUES ON INTERACTING NETWORKS
6:00PM MONDAY 13 FEB
THE UNIVERSITY OF ADELAIDE
4:00PM WEDNESDAY 15 FEB
THE UNIVERSITY OF WESTERN AUSTRALIA
6:15PM FRIDAY 17 FEB
THE UNIVERSITY OF MELBOURNE

SPECIALIST LECTURES
LAYERED AND INTERACTING QUEUES
1:00PM TUESDAY 21 FEB
VICTORIA UNIVERSITY
HEAVY-TRAFFIC LIMITS FOR LAYERED QUEUEING NETWORKS
2:00PM WEDNESDAY 22 FEB
THE UNIVERSITY OF SYDNEY

RESEARCH.AMSI.ORG.AU/AMSI-LECTURER ▲

AMSI ANZIAM SOCIETY OF MATHEMATICS IN AUSTRALIA AMSI RESEARCH

Public Lecture

Queues on Interacting Networks

We have all had the unpleasant experience of waiting for too long in some queue. We seem to lose a significant amount of time waiting for some operator to reply to our call or for the doctor to be able to see us. Queues are the object of study of queueing theory, i.e. the branch of applied mathematics that studies models involving a number of servers providing service to at least one queue of customers. Queues are an example of a stochastic process and a group of connected queues is an example of a network. Providing a brief overview of the area of stochastic processes, this talk covered a range of examples of their impact from the classroom to industry and technology. Introducing networks with interacting architectures and looking at different architectures through examples, Maria explored the mathematical challenges that these interactions create and the importance of incorporating this level of detail in mathematical analysis.

University of Sydney Specialist Lecture

Heavy-Traffic Limits for Layered Queueing Networks

Heavy-traffic limits for queueing networks are a topic of continuing interest. Presently, the class of networks for which these limits have been rigorously derived is restricted. An important ingredient in such work is the demonstration of state space collapse (SSC), which, loosely speaking, shows that in diffusion scale the queueing process for the stochastic model can be approximately recovered as a continuous lifting of the workload process. This often results in a reduction of the dimensions of the original system in the limit, leading to improved tractability. This talk explored diffusion approximations of layered queueing networks using two case studies. The first focused on heavy-traffic limits through SSC for a computer network mode, with the second exploring a network of parallel single-server queues where server speeds vary over time governed by a single continuous-time Markov chain.

Making Decisions in the Face of Uncertainty

An interview with Maria Vlasiou, Eindhoven University of Technology

What drew you to your area of research?

A wish to do maths for what I considered practically relevant problems. I wanted to be connected in some manner to the society that raised me. I now realise that even what is called “pure” mathematics has practical applications. I find this distinction misleading, artificial, and thus not helpful. But there you go, I was a victim of labelling. (And a happy one at that, as I love my area. I do wonder though if this is because I love research or because of the area per se. I typically find this a philosophical question of little worth and simply go on doing things in an area I enjoy.)

Your public lecture explored connected queues known as networks, can you give me some practical examples of such networks and their industry impacts?

Queuing theory has made an impact in virtually any field in which there is competition for scarce resources and where strategic and/or operational decisions need to be made facing uncertainty. Indeed, as you mention, examples are the dimensioning of telephone networks (since 1909, started by Erlang), the design of the early Internet (Kleinrock in the 60s) and other telecommunication networks, and the operations of manufacturing systems and telephone call centres. Many of my direct colleagues are working on traffic lights. Current interests in the area focus on health care logistics, energy problems and self-organising networks.

What are you currently working on?

I currently work on a specific type of queuing networks, which I call layered networks. Traditional queuing networks have entities that provide service (e.g. a doctor) and entities that receive service (e.g. a patient). I work on networks where these lines are blurred. Think of a person installing solar panels on their roof. She uses the mains and the energy she produces and sells any excess to back to the main electricity supplier (after all, energy is not produced on a fixed rate and how you produce energy may not correspond to your usage patterns. Thus, though you buy energy, you may still have excess to sell.) Such a person is both a customer and a producer (i.e. server).

This double role causes all sorts of mathematical problems when trying to design models capturing the relationship between supplier and customer. Oftentimes, in these layered networks, traditional techniques we have developed in queuing theory do not work as well or lead to surprising results. Ultimately, it is these mathematical peculiarities that drive me.

As 2017 AMSI-ANZIAM Lecturer, what was the most important message you wanted people to take away from these events?

My primary wish (and concern) for the public lecture was to be able to convey the far-reaching implications of the material we are taught using my area as an example.

At school (any grade, university even), we are inevitably taught things in a constructive way. We start with simple notions and build upon them one step at a time. It might be hard to see where all this goes. I have heard this “complaint” from many adults who have completed their education, that as a XXX professional (e.g. nurse) they never had to use the YYY mathematical notion that tortured them during their school years (e.g. ODEs). Thus, my goal was to show how “boring” school exercises are the first stepping stone for a wonderful theory that impacts our lives on a daily basis. I hope to start with

a “boring” maths exercise we are taught in our first course in probability or stochastic processes and move all the way to my own research. If all that also conveys my love of exploration and excitement of being in a position to give this to other people, well, then I’ll be a very happy speaker.



PHOTO: MICHAEL SHAW

2.3 ACE SHORT COURSES AND SEMINARS

Through the ACE Network, AMSI offers a variety of seminars and short courses of interest to members.

Advanced Collaborative Environment (ACE) Network

The Advanced Collaborative Environment (ACE) at AMSI member universities enables maths departments to collaborate through advanced video conferencing and desktop sharing facilities. It has been established to facilitate greater collaboration between the mathematical sciences community both within Australia and internationally.

Fourteen Australian universities — about half of AMSI's 29 member and non-member universities — belong to the ACE Network. In addition to offering honours courses (see page 75), the facilities are used to bring interest groups from the mathematical sciences community together for workshops and seminars.

2.3.1 ACEMS/AMSI Workshop on Measuring Research Engagement and Impact in the Mathematical Sciences

28 September 2016

In 2016, the ACE Network facilitated a workshop on the Australian Research Council and Excellence in Research Australia's proposed national framework for the assessment of the engagement and impact of university research.

Attendees included representatives from AMSI, AustMS, ACEMS and a number of university mathematical sciences departments. Participants in the workshop focused on a number of aspects of the proposed framework including:

- What engagement and impact mean in the context of the mathematical sciences
- How impact and engagement should be measured
- Current structures for industry collaboration and how these can be built upon
- How *blue sky* research fits into the picture and how the engagement and impact of fundamental research can be measured

This discussion informed development of a joint response to the ARC consultation submitted by AMSI, the Australian Mathematical Society and the ARC Centre of Excellence of Mathematical and Statistical Frontiers (ACEMS).

Speakers

Moderator: Prof. Peter Taylor, Australian Laureate Fellow, The University of Melbourne, Director of ACEMS

Leanne Harvey, ARC Acting Chief Executive Officer

Prof. Kerrie Mengersen, Australian Laureate Fellow, Queensland University of Technology, Deputy Director of ACEMS

Prof. Geoff Prince, Director of AMSI

Prof. Tim Marchant, Professor of Applied Mathematics and Dean of Research, University of Wollongong, President of AustMS

Prof. Jacqui Ramagge, Head, School of Mathematics and Statistics, The University of Sydney

2.3.2 AustMS/AMSI Teaching Seminar Series

This nation-wide seminar series includes talks and discussion forums with a focus on academic teaching of mathematics and statistics at universities. The events aim to strengthen engagement between university teaching staff within Australia's mathematical sciences departments (and related areas) and broader networks with a vested interest in university mathematics and statistics education best practice.

Commencing March 2017, this series is an initiative of the AustMS Standing Committee on Mathematics Education in response to an identified need for an online seminar series for university mathematics teaching.

Seminar: Active Learning in a Large First-Year Discrete Mathematics Course

Dr Barbara Maenhaut, The University of Queensland
29 March 2017

The seminar explored the implementation of active learning techniques, including achievement data and feedback from students.

Used to describe a range of teaching practices to encourage students to think rather than listen passively in class, the benefits of active learning are well documented within tertiary science and

mathematics. Recently, the University of Queensland implemented these approaches as part of first-year discrete mathematics MATH1061. This course has an enrolment of approximately 400 students each semester, including students in Information Technology, Software Engineering and Mathematics.

Seminar: The Choose Maths Program and Teacher Education, Experience and Confidence

Associate Professor Inge Koch, Executive Director, AMSI Choose Maths

19 April 2017

The seminar introduced AMSI's Choose Maths program, which aims to increase participation of women in mathematics education, including tertiary education, to change awareness of the importance of mathematics, and to improve the career paths for women in STEM-related disciplines.

The results of the Choose Maths teacher surveys for primary and secondary teachers were presented and implications of the results were discussed.

Forum: Women in Research and Higher Degrees in the Mathematical Sciences

23 June 2017

Australia has a long history of low female participation within the mathematical sciences, a problem that has deepened over the past decade with a further decline in the number and proportion of female Honours students. Growing international student enrolments have prevented a similar decline in the number and proportion of female PhD students.

With an urgent need to address gender equity in research and higher degrees in mathematics and statistics, this forum helped stimulate much-needed discussion within the mathematical community. The panel members shared their own student and academic experiences of the discipline, providing opportunity to reflect on effectiveness of current measures and approaches.

Speakers:

Discussion leader: Assoc. Prof. Yvonne Stokes, Chair, Women in Mathematics Special Interest Group; The University of Adelaide

Prof. **Peter Bouwknegt**, Director Mathematical Sciences Institute, The Australian National University

Assoc. Prof. Inge Koch, AMSI Choose Maths Executive Director; The University of Adelaide

Courtney Darville, Honours student in Pure Mathematics, The University of Sydney

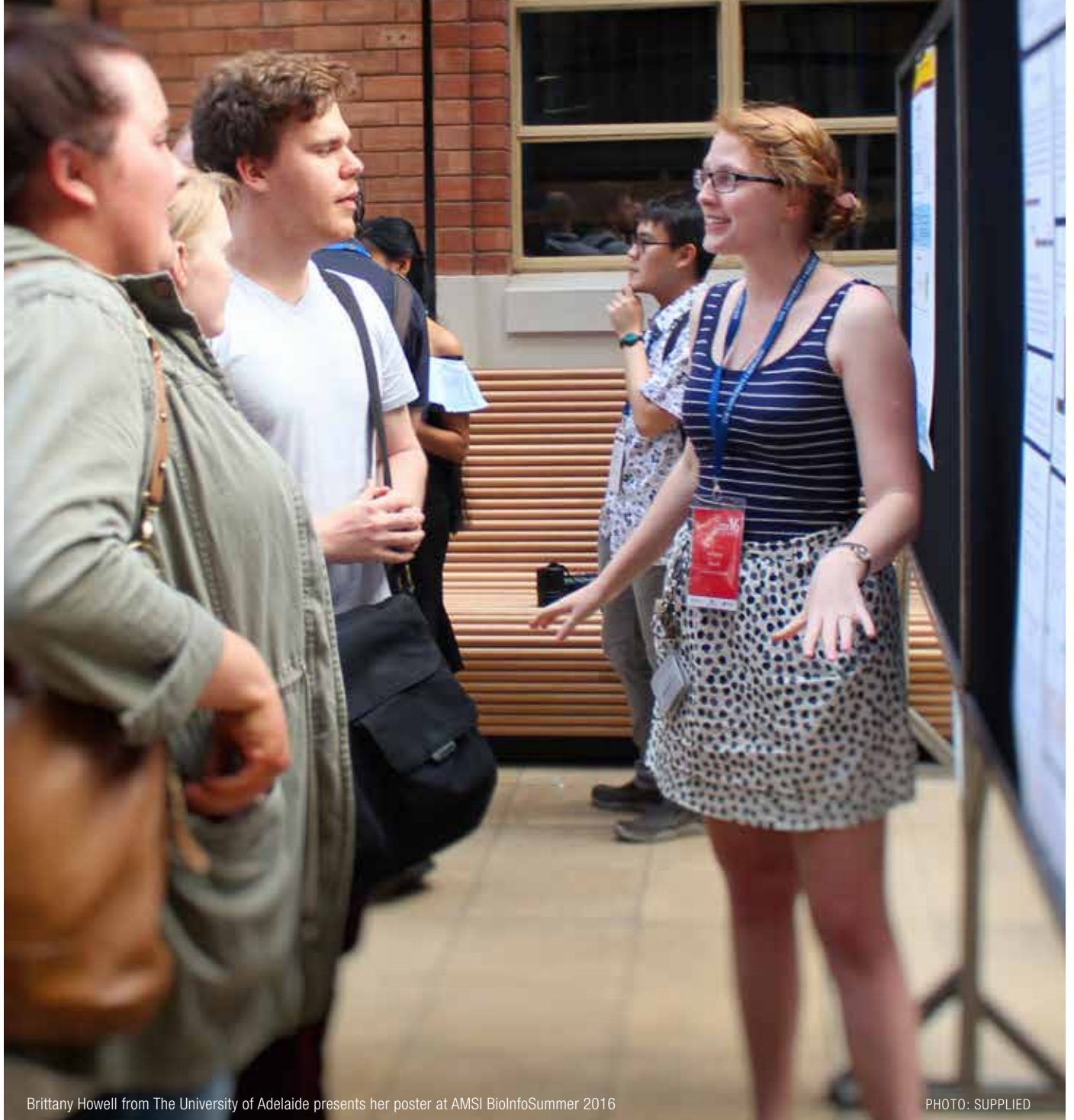
Prof. Cheryl Praeger, Professor of Mathematics, The University of Western Australia

Rheanna Mainzer, PhD student in Statistics, La Trobe University



PHOTO: MICHAEL SHAW

Research Training 3



Brittany Howell from The University of Adelaide presents her poster at AMSI BioInfoSummer 2016

PHOTO: SUPPLIED

3 RESEARCH TRAINING

AMSI's national research training infrastructure sets the gold standard for discipline-wide higher degrees by research (HDR) graduate training in Australia.

Established in 2003, our flagship training schools, graduate courses and scholarships prepare STEM graduates to engage in cross-disciplinary research and drive industry innovation. This year's training program attracted over 560 students and researchers, with the launch of AMSI Optimise strengthening links between the mathematical sciences and industry.

564 attendees at AMSI flagship programs
39% female participants, **29%** undergraduate students,
42% postgraduate students and **3%** ECRs
83 students received AMSI Travel Grants and **36** female
 students received Choose Maths Travel Grants

“AMSI's popular flagship training programs span the mathematics education pipeline, from Honours students wanting a taste of real research to postgraduate and early career researchers building their skillsets to tackle mathematical challenges from research to industry and everywhere in between.”

Professor Markus Hegland, AMSI Deputy Director and Chair, RHE Advisory Committee

Research Training Events

3.01	AMSI Winter School on Biological and Environmental Modelling, 2016	56
	Land of Geometry to Environmental Modelling	57
3.02	AMSI BioInfoSummer 2016.....	60
	YouTube to BioInfoSummer: the Guts of Data Analysis	61
3.03	AMSI Summer School 2017	62
	From Euclid and Boole to Summer School	63
3.04	AMSI Optimise.....	66
	The Importance of Optimisation.....	68
3.05	AMSI Vacation Research Scholarships 2016/17	70
	VRS STORIES	72
	Choose Maths Grants.....	74
	Choosing Maths to Fight Cancer	74
3.07	Advanced Collaborative Environment (ACE) Network.....	75
3.08	Heidelberg Laureate Forum.....	76
	Interview with the 2016 Heidelberg Laureate Forum Travel Fund Recipients.....	76
3.09	Early Career Workshop at the AustMS 2016 Conference	77
3.10	Women in Mathematics.....	78
	Interview with Professor Asha Rao: Mentoring the Next Generation	80

AMSI co-funds a program of vacation schools and scholarship programs with the Australian Government Department of Education and Training.

3.01 AMSI WINTER SCHOOL ON BIOLOGICAL AND ENVIRONMENTAL MODELLING, 2016

4–15 July 2016, The University of Queensland

A two-week residential training program, AMSI Winter School is a popular destination for graduate students, postdoctoral fellows and early career researchers in the mathematical sciences. With a focus on skills development and fostering essential research networks, the program features a lecture panel of prominent international and Australian field leaders, as well as social events, guest public lectures, careers sessions and a panel discussion on women in the mathematical sciences.

Hosted by the University of Queensland, the 11th annual AMSI Winter School explored contemporary aspects of biological and environmental modelling. Aimed at postgraduate students and postdoctoral fellows in the mathematical sciences and related disciplines, the courses expand on traditional academic programs to expose participants to new skillsets and areas of research.

Over two weeks, 45 students and early career researchers participated in a series of mini-courses, introductory lectures and specialist lectures. The program focused on biological modelling in Week 1 and environmental modelling in Week 2, enabling participants to expand their skills, and broaden and deepen their mathematical knowledge.

In a program highlight, Professor Hugh Possingham, Director of the ARC Centre of Excellence for Environmental Decisions, led a fascinating public lecture on decision science. Using powerful examples such as the Great Barrier Reef, he explored the value of monitoring and information for achieving nature conservation outcomes and used decision science tools (optimisation) as the framework for deciding which research is useful.

Women in Maths once again proved a drawcard with this year's networking event hosted by AMSI and Australian Mathematical Society's (AustMS) Women in Mathematics Special Interest Group (WIMSIG) attracting over 70 people attending including Winter School attendees and invited academic guests. Panellists included Professor Kerry Landman (The University of Melbourne), Julia Bruerton (Brisbane Grammar School) and Ellie Foxcroft (Biarri). The event stimulated a lively discussion on current issues

facing women in mathematics and their contributions to the field.

Other events included a guest lecture from Professor Geoffrey Goodhill on computational neuroscience research at the Queensland Brain Institute and several social events.

WS.AMSI.ORG.AU

Director: Dr Phillip Isaac, The University of Queensland

EVENT PARTICIPATION

- 45** Attendees
- 42%** Female participants
- 6%** Undergraduate students
- 80%** Postgraduate students
- 4%** Early career researchers

PARTICIPATION SUPPORT

- 18** Students from **12** member universities received AMSI Travel Grants
- 5** Female attendees received Choose Maths Grants to support their participation

“The interplay between modelling and experiment was often revisited throughout the academic program—emphasising the importance of mathematical models, rather than presenting reproduced existing experimental results, but predicting new and unanticipated results.”

**Dr Phillip Isaac, AMSI Winter School 2016 Event Director,
The University of Queensland**



Dr Phillip Isaac, Prof. Joseph Grotowski, Andree Phillips, Anne Nuguid and Prof. Markus Hegland

PHOTO: ANJANETTE WEBB

AMSI Winter School 2016 attendees were given the opportunity to give a 15-minute presentation on the area of their research or a related field to assist in building networks, and share study investigations with peers. Q&A sessions at the end of each talk proved powerful platforms for establishing new collaborative networks. The overall winner was determined through a secret vote at the end of the final session.

2016 winner Vira Koshkina (RMIT University) was acclaimed for her presentation on *Stochastic ecological models for predicting species distribution and extinction*. Earning an honourable mention and second place, David Harman (Griffith University) also impressed with his presentation *Applying generalised polynomial chaos to epidemic models with individualised parameter distributions*.

Land of Geometry to Environmental Modelling



AS SHE READ ABOUT THE ADVENTURES OF DOT, PENCIL, LINE and the villainous eraser in the popular Ukrainian children's book *Journey in the Land of Geometry*, Vira Koshkina could never have imagined she was already on a path that would lead her to Australia and a career in mathematical ecology.

Fast forward to 2016 and the Mathematical Ecology PhD student is buzzing from her experience at AMSI Winter School.

"As a maths student, you spend a lot of time working on your own or within your fixed research group. It was exciting to connect with ambitious researchers from around Australia and explore different areas of mathematics and opportunities for future collaboration," she says.

Given her area of research, this year's theme of biological and environmental modelling was perfect for Vira.

"I research species distribution models, so environmental modelling was very relevant and interesting for me. I love this area, as there is something magical about the fact we can use mathematical formulas to describe something as complex as animal distribution," she explains.

While she may be busy mapping species, her future is a different matter. She believes, "doing research in something as fundamental as maths opens all kinds of doors. Whatever I do, I hope it will make people's lives better."

Singing the event's praises, Vira is quick to point out Winter School's enormous value as a student-networking platform – essential as you establish a career in science.

"The friendships and collaborations we made will stay with us for a long time. It was an amazing opportunity to see what else is out there and learn about other approaches you can use in your own work"

Vira Koshkina received an AMSI Travel Grant to attend AMSI's 2016 Winter School.



PHOTO: ANJANETTE WEBB

Course Details

Our Second Brain: Modelling its Development and Disease

Prof. Kerry A. Landman, The University of Melbourne

The enteric nervous system is responsible for normal stomach function and peristaltic contraction. Embryonic development of the enteric nervous system involves the colonisation of the stomach wall from one end to the other by a population of proliferating neural crest cells. Failure of these cells to invade the whole stomach results in the relatively common, potentially fatal condition known as Hirschsprung's disease.

This course explored cell invasion, whereby cells move and undergo cell division, which occurs in tumour growth, wound healing and during embryonic development. A perfect example of this is the development of the enteric nervous system (ENS) in our gastrointestinal tract. The connection between our brain and our stomach leads to the nickname for the enteric nervous system as the *second brain*.

Mathematical modelling, both continuum and discrete, was shown to provide insight into the key biological processes required for complete colonisation, and to the generation of experimentally testable predictions. This gave rise to interesting mathematical problems such as the problem of modelling cell proliferation on a growing domain.

Particular emphasis was given to Fisher's equation, with some historical perspective provided. Enlightening derivations of relevant discrete master equations and their continuum limits were discussed. Overall, the audience was treated to deep insights of an accomplished applied mathematician that would enable them to further develop essential mathematical modelling skills.

The Mathematical Modelling of Chemotaxis as a Mechanism for Structure and Pattern in Cell Populations

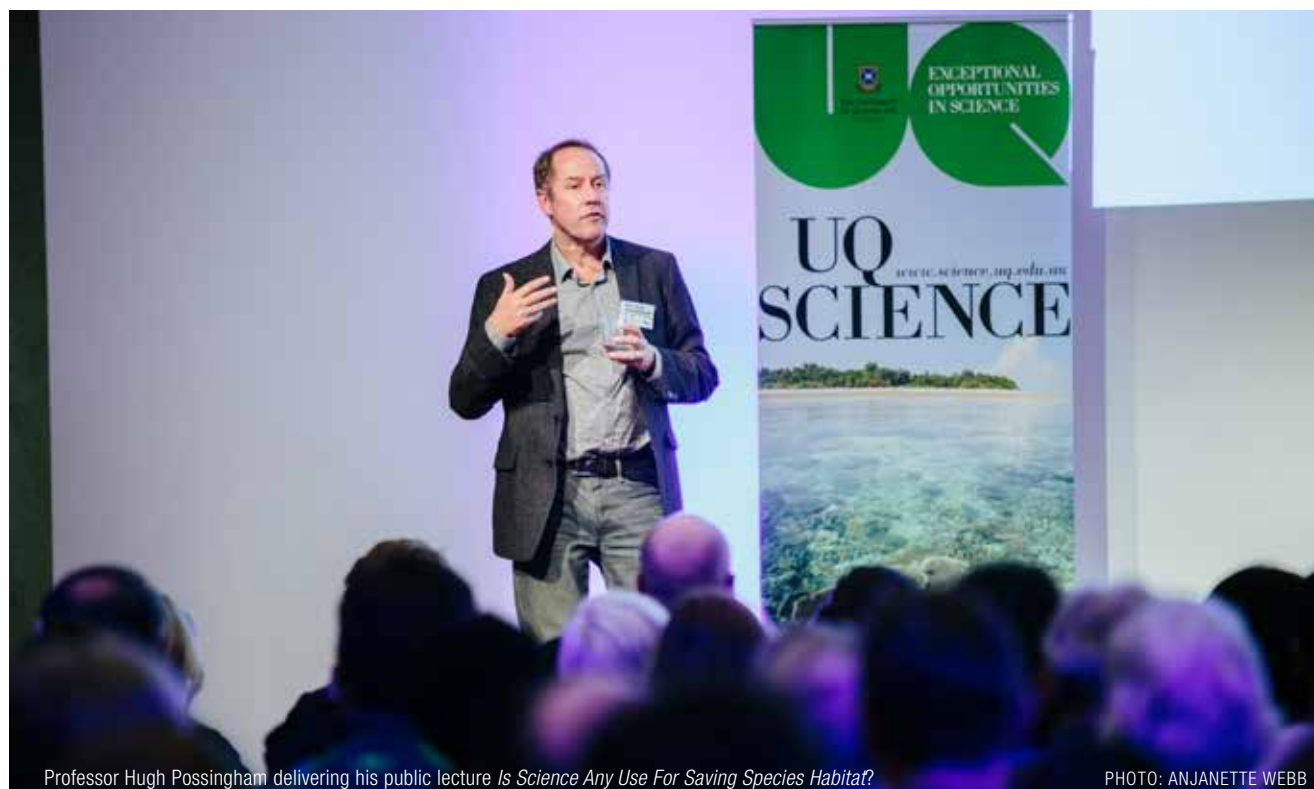
Prof. Graeme Pettet, Queensland University of Technology

Single-celled organisms, and many of the cells found in tissues of higher-order organisms, have the capacity to be motile and in particular respond to gradients in concentration of locally distributed molecules. In certain instances, this directed motility known as chemotaxis provides the underlying mechanism for the formation of striking patterns in tissues and populations of single-celled organisms.

In this course, participants explored methods of mathematical modelling and solutions for classic experimental examples of bacterial chemotaxis and for some more recent models of tissue invasion. Attendees were introduced to the characterisation of travelling wave solutions to many of these models. This was shown to provide a foundation for recent developments in dynamical systems theory that was considered further.

The course predominantly formulated continuum models as coupled systems of partial differential equations, using MATLAB or Mathematica as a tool for exploring numerical simulations. This was compared with known special-case solutions and phase plane methods for exploring the existence of travelling wave solutions and confirming related analytically derived results.

One model that featured throughout the discussions was the Keller-Segel model. Related geometric, analytic and numeric methods were considered, and the connection to travelling wave solutions examined. The audience spent time in the computer lab during this first week, and were introduced to NetLogo as an online visualisation tool and programmable modelling environment.



Professor Hugh Possingham delivering his public lecture *Is Science Any Use For Saving Species Habitat?*

PHOTO: ANJANETTE WEBB

Introduction to the Mathematics of Environmental Decision Science

Dr Eve McDonald-Madden, The University of Queensland

Prof. Hugh Possingham, The University of Queensland

Recent decades have seen a dramatic decline in the plants and animals that supply our food, medicine and clean air — our way of life. Drawing from concepts in mathematics, computer science, economics, social science and ecology, the field of Environmental Decision Science is working at the cutting edge to use theory to inform the management of our natural world.

In this course, the lecturers shared their experience using mathematics in environmental decision science through a sequence of lectures, research examples and problem-solving sessions, covering: structuring environmental decision problems, modelling ecological populations, prioritisations and the knapsack problem, resource allocation and stochastic dynamic programming, game theory and conservation actors, and spatial planning to inform protected area reserve design.

A wide range of related mathematical methods were exhibited throughout the course, from Markov processes to coupled systems of nonlinear differential equations. Emphasis was placed on the construction of models and the interpretation of the mathematical analysis and the prediction of unexpected features.

Short guest presentations from researchers from The University of Queensland were incorporated into the course, demonstrating how they use these theories to inform conservation decisions, as well as computer lab sessions, working through carefully prepared modelling problems and exercises related to topics such as the effect of policy on how people modify their behaviour in the context of wildlife conservation, decision making in the context of relocation of endangered species of birds to protected reserves, and implementation of solutions to the knapsack problem.

The Dynamics of Calcium: The Interaction of Modelling and Experiments

Prof. James Sneyd, The University of Auckland

Modulation of the concentration of free intracellular calcium is one of the most ubiquitous and important intracellular signalling mechanisms. As a result, the study of how intracellular calcium concentration is controlled has become an important research area in cell physiology and signalling. Furthermore, because of the intricate complexities of the calcium response, which exhibits spikes, oscillations and waves, the study of calcium dynamics is one area where there is a close relationship between experimentalists and modellers.

This course gave an introduction to the physiology of calcium dynamics, and described how to construct models of intracellular calcium oscillations and waves. After the delivery of a more generic introduction to the field, the course covered some case examples in more detail.

These applications showed how experiments and theory interact, including smooth muscle contraction, water secretion by secretory epithelial cells, and bursting action potentials in neuroendocrine cells. Modelling oscillations of calcium ions (Ca^{2+}) and inositol (1,4,5)-trisphosphate (IP_3) is just one example of many mathematical models that were used to predict new results.

The course also highlighted aspects of the books *Mathematical Physiology (I: Cellular Physiology and II: Systems Physiology)* by James Keener and James Sneyd, including material on biochemical reactions and cellular homeostasis, excitability and, ultimately, calcium dynamics.

Other Sponsors

Department of Education and Training, The University of Queensland, QCIF, ACEMS, The Simulation Group, BHP Billiton Foundation (part of the Choose Maths initiative).

3.02 AMSI BIOINFOSUMMER 2016

28 November – 2 December 2016, The University of Adelaide

Australia's leading bioinformatics and mathematical and computational biology training event, AMSI BioInfoSummer has been running since 2003. Aimed at undergraduate and postgraduate students, researchers and professionals, it aims to foster Australia's bioinformatics and computational biology research capability.

Fast moving and truly interdisciplinary, bioinformatics uses mathematics, statistics and information technology to analyse and simulate large and complex biological datasets. Helmed by a panel of Australian, European and American field experts, this year's event featured cutting edge research and field developments and hands-on introductory and advanced computer workshops.

More than 200 researchers and students from a variety of scientific backgrounds were inspired and upskilled by an outstanding array of Australian and international speakers and a series of tailored interactive lab sessions.

Other highlights included The University of Sydney's Professor Claire Wade's public lecture, as well as the COMBINE Careers Panel, a Women in STEM lunch and a poster session. Participants also had the opportunity to enter a coding competition.

Best Poster

Katherine Aiello, The University of Utah, *Platform-Independent Genome-Wide Pattern of DNA Copy-Number Alterations Predicting Astrocytoma Survival and Response to Treatment Revealed by the GSVD Formulated as a Comparative Spectral Decomposition*

Best Student Poster

Moeen Riaz, The University of Melbourne, *Uncovering the pharmacogenetic basis of age-related macular degeneration using a next-generation sequencing approach*

Algorithms and Data Structures Competition Winner

Dr Michael Roach, Australian Wine Research Institute

Other Sponsors

Department of Education and Training, The University of Adelaide, BHP Billiton Foundation (part of the Choose Maths initiative), ABACBS, EMBL Australia, Illumina, Flinders University, University of South Australia

Conference Speakers

Speaker	Organisation	Talk Title
Prof. Terry Speed	The Walter and Eliza Hall Institute of Medical Research	Codes, genetics and the genetic code
Dr Philippa Griffin	VLSCI & The University of Melbourne	EMBL Australia Bioinformatics Resource (EMBL-ABR)
Assoc. Prof. Orly Alter	The University of Utah	Cancer diagnostics and prognostics from comparative spectral decompositions of patient-matched genomic profiles
Dr Melissa Davis	The Walter and Eliza Hall Institute of Medical Research	Analysis and visualisation of high-dimensional data using molecular networks
Assoc. Prof. Xia Yang	University of California, Los Angeles	Elucidating gene networks of cardiometabolic diseases via systems genomics
Dr Mingyao Li	University of Pennsylvania	Statistical issues in single-cell RNA sequencing analysis
Prof. Gordon Smyth	The Walter & Eliza Hall Institute of Medical Research	Statistical analysis of RNA-seq data: from reads to genes to pathways
Dr Katherine Pillman	University of South Australia & The University of Adelaide	Alternative splicing: one cell's trash is another's treasure
Dr Jason Chin	Pacific Biosciences	Recent progress in long-read genome assembly: theory, practice and future challenges
Dr Richard Edwards	The University of New South Wales	The SMRT way to sequence a genome: adventures in PacBio sequencing
Dr Denis O'Meally	University of the Sunshine Coast	Sequencing the koala genome with long reads
Dr Thomas Conway	IBM Research Australia & The University of Melbourne	Why I love k-mers, and why you should too
Dr Simon Anders	Institute for Molecular Medicine Finland, University of Helsinki	Exploration of big multi-omics data sets, and comparative analysis beyond DESeq2
Assoc. Prof. Torsten Seemann	The University of Melbourne	How to write bioinformatics software that people will use and cite

Workshops

Workshop leader	Organisation	Workshop Title
Prof. David Adelson	The University of Adelaide	Wet lab introductory session
Assoc. Prof. Gary Glonek	The University of Adelaide	Introduction to statistics session
Prof. Jean Yang	The University of Sydney	
Assoc. Prof. Ville-Petteri Mäkinen	The University of Adelaide	High-dimension data computing lab
Dr Melissa Davis	The Walter and Eliza Hall Institute of Medical Research	
Dr Katherine Pillman	University of South Australia & The University of Adelaide	RNA-seq data computing lab
Prof. David Adelson	The University of Adelaide	Integrating long reads with short reads computing lab
Dr Paul Wang	SA Pathology & The University of Adelaide	Genomics in Python computing lab
Dave Lawrence	Centre for Cancer Biology	
Stephen Pederson	The University of Adelaide	Graphics in R computing lab
Dr Thomas Conway	IBM Research Australia & The University of Melbourne	k-mer manipulation with python computing lab

BIS.AMSI.ORG.AU

Director: Assoc. Prof. Gary Glonek, The University of Adelaide

EVENT PARTICIPATION

- 206** Attendees
51% Female participants
24% Undergraduate students
52% Postgraduate students
7% Early career researchers

PARTICIPATION SUPPORT

- 7** Students from **7** member universities received AMSI Travel Grants
9 Female attendees received Choose Maths Grants

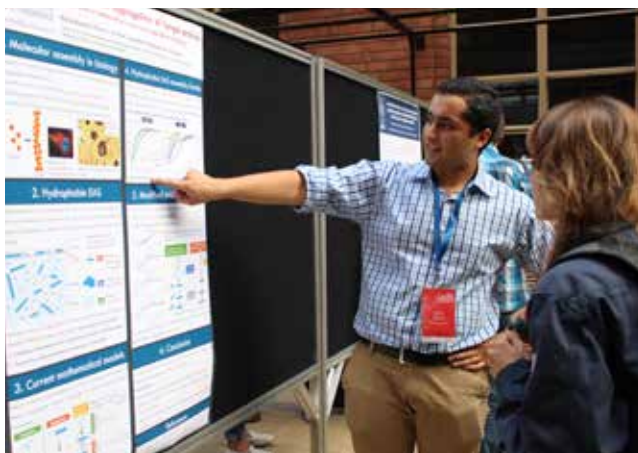
YouTube to BioInfoSummer: the Guts of Data Analysis

HAVING TAUGHT HERSELF CODING using instructional videos on YouTube, PhD student Daniela Gaio arrived at AMSI BioInfoSummer 2016 (BIS) with some gaps to fill. “BIS helped me put the pieces together from my own learning. I came away with a better understanding of the data-analysis steps in genomic, transcriptional and proteomic analysis,” she says.

Currently studying the microbial community of the gut in health and disease, the University of Technology Sydney student also gained valuable contacts within the field.

“I was excited to meet and network with highly-skilled people also working on projects within the bioinformatics space,” she explains.

With a background in genetics, microbiology and neurobiology, Daniela is new to bioinformatics, having entered the field only last year.



“As I strive to understand the health impacts of the microbiome on the gut, bioinformatics allows me to explore different aspects of biology. I can zoom in on cellular processes, use tools to investigate interactions of molecules and make sense out of large datasets,”

Undertaking your own data analysis and learning how to write your own scripts, she believes, is the only way you can fully appreciate your data's meaning.

“Without bioinformatics skills, if the output differs from your expectations you are not equipped to understand the results and seek other explanations for the outcome,” she says.

Daniela Gaio received a Choose Maths Grant to attend AMSI BioInfoSummer in 2016.

3.03 AMSI SUMMER SCHOOL 2017

9 January – 3 February 2017, The University of Sydney

Australia's biggest residential student mathematical sciences event, AMSI Summer School takes students to the cutting edge of mathematical sciences to enhance discipline knowledge and employability. With a commitment to outstanding education and training, sessions count as course credits, with career development and networking opportunities giving students the competitive edge as they pursue their research career.

The 15th annual AMSI Summer School brought together 168 honours and postgraduate students from around the country for an intensive four-week residential program. Students had the opportunity to tackle one or two of the eight intensive honours-level pure and applied mathematics and statistics subjects on offer. Students also benefited from enrichment lectures, social events, a careers afternoon and other special events.

Drawing an attendance of over 300, Assistant Professor Genevera Allen (Rice University, USA) delivered a popular public lecture on *Networks for Big Data*. Featured in the media, this session stimulated a lively discussion.

The 15th annual Summer School Careers Afternoon was also extremely popular, providing the rare chance to network with specialists from industry leaders including Google, the Commonwealth Bank of Australia and the Australian Bureau of Statistics. As well as networking, the session provided insights into career opportunities across the mathematical sciences.

This year's Women in the Mathematical Sciences panel discussion and dinner also proved popular with both Summer School students and external guests. A number of frank and useful pieces of career advice were given by the panel.



PHOTO: VINCENT CHU

“Events such as the AMSI Summer School program are critical for highlighting how math, statistics, and data science can be used to make ground-breaking discoveries from data.”

Assistant Professor Genevera Allen (Rice University, USA)

SS.AMSI.ORG.AU

Director: **Prof. Anthony Henderson**, The University of Sydney

EVENT PARTICIPATION

- 168** Attendees
- 84** Attendees taking course for credit
- 30%** Female participants
- 41%** Undergraduate students
- 55%** Postgraduate students
- 1%** Early career researchers

PARTICIPATION SUPPORT

- 56** Students from **12** member universities received AMSI Travel Grants
- 20** Female attendees received Choose Maths Grants

Course Details

Category Theory and Computer Science

Dr Richard Garner, Macquarie University

Prof. Dominic Verity, Macquarie University

Theoretical computer science enables us to reason in a mathematically rigorous way about computation: e.g. proving that a given program is error-free. Much of this reasoning makes use of category theory, an abstract meta-language for mathematical discourse. This course was an introduction to category theory, with an emphasis on various kinds of monoidal categories.

- Basic notions of category theory
- Braided and symmetric monoidal categories
- Internal homs and duals
- Traced monoidal categories
- Concurrent systems
- Linear logic and *-autonomous categories
- Monoidal categories of games
- Girard's geometry of interaction

Computational Bayesian Statistics

Prof. Scott Sisson, The University of New South Wales

Bayesian statistics could be described as the systematic application of probability to decision-making in the face of uncertainty. After describing the fundamentals of Bayesian inference, this course examined specification of prior distributions, Bayesian model-comparison, Bayesian computational methods and links between Bayesian and classical frequentist inference.

- General introduction to Bayesian statistics and Monte Carlo methods
- Conjugate, improper and Jeffreys priors
- Univariate and multivariate models
- Monte Carlo integration, inversion sampling, rejection sampling, importance sampling
- Loss functions
- Predictive inference
- Posterior asymptotics
- Markov chain Monte Carlo, Gibbs sampling, adaptive rejection sampling, Metropolis-Hastings sampling, auxiliary variable samplers
- Conditional independence graphs
- WinBUGS/OpenBUGS software
- Bayesian hypothesis testing
- Bayes Factors and marginal likelihoods
- Bayes factors with improper priors, imaginary observations, partial Bayes factors, intrinsic Bayes factors, fractional Bayes factors
- Hierarchical models, mixture models, changepoint models

Continued on page 64

From Euclid and Boole to Summer School

A VISIT TO HER LOCAL LIBRARY IN Year 11 changed Diclehan Erdal's life forever when she discovered her future in a book on mathematicians and their breakthroughs.

"I remember reading about Euclid, George Boole and Alan Turing and trying read Euclid's elements and being really drawn to the idea of studying mathematics. I decided to study as much of the subject as I could in Year 12," she says.

Fast forward to 2017 and recent University of Adelaide mathematics and computer science graduate Diclehan is full of excitement and refreshed enthusiasm following her AMSI Summer School experience.

"It not only offered a number of courses aligned with my potential interests but allowed me to meet other students from a wide range of pure mathematics disciplines," she says.

The pure maths major also relished the opportunity to explore research and techniques beyond the scope of her academic studies, knowledge she hopes to apply to her future master's research.



"Summer School introduced me to areas of mathematics I would not have been exposed to otherwise and spiked my interest to learn more about these fields."

In addition to the main program, Diclehan found inspiration and new networks at the Women in Mathematics events.

"As well as raising awareness of the lack of women pursuing mathematics, these events promote the opportunities available to those who do. They are also a fantastic way to meet more women in a male-dominated discipline."

Now a long way from that Year 11 girl in the library, Diclehan plans to make the most of her new knowledge and networks as she wishes to pursue a master's degree and doctorate in mathematics, and ultimately a career in academia or software development.

Who knows? Maybe one day, a high-school student will happen upon a book including her work and they too will be inspired to explore the possibilities and beauty of mathematics.

Diclehan Erdal received a Choose Maths Grant to attend AMSI's 2017 Summer School

Course Details - *continued*

Geometric Group Theory and Harmonic Analysis

Dr Lawrence Reeves, The University of Melbourne

Dr Anne Thomas, The University of Sydney

Groups and geometry are ubiquitous in mathematics. This course introduced students to the study of infinite groups from the geometrical viewpoint, drawing on ideas from low-dimensional topology and from hyperbolic geometry, while making connections to analysis and algebra as well.

- Free groups, presentations
- Decision problems
- Cayley graphs, word metrics and coarse geometry
- Hyperbolic groups
- Amenable groups
- Right-angled Coxeter groups

Harmonic Analysis

Dr Pierre Portal, The Australian National University

Harmonic analysis is a branch of analysis inspired by the decomposition of square integrable functions on the circle into Fourier series. It includes a range of methods to decompose functions defined on certain metric measure spaces (e.g. Euclidean space, Lie groups, Riemannian manifolds) into pieces in such a way that various properties of these functions (e.g. smoothness, integrability, oscillations) can be easily uncovered. This is helpful for a range of problems, from PDE to geometry to number theory. This course concerned the foundations of harmonic analysis on Euclidean space, concluding with Mihlin-Hormander's Fourier multiplier theorem.

- L_p spaces
- Distributions
- Fourier transform
- Maximal functions
- Interpolation
- Calderon-Zygmund decomposition
- Fourier multipliers

Mathematical Biology

Prof. Mary Myerscough, The University of Sydney

Mathematics has a plethora of applications to biological systems. This course covered some of the models and techniques of classical mathematical biology, including population biology, epidemiology, oscillating systems and neural action potentials, and associated mathematical techniques.

- Basic techniques of nonlinear ODEs: phase planes and linear analysis of steady states
- Limit cycles, the Hopf bifurcation theorem, the Poincaré-Bendixson theorem, limit cycle stability
- Slow-fast systems, excitable kinetics and relaxation oscillators
- Stationary bifurcations. Classifying bifurcations using singularity theory
- Travelling wave analysis
- Travelling waves in excitable media
- Epidemiological models. SIR models and extensions. Endemic disease and R_0
- Continuous age/size population models and McKendrick-von Foerster equations. Discrete age- or stage- structured. Leslie matrices. Coates graphs. The Perron-Frobenius Theorem

Mathematics and Statistics of Big Data

Prof. Kerrie Mengersen, Queensland University of Technology

A/Prof. Tomasz Bednarz, Queensland University of Technology & CSIRO Data61

What is this thing called *big data*? What does it mean for the world in general, and for mathematical scientists in particular? What skills do mathematical scientists need to develop in order to engage effectively in the *big data era*? This course addressed these questions and covered some of the theory, methods and computational tools that are useful in modelling, analysis and visualisation of big data.

- Big data: what, where and why?
- The Big Data Wheel
- Big data papers that changed the world
- Managing big data
- Big-data management tools 1: SQL, HDFS and Hadoop
- Big-data management tools 2: MapReduce, Apache Pig, Apache Spark
- Big-data methods: classification, clustering, regression and dimension reduction
- Popular algorithms for big-data analysis
- Software tools for big-data analysis
- Visualisation: science visualisation, information visualisation, communication, aesthetics and design approaches to visualisation

Optimisation

Dr Michelle Dunbar, The University of Sydney

In many real-world problems, we wish to seek the best possible solution under a given set of constraints. How do we achieve this? The answer is optimisation! This course investigated the art of translating real-world problems into mathematics, and developed the mathematical tools and techniques to solve these problems efficiently in practice, considering real-world examples from medicine and industry.

- Linear programming: formulations, graphical solutions
- The simplex method for solving linear programs
- Duality
- Network optimisation: link and path-flow formulations for networks
- Shortest-path algorithms
- Integer programming
- Introduction to non-linear optimisation
- Real-world applications

Other Sponsors

Department of Education and Training, The University of Sydney, BHP Billiton Foundation (part of the Choose Maths initiative), AustMS, ANZIAM, Department of Defence, Optiver



Assistant Professor Genevera Allen (Rice University, USA) delivering the public lecture on Networks for Big Data

PHOTO: VINCENT CHU

3.04 AMSI OPTIMISE

26–30 June 2017, Monash Conference Centre, Melbourne

The Institute's newest networking and research training event, AMSI Optimise aims to strengthen mathematical research engagement and its applications across industry.

Opened by Victoria's Lead Scientist, Dr Amanda Caples, this exciting addition to AMSI's flagship training program aims to strengthen collaboration between industry practitioners, academics and postgraduate students working in optimisation. This year's launch conference provided insights into cutting edge optimisation research while opening avenues for networking. Featuring a three-day conference and two-day workshop, the

event made considerable impact in its first year. A series of presentations on topics including utilities, logistics and current optimisation practices with industry challenges stimulated vigorous discussion over the first three days, along with panel discussions and hands-on sessions. This was followed by a two-day workshop exploring routing, radiotherapy, scheduling, continuous optimisation, healthcare, optimisation of data analysis, stochastic MIP and other applications.

Other events included a poster session by participants in the APR Intern program. Networking events included the conference dinner and drinks.

OPTIMISE.AMSI.ORG.AU

Director: Prof. Andreas Ernst, Monash University

EVENT PARTICIPATION

- 108** Attendees (83 registered participants plus 25 speakers)
- 30%** Female participants
- 43%** Undergraduate and postgraduate students
- 7%** Early career researchers
- 25%** Industry

PARTICIPATION SUPPORT

- 2** Students from member universities received AMSI Travel Grants
- 2** Female attendees received Choose Maths Grants to support their participation

“AMSI's Optimise conference is a fantastic opportunity for industry to connect with optimisation experts and together solve key business problems and identify new ways to drive efficiency. The conference will highlight the growing importance of optimisation, lead to new industry research collaborations, and grow our capabilities by providing postgraduate students with opportunities to apply their skills to real-world problems.”

Dr Amanda Caples, Lead Scientist, Victorian State Government

Conference Speakers

Plenary talks

Speaker	Organisation	Talk Title
Prof. Steve Wright	University of Wisconsin-Madison, USA	Some optimisation problems in electrical power systems
Prof. Roberto Cominetti	Universidad Adolfo Ibáñez, Chile	Optimisation in data analysis: survey and recent developments
Prof. Alejandro Jofré	Universidad de Chile, Chile	Optimisation and games in transportation
Dr Guoyin Li	The University of New South Wales	Optimal convergence rates for Krasnoselskii-Mann fixed-point iterations
Prof. María García de la Banda	Monash University	Stochastic optimisation and game theory on energy markets
		Some recent advances in polynomial optimisation
		Better support for combinatorial optimisation problem modellers

Conference Talks

Speaker	Organisation	Talk Title
Dr Ross Gawler	Monash Energy Materials and Systems Institute	Optimisation in deregulated electricity markets: Australian experience
Mahes Maheswaran	WaterNSW	Water supply optimisation
Prof. Peter Stuckey	The University of Melbourne & NICTA	Automatic logic-based benders decomposition with MiniZinc
Dr Geoffrey Brent	Australian Bureau of Statistics	Optimisation applications at the Australian Bureau of Statistics
Prof. Mohan Krishnamoorthy	Monash University	Operations research: for and with industry
Dr Michael Forbes	The University of Queensland	Electric vehicle routing
Prof. Xiaodong Li	RMIT University	Seeking multiple solutions: multi-modal optimisation using niching methods
Dr Hamish Waterer	The University of Newcastle	Evaluating the impact of maintenance on the throughput capacity of Australian coal chains
Dr Rodolfo García-Flores	CSIRO Data61	Optimisation for the livestock industry in northern Australia
Dr Hamideh Anjomshoa and Dr Olivia Smith	IBM Research Australia	Case study: South African health worker allocation

Workshop Talks

Speaker	Organisation	Workshop Title
Ashwin Zade	Optym	Simulation-guided optimisation algorithms for real-time train scheduling
Assoc. Prof. Russell G. Thompson	The University of Melbourne	Routing: Optimising courier routes in central business districts
Dr A. A. N. Perwira Redi	Monash University	Routing: Selective discrete symbiotic organism search for capacitated vehicle-routing problem
Dr Yalçın Kaya	University of South Australia	Routing: Optimal path planning
Dr Davaa Baatar	Monash University	Radiotherapy: Minimising the number of apertures in multileaf collimator sequencing with field-splitting
Dr Michelle Dunbar	The University of Sydney	Radiotherapy: Mathematics in medicine: optimising image acquisition and cancer treatment in radiotherapy
Steven Edwards	Monash University	Scheduling: Scheduling automated cell staining: an iterative approach
Kenneth Young	The University of Melbourne	Scheduling: A hybrid Benders decomposition of the assembly line
Assoc. Prof. Regina Burachik	University of South Australia	Continuous optimisation: An approach for the convex feasibility problem via monotropic programming
Assoc. Prof. Alexander Kruger	Federation University Australia	Continuous optimisation: Regularity of mappings vs. transversality of sets
Dr Vera Roshchina	RMIT University	Continuous optimisation: Open problems in convex optimisation
Scott Lindstrom	The University of Newcastle	Continuous optimisation: Regularising with Bregman-Moreau envelopes
Dr Minh Dao	The University of Newcastle	Continuous optimisation: Linear convergence of projection algorithms
Ashwani Kumar	The University of Melbourne	Healthcare: optimising patient flow and throughput in a surgical suite
Ellie Dillon	The University of Melbourne	Healthcare: A two-stage stochastic programming model for inventory management in the blood supply chain
Belinda Spratt	Queensland University of Technology	Healthcare: Reactive multi-operating room surgical case sequencing problem
Joseph Bunton	Monash University	Healthcare: A large neighbourhood search approach for the nurse rostering problem
Prof. Andrew Eberhard	RMIT University	Stochastic MIP: Computing high-quality Lagrangian bounds of the stochastic mixed-integer programming problem
Dr Fabricio Oliveira	University of South Australia	Stochastic MIP: Efficiently solving stochastic mixed-integer problems combining Gauss-Siedel and penalty-based methods
Ilankaikone Senthoooran	Monash University	Applications: Modelling a water supply system to generate long-term operating plans
Rehan Abdul Aziz	Quintiq	Applications: optimising a vendor managed inventory problem in the fuel industry

Other Sponsors

Department of Education and Training, Monash University, Maxima, Optym, AMSI Intern



Prof. Mohan Krishnamoorthy of Monash University, Dr Amanda Caples, Lead Scientist - Victoria and Professor Geoff Prince

PHOTO: NICHOLAS ARCHER

The Importance of Optimisation

Interview with Dan Sutherland, Energy, Mining and Infrastructure Lead, Biarri

BIARRI IS AN AUSTRALIAN COMMERCIAL MATHEMATICS COMPANY that works across a range of industry sectors to assist companies with optimisation and other maths-based problems. Biarri's Energy, Mining and Infrastructure Lead Dan Sutherland, who was on a panel discussing the challenges of optimisation at AMSI Optimise, recently shared his thoughts on optimisation in the energy, mining and infrastructure sectors.

How does Biarri apply optimisation innovation within Energy, Mining & Infrastructure (EMI)?

The most frequent way in which we apply our optimisation capability in the EMI sectors is to solve logistics problems. Common examples are FIFO scheduling, maintenance scheduling, transport load consolidation. In addition to the logistics problems common across the three industries, optimisation is also crucial in industry specific problems such as operational mine throughput optimisation, long term mine design and planning and utilities (e.g. water) flow optimisation. The overarching benefits of these optimisations are an increase in safety, productivity and revenue and a decrease in cost and waste.

Recently we have been involved in a number of projects to reduce unnecessary driving and increase efficiency in onshore LNG projects. These focus around the scheduling and prioritisation of work to create an overall reduction in the travel required to do this work while considering constraints such as worker skills and work interactions. In addition to optimisation a key aspect of this work centres around identifying the opportunities for optimisation and where a business process change can unlock further optimisation capability. This has demonstrated an overall decrease of as much as 30 per cent in driving time and distance. The flow on effects of decreasing driving time and distance are increased productivity and increased safety which is a particularly large consideration in these industries.

Biarri has also been involved in underground mining throughput optimisation by optimising the scheduling of loaders and trucks to work in synergy. This has demonstrated an increase in productivity and ultimately revenue through the mine. A long-term customer of Biarri's continually use our water flow model to optimise their capital and operational spend in maintaining and upgrading their water supply network. We're currently undertaking new projects with clients to globally reduce travel and increase efficiency

What will we see next? What are the emerging challenges in EMI Optimisation?

The future is coming, the only thing we can control is how we respond to it. As we move into the fourth Industrial Revolution the EMI sectors will need to keep up with the changing environment and new workforce used to this new environment. Being industries with large capital expenditure and costly assets, EMI companies typically make decisions based on long term forecasts and decisions. As the world continues to change at an accelerated rate (it is frequently said that we will see more change in the next 5 years than in the previous 30), this will pose a particularly big challenge for the EMI sectors.

As we negotiate the changing tides of our world, optimisation and mathematical modelling can provide

a framework for data driven decision making for responding to the changing world. Using optimisation for decision making can help change the operating dynamic from "the way it's always been done" to "it's the most efficient way to operate". Having the capability to run scenarios and mathematically model the impact a major shift in environment will make to operations (e.g. a large increase in power demand, or modelling the benefit of drone usage on power line inspection) and establish the most effective response.

I think we'll see a large up take in the use of drone / automated / remote technology. Mines have already started using automated trains, trucks and loaders. The energy sector has already started using drones to inspect assets throughout distributed networks. In the next five years I believe these technologies will become "table stakes"; they'll be used ubiquitously.

"There's also likely to be fundamental shifts in the operating models of some businesses, but what I can't yet tell. All of this will create a confusing environment in which mathematical modelling and optimisation can play a key role in understanding."

Where does Australia's energy sector lag in terms of its engagement with optimisation?

The EMI sectors are engaging with optimisation as a part of software products or developments. While this is a step in the right direction there is still a gap in explorative use of optimisation. Collaboration between industry, research and optimisation providers such as Biarri will help to close this gap. However, I see the most important step as the incorporation of mathematics graduates and professionals into these companies to identify and model early opportunities for optimisation (as is done in the financial and meteorological industries).

With the setup of the Australian government Growth Centres, the industries are well poised to take advantage of research and development opportunities. The Collaborative Project Funds offered by both NERA and METS Ignited (the growth centres for Energy and Mining Equipment, Technology and Services (METS) industries) are already encouraging and providing great opportunity for collaboration between industry, technology providers and research institutions.



Dan Sutherland, Biarri's Energy, Mining and Infrastructure Lead, presenting at AMSI Optimise

PHOTO: NICHOLAS ARCHER

3.05 AMSI VACATION RESEARCH SCHOLARSHIPS 2016/17

December 2016 – January 2017

AMSI Vacation Research Scholarships are a chance for undergraduate mathematics students to spend six weeks at the frontline of their chosen area of the mathematical sciences. Students develop essential research and communications skills, as well as building new networks and investigating career pathways. Completing the research experience, the two-day AMSIConnect conference challenges each student to present their project findings and ponder their research futures in a series of information and networking sessions. Inspiring and empowering, the AMSI Vacation Research Scholarship project has led some students to their first academic publication

Through this program, AMSI provides monetary scholarships to give students a taste of research life and encourage them to pursue mathematics as a career. Over six weeks, participants experience life as a researcher, working closely with a supervisor to complete a research project. The program aims to inspire students to continue with further research in the future.

PROGRAM PARTICIPATION

- 43** Attendees
- 28%** Female participants
- 16** Member universities participating

VRS.AMSI.ORG.AU

AMSIConnect

8–9 February 2017, The University of Melbourne

Concluding the VRS experience, the two-day residential student conference AMSIConnect (formerly known as the Big Day In) was hosted by AMSI on 8–9 February 2017 at The University of Melbourne's International House. Scholars were funded to travel to and stay in Melbourne to participate in this event, viewed as an invaluable professional-development experience in communication and networking skills.

The program began with the annual VRS Dodgeball tournament to break the ice. Over the next two days, all Scholars delivered 20-minute talks, providing an overview of their project and findings.

Invited speakers included AMSI Director Professor Geoff Prince, who spoke about careers in maths, Kate Saunders (The University of Melbourne), who reflected on her experiences as a PhD student, and Dr Peter Steinle from the Bureau of Meteorology, who gave a presentation about his experiences as an agency researcher.

Kimberley Becker (The University of Adelaide) won the Best Presentation award for her research talk, *How to assemble simplicial sets*, in the peer voted competition. Honourable mentions were awarded to Sean McInerney (Queensland University of Technology) for his presentation, *How to cool a burn using maths* and Kyle Stevens (University of Wollongong) for *Spatial modelling of invasive species*.

"The VRS experience was fantastic! The research project gave me a great understanding of what it would be like to pursue research after my undergraduate degree, and the AMSIConnect experience was very positive—presenting my work made the whole experience real, I was slightly nervous but it was truly exciting... I think the whole program was organised incredibly well."

Phuong Tran, Queensland University of Technology



2017 Students and Projects

Student	Supervisor/s	Project Title
FEDERATION UNIVERSITY AUSTRALIA		
Leonard Whitehead	Assoc. Prof. Alexander Kruger	Visualisation of subdifferentials
LA TROBE UNIVERSITY		
Luke Agosta	Dr Yuri Nikolayevsky & Assoc. Prof. Grant Cairns	Unital associative algebras over the field \mathbb{R} and how they relate to the groups $SU(2)$ and $Spin(3)$
Jonathan Baldwin	Dr Yuri Nikolayevsky & Assoc. Prof. Grant Cairns	Hopf fibration
Daniel Vidali Fryer	Dr Andriy Olenko	Functionals of long-range dependent fields and Hermite distributions
James Koussas	Assoc. Prof. Tomasz Kowalski	Complex algebras of graphs
Melissa Scott	Dr Agus Salim	Statistical challenges and approaches in analysis of small-RNA sequencing data

2017 Students and Projects

Student	Supervisor/s	Project Title
MONASH UNIVERSITY		
Randall Chu	Prof. Hans De Sterck	Numerical optimisation methods for Big-Data analytics
Antony Kennett	Assoc. Prof. Kais Hamza & Dr Andrea Collevicchio	The percolation of cellular automata
Peizheng Ni	Dr Daniel Mathews & Dr Norman Do	Counting curve on surface
Samuel Schneider	Prof. Hans De Sterck & Assoc. Prof. Gregoire Loeper	Deep neural networks: algorithms and applications
QUEENSLAND UNIVERSITY OF TECHNOLOGY		
Sean McInerney	Prof. Matthew Simpson & Dr Elliot Carr	How to cool a burn using maths
Phuong Tran	Dr Chris Drovandi	Statistical methods for accelerometer data
RMIT UNIVERSITY		
Fei Lu	Dr Vera Roshchina	Unfoldings of polytopes
THE AUSTRALIAN NATIONAL UNIVERSITY		
James Baillie	Dr Vigleik Angeltveit	Stable homotopy theory and category of spectra
SWINBURNE UNIVERSITY OF TECHNOLOGY		
Oliver Clemenston	Dr Tonghua Zhang	Time delays in gene expression
THE UNIVERSITY OF ADELAIDE		
Kimberley Becker	Dr Daniel Stevenson	How to assemble simplicial sets
Lachlan Bridges	Dr Giang Nguyen	The effect of boundary constraints on Markov-modulated diffusion processes
Adam Hamilton	Prof. Matthew Roughan	Privacy-preserving integer linear programming
Nicholas McLean	Prof. Finnur Lárússon	Chaotic dynamics on the Riemann sphere
Jessica Penfold	Dr Lewis Mitchell	Determining the link between influenza dynamics and climatic factors in Australia
Bethany Phipps	Prof. Patricia Solomon & Dr Tyman Stanford	Longitudinal data analysis for improving patient outcomes
THE UNIVERSITY OF MELBOURNE		
Robert Dusanovic	Dr Thomas Quella	Topological invariants in quantum systems
Edmund Lau	Prof. Barry Hughes	Extending stochastic agent-based model for evolutionary dynamics of phenotype-structured population
Qiuyi Li	Dr Yao-ban Chan & Dr Nathan Clisby	Endless self-avoiding walks in two dimensions
Nicholas Liu	Prof. John Sader & Daniel Ladiges	Monte Carlo simulation of low-Mach number oscillatory Couette flow and applications
Alexander Nunn	Prof. John Sader & Jesse Collis	Flapping of leaves and inverted flags in a steady flow
Nicolau Andres Thio	Dr Charl Ras	Minimum weight triangulations
William Troiani	Dr Daniel Murfet	Programming in three dimensions
THE UNIVERSITY OF NEWCASTLE		
Elliot Catt	Prof. Pablo Moscato & Dr Luke Mathieson	Edge elimination and vital edges in the travelling-salesman problem
Joshua Connor	Prof. Brian Alspach & Dr Thomas Kalinowski	Cycle spectrum for honeycomb toroidal graphs
Jacob Crawford	Prof. Brian Alspach & Dr Thomas Kalinowski	Hamiltonian laceability in honeycomb toroidal graphs
THE UNIVERSITY OF QUEENSLAND		
Seamus Albion	Prof. Ole Warnaar & Dr Chul-hee Lee	Characters and q-series
Adele Jackson	Prof. Benjamin Burton	The unknotting problem and fixed-parameter tractability
Julia Lynch	Dr Toby Meadows	Forcing and set-theoretic geology
THE UNIVERSITY OF SYDNEY		
Timothy Collier	Dr Daniel Hauer	Navier-Stokes equations: a Millennium Prize problem
Courtney Darville	Dr Nathan Brownlowe	Characterising unitaries in Leavitt algebras
Terry Shang	Dr Robert Marangell & Prof. Holger Dullin	Complex-valued Hill's equations
Asem Wardak	Assoc. Prof. Stephan Tillmann	Negatively-curved structures in dimensions three and four via discrete geometry
THE UNIVERSITY OF WESTERN AUSTRALIA		
Stephen Lamb	Prof. Lyle Noakes	Classical problems in the calculus of variations
UNIVERSITY OF SOUTH AUSTRALIA		
Alycia Winter	Dr Yalçın Kaya	Study of a generalised Newton method for solution of nonlinear equations
UNIVERSITY OF WOLLONGONG		
Wern Shing Ng	Assoc. Prof. Mark Nelson	Harvesting algae
Kyle Stevens	Assoc. Prof. James McCoy & Assoc. Prof. Ngamta Thamwattana	Spatial modelling of invasive species
WESTERN SYDNEY UNIVERSITY		
Olivia Michael	Assoc. Prof. Oliver Obst	Representation learning for mobile robots in dynamic environments

Web Links

vrs.amsi.org.au,

vrs.amsi.org.au/projects/

vrs.amsi.org.au/vrs-blog/

VRS STORIES

Each student writes up their research at the end of their project as well as a blog post about their experiences. Links to all reports and blog posts can be found at vrs.amsi.org.au/projects/.

Survival Data Analysis for Improving Patient Outcomes



Student: Bethany Phipps, The University of Adelaide
Supervisors: Prof. Patricia Solomon & Dr Tyman Stanford

FOR A PATIENT TO UNDERGO ELECTIVE JOINT REPLACEMENT surgery (JRS), clinicians must decide that coexisting chronic conditions are stable and impose minimal surgical risks. However, the increased risk of patient outcomes after JRS due to comorbidity and multi-morbidity is not always addressed (where multi-morbidity is the presence of additional diseases or disorders co-occurring with a primary disease or disorder). In 2009, 49 per cent of people aged 65 to 74 had 5 or more long-term chronic health conditions and this prevalence increased with age (Statistics 2009). This means that patients presenting with JRS are likely to have multi morbidities. The management of patient care for patients with multiple morbidities needs to be improved.

We can also see that The Australian Orthopaedic Association National Joint Replacement Registry fails to provide data on the success of JRS in terms of subjective reports of symptomatic relief and patient satisfaction (AOA National Joint Replacement Registry, Annual Report 2014). From the literature, on average between 25 per cent and 50 per cent of patients report persistent postoperative pain and function limitations at 1 to 2 years after JRS by which time there should be resolution of symptoms (*When Musculoskeletal Conditions and Mental Disorders Occur Together*, AIHW Bulletin no. 80, 2014). Therefore, the intended advantages of JRS, such as reducing individual, social and health care burdens, are not fully realised. This study will develop predictive algorithms to determine the likelihood of poor symptomatic recovery and dissatisfaction with surgery within the first two years following JRS. Not only will this enable patients to make an informed decision before choosing to undergo surgery but it can also optimise pre-operative patient education with a greater holistic approach.

The aim of the study is to develop a statistical model to predict post-operative patient pain and function using individual (pre-operative) patient multi-morbidity data. The ultimate purpose of the statistical analysis is to provide clinicians with a diagnostic tool for assessing the potential benefits of knee- and hip-replacement surgery for patients with multi morbidities (initially looking at the effect that these pre-operative factors such as co-morbidity have on patient survival, as the pain and function data arrived later than the patient survival data).

The full research report can be found at vrs.amsi.org.au/bethany-hipps-2017/.

“... From Zero to Hero in About Eight Months”

Student: Daniel Fryer, La Trobe University
Supervisor: Dr Andriy Olenko

I STARTED STUDYING MATHS AT AGE 25, IN JANUARY 2013. When I was 24 I wondered what the word “calculus” meant, possibly for the first time in my life. I assumed it had something to do with calculators, but I knew that Isaac Newton had discovered it sometime in the 1600s. Did Newton predict calculators?

I remember learning to add fractions around April 2013. By June I reached a section of a textbook that read, “We commence with the definition of a logarithm”. I was almost embarrassingly excited. I was reading through a textbook series consisting of nine modules that would take me from zero to hero in about eight months (hero meaning roughly the level of knowledge in a standard Year 12 maths course). I knew I was ready for the definition of the logarithm, because my course was on rails and it ran at my own pace. So, whatever the definition was, I



knew I was going to be able to understand it. That’s what was so exciting: I had the time, the space and the skills. The logarithm was a complicated mathematical construction that I had heard

of but known little about, and I was about to understand it.

I still get this rush now. It is the rush of truly learning something. It is the rush of climbing a mountain, when you have a map and a compass, and all the right gear and training. I crave that rush and even sometimes feel that I live for it.

By 2014, when I started my science degree, I didn't want to make maths my main course of study. First, I was pretty sure I wasn't "smart" enough to do well in maths. Second, to me maths was just a tool for studying physical phenomena; it didn't exist for its own sake. I found out how wrong I was some time during second year. To quote Paul Lockhart in *A Mathematician's Lament*:

"Mathematics is the music of reason. To do mathematics is to engage in an act of discovery and conjecture, intuition and inspiration; to be in a state of confusion—not because it makes no sense to you, but because you gave it sense and you still don't understand what your creation is up to; to have a break-through idea; to be frustrated as an artist; to be awed and

overwhelmed by an almost painful beauty; to be alive, damn it."

At this time, I saw a new world. I had been blind to it my whole life. A world in which space could have infinitely many dimensions, where everything could have distance "1" from everything else, and where seemingly simple intuitive assumptions (like the Axiom of Choice) could lead to alarming and disturbing paradoxes. It is no wonder that Lewis Carol was a mathematician.

This year, 2017, I want to reach out to others who are in a similar position to the one I was in when I was 24. People who want to know, but don't know where to start. I want to leverage the wealth of free educational tools that exist online (places like KhanAcademy.org, edX.org, Udacity.org, Coursera.org, and so on) to give interested people a chance to learn introductory maths and science for free in a tutored and low-stress environment, with assistance from volunteer uni students. The project is called Science Stems. Check it out at ScienceStems.com.

From Research to Industry: Connecting the Dots—A VRS Light-Bulb Moment



Student: **Asem Wardak**, The University of Sydney

Supervisor: **Assoc. Prof. Stephan Tillmann**

ASEM WARDAK'S RECENT VRS PLACEMENT WAS SOMETHING OF a light-bulb moment. The program, including presenting at AMSIConnect, was the first time the University of Sydney maths and physics student had encountered industry research.

"Linking industry and maths research allowed me to develop a clearer picture of the multi-discipline opportunities available within mathematics."

Now completing Honours in Physics, Asem spent six weeks from December to February exploring negatively-curved structures in dimensions three and four via discrete geometry. These higher-dimensional versions of making a saddle out of triangles have angle sums greater than 360 degrees around a point, meaning they are negatively curved.

"Negatively-curved structures are extremely important in natural sciences such as general relativity and molecular structure in chemistry," says Asem.

As well as being used in general relativity—a branch of physics focused on understanding the nature of gravity in the universe—these structures are also used in knot theory. Inspired

by knots in everyday life, such as those in a rope or a shoelace, this field of research enables prediction of molecule properties.

Having completed a Bachelor degree in Pure Mathematics and Physics, Asem experienced the VRS project as a chance to bring together two subjects of passion.

"This project looked at metric spaces and differential geometry. This type of research greatly interests me and I hope to pursue it in the future," he says.

During 2017, however, Asem will focus on his Honours in Physics and a project at the bridge of neuroscience and artificial intelligence. He hopes to apply some of the skills developed during VRS to these studies.

"I realised how vital communication is to the production of research. With effective communication, existing ideas may be improved in subtle ways which end up making significant contributions," he explains.

For Asem the biggest drawcard for completing the intense six-week VRS program was the opportunity to tackle real-world research challenges alongside field leaders, the program's beauty being the opportunities for students to see their work have impact and to propel themselves forward as researchers.

"My main aim, which I achieved, was to participate in current research in pure mathematics and produce real scientific outcomes," says Asem.

A program highlight, AMSIConnect, acts as a punctuation mark for the experience, giving VRS participants a platform to both present their work and hear from industry and research experts. The two-day conference allows students to connect the dots between research and commercial application and the many opportunities beyond their studies.

"The various events expounding this connection between industry and research were enormously valuable. It allowed me to develop a clearer picture of the opportunities available in a range of disciplines within mathematics," he says.

With PhD and postgraduate research on the horizon, Asem discovered that at VRS anything is possible.

3.06 CHOOSE MATHS GRANTS

The Choose Maths Grants provide full or partial support for Australian female mathematical sciences students and early career researchers seeking to build and extend their skills and professional networks at AMSI training events.

These grants are funded by the BHP Billiton Foundation under the Choose Maths project, a partnership with AMSI

to strengthen mathematics teaching, and foster participation and career awareness of girls and women in mathematics.

Working across four key components including a national careers awareness campaign and women in maths network, the Choose Maths project aims to improve the health of the mathematical pipeline from classroom through university and the workplace.

Awarded on a competitive basis by the Choose Maths Grant Committee, the grants support:

- Attendance at AMSI Flagship events (including support for second time attendees)
- Partner & child travel and/or accommodation support
- Caring responsibility support (for example, childcare or temporary respite)

2016–2017 recipients

AMSI Winter School

Zahra Al Helal, Curtin University of Technology
Russul Alanni, Deakin University
Hilary Hunt, The University of Melbourne
Elisa Jager, University of Wollongong
Catherine Penington, Queensland University of Technology

AMSI BioInfoSummer

Alysha De Livera, The University of Melbourne
Mary Dillon, The University of Melbourne
Xiaochen Fan, The University of Sydney
Daniela Gaio, University of Technology Sydney
Anna Kretschmar, University of Technology Sydney

Yingxin Lin, The University of Sydney
Loan Nguyen, The University of Queensland
Julia Shore, The University of Tasmania
Letitia Sng, The University of Sydney

AMSI Summer School

Amani Alahmadi, Monash University
Catherine Attard, Monash University
An Ran Chen, The Australian National University
Diclehan Erdal, The University of Adelaide
Alexandra Grant, The Australian National University
Vanessa Haller, James Cook University
Jingya Han, The Australian National University
Maria Kleshnina, Flinders University
Aline Kunnel, Flinders University
Xuemei Liu, University of South Australia

Georgina Matta, RMIT University
Nicole Mckenna, RMIT University
Rachel McLean, The University of Adelaide
Jessica Penfold, The University of Adelaide
Jie Ren, The University of Melbourne
Olga Shulyarenko, The University of Melbourne
Aashima Thukral, The University of Melbourne
Jiali Wang, The Australian National University
Hui (Alice) Yao, The University of Queensland
Yan Yu, The University of Melbourne

AMSI Optimise

Khushboo Singh, Macquarie University
Busayasachee Puang-Ngern, Macquarie University

Choosing Maths to Fight Cancer

CURRENTLY STUDYING FOR HER PHD IN bioinformatics, Deakin University's Russul Alanni hopes to use maths to help cancer patients. Her research involves modelling gene mutations to increase understanding of cancer growth, survival time and recurrence in the hopes of improving treatment outcomes.

"Clinical application of machine learning approaches and biological data analysis is still open, as they are theories. My dream, however, is to develop an accurate prognosis model that can deliver clinical benefit," says Russul.

With such big ambitions, Russul knows it is important to establish collaborative networks and engage with experienced mentors as early as possible. However, with husband Haseeb also pursuing a career in science and two boys to care for, this can seem like an out-of-reach luxury.

"With research a bit of a family business, it is often difficult to balance

home and work commitments and, as is the case in many families, the sacrifices come back to me," says Russul.

With the chance to expand their field expertise and network with global leaders at AMSI Winter School beckoning, the pair received a much-needed helping hand through the Choose Maths Grant program. Covering childcare expenses, this funding meant that both Russul and Haseeb could not only attend the event but engage fully with everything on offer.

"Both my husband and I wanted to be part of this opportunity, but with the need to cover childcare this seemed impossible. The Choose Maths Grant meant I could also attend and be part of this exciting conversation"

Providing answers to questions not covered in her textbooks and studies, it was also a chance for Russul to deepen her field knowledge and seek out new tools to aid her quest against cancer. For Russul the true value of the grant as an access pathway was immeasurable.

"So often for women in particular, additional networking and training seems like an unattainable luxury. This grant meant I had access to expert knowledge and new tools and techniques at the cutting edge of my field. This is invaluable as an establishing researcher in a male dominated and hugely competitive field," says Russul.

A step closer to her dream, Russul now plans to build on her newly expanded networks as she draws on her Winter School experience to make cancer treatment add up for patients.

Russul Alanni received a Choose Maths Grant to attend AMSI's 2016 Winter School

3.07 ADVANCED COLLABORATIVE ENVIRONMENT (ACE) NETWORK

Enhancing student learning, the platform allows member institutions to remotely deliver mathematical Honours and Masters subjects to students from universities around Australia. Short courses open to both students and academics are also offered on an occasional basis.

The Advanced Collaborative Environment (ACE) at AMSI member universities enables maths departments to collaborate through advanced video conferencing and desktop sharing facilities. It

ACE Honours/Masters Courses

AMSI member institutions run annual mathematical Honours year subjects in the Advanced Collaborative Environment (ACE Network) enabling students from several universities at once to participate in Honours subjects remotely. These courses may also be offered to Masters students.

has been established to facilitate greater collaboration between the mathematical sciences community both within Australia and internationally.

Fourteen Australian universities — about half of AMSI's 29 member and non-member universities — belong to the ACE Network. In addition to offering honours courses, the facilities are used to bring interest groups from the mathematical sciences community together for workshops and seminars (see p. 52).

SEMESTER 2 2016

6 subjects offered by 4 universities
More than 60 students from 12 universities participated

SEMESTER 1 2017

4 subjects offered by 3 universities

2016 Semester 2

Host University	Name of Course	Lecturer	Number of Students Enrolled
La Trobe University	Theory of statistics	Assoc. Prof. Paul Kabaila	17
Macquarie University	Research topics in mathematics 3: category theory	Dr Richard Garner	18
Macquarie University	Advanced methods in mathematics 1: perturbation methods	Prof. Jim Denier	14
RMIT University	Convex and nonsmooth optimisation	Prof. Andrew Eberhard	7
The University of Queensland	Mathematical control theory	Dr Yoni Nazarathy	>2
The University of Queensland	Measure theory	Dr Huy Nguyen	>3

2017 Semester 1

Host University	Name of Course	Lecturer	Number of Students Enrolled
The University of Newcastle	The probabilistic method	Dr Thomas Kalinowski	n/a*
The University of Sydney	Asymptotic methods and perturbation theory	Assoc. Prof. Sharon Stephen	n/a*
University of Wollongong	Measure, integral and probability	Dr Marianito Rodrigo	n/a*
University of Wollongong	Advanced data analysis	Dr Thomas Suesse	n/a*

* participation data not available at this time

ACE Short Courses

From time to time, the AMSI member institutions offer short courses in the Advanced Collaborative Environment. These courses are usually run outside general teaching weeks,

in a short but intense period of a couple of weeks. The specialist subject matter might be of interest to students as well as academics. There is no assessment or examination.

Stochastic Equations and Processes in Physics and Biology

Dr Andriy Pototsky, Swinburne University, February 2017
 Fluctuations, noise and randomness determine basic properties of micro scale sized systems and are ubiquitous in nature. Our experience shows that if a classical system, no matter how large or small, is subjected to a process of a measurement, the outcome cannot be predicted with absolute certainty. Thus, the position of pollen grains, suspended in water, changes randomly in time as they jiggle due to Brownian motion; neural cells in any living organism generate a random series of electric pulses in response to the synaptic input from other cells; weather forecasts are unreliable because of the chaotic nature of global weather. In

all these examples, the quantum effects can be neglected, and the origin of randomness is traced down to the complexity of the system or chaos. This course of lectures is designed to give an introduction into the phenomenological theory of stochastic equations and processes. The mathematical formalism of the stochastic calculus is explained using examples borrowed from physics and biology. The course is designed to be accessible for non-experts in the field.

Registrations for this course: 16

3.08 HEIDELBERG LAUREATE FORUM

Heidelberg, Germany, 18–23 September 2016

A highlight of the international mathematics and computer science calendars, the Heidelberg Laureate Forum provides highly talented young researchers with the opportunity to engage with the winners of the most prestigious scientific awards in Mathematics (Abel Prize, Fields Medal and Nevanlinna Prize) and Computer Science (ACM A. M. Turing Award). This provides an outstanding platform for scientific dialogue across generations.

Each year AMSI and AustMS provide funding to support young Australian researchers' attendance at the event, which brings together 200 young mathematicians and computer scientists from

around the world for the unique opportunity to interact with their scholarly role models during lectures, panels and discussions. At the same time, the up-and-coming scientists can engage in inspiring and motivating conversations with the laureates during various social events.

2016 Recipients

Mark Bugden, The Australian National University

Tian Sang, RMIT University

David Khoury, The University of New South Wales

Bao Ho, La Trobe University

Interview with the 2016 Heidelberg Laureate Forum Travel Fund Recipients

SOME OF US WERE SCEPTICAL GOING INTO THE CONFERENCE. NO doubt it was a good opportunity, but would it really “inspire”, could it really change our outlook? Well, once at the HLF it was hard not to get caught up in the excitement—even when hearing about work outside our fields.

It is fair to say that the four of us felt like we did not know much about the Laureates before attending the conference. But we were all soon to learn just how impressive the Laureates’

impacts on their fields have been (and really their impact on the world). It is no exaggeration. We had the chance to meet Vint Cerf who was pivotal in creating the internet, and Ivan Sutherland who we can thank for computer graphics, the GUI interface and for virtual reality. David asked these Turing Award winners if they had any idea how important their work would be at the time they were doing it. Both of them shook their heads and said they just worked on what they thought was interesting



© Heidelberg Laureate Forum Foundation / Flemming – 2016

or important at the time. The presence of these humble and impressive Laureates made us feel as though anything is possible.

Each day there were leisurely lunches, and incredible dinners. These social events were a key part of the HLF program, and were designed such that we usually found ourselves at a table with a Laureate. Tian reflected, “I shared very nice conversations with the Turing Award winner Raj Reddy on many connections between mathematics and computer science. I also had the opportunity to sit with Fields Medallist as well as Abel Prize winner Sir Michael Atiyah twice at the dinner table, and hear about many of his interesting ideas about mathematics and life in general. Apart from that, I also chatted with Nobel Prize winner Brian Schmidt from ANU during our Speyer city tour in Germany, and I found his project on women in science and mathematics is absolutely adorable.”

The Laureates talks were genuinely inspiring and informative. Bao shared that he was “especially motivated by Andrew Wiles’ story of solving Fermat’s Last Theorem, encouraging me to think again about a problem that I have almost given up.” And Tian

found “the talk by Sir Andrew Wiles on Fermat’s Last Theorem was beautifully delivered, also the talk by Fields Medallist Vladimir Voevodsky has given me some ideas on one of the research problem I came across recently.”

A question we all had before the conference was would the Laureates' talks be comprehensible? We can now report the answer is a resounding yes.

Mark best summarises our experience of the HLF: “The [final] dinner was held inside the Heidelberger Schloss, a castle overlooking the city of Heidelberg. I had the good fortune to be sitting at a table with Sir Michael Atiyah for dinner. Having dinner (and discussing complex geometry) with an actual knight, inside an actual castle, is an experience I won’t soon forget.”

3.09 EARLY CAREER WORKSHOP AT THE AUSTMS 2016 CONFERENCE

AAS Shine Dome, Canberra, 3–4 December 2016

The AustMS Early Career Workshop provides an opportunity for early career researchers – from PhD students to those who are about five years post-PhD – to network while learning from the experience of a panel of world field leaders.

Held immediately preceding the AustMS Conference, this year’s workshop focused on academic and industry career opportunities and skill development to improve opportunities for current students and recent graduates, with the theme *Addressing your Audience*.

The majority of the 70 participants were PhD students, with a small number of postdoctoral researchers and other early career mathematicians. The speakers included both established mathematicians and early career researchers, who talked about their research against the backdrop of their own career trajectories. In addition to the presentations, Q&A sessions were built in to the program.

Organisers

Dr Michael Coons, The University of Newcastle

Dr Norman Do, Monash University

Prof. George Willis, The University of Newcastle

Invited Speakers

Dr Aidan Sims, University of Wollongong

Asst. Prof. Matthew Kennedy, University of Waterloo, Canada

Prof. Jacqui Ramagge, The University of Sydney

Dr Giang Nguyen, The University of Adelaide

Dr Nicholas McConnell, Defence Science and Technology Group

Dr Masoud Kamgarpour, The University of Queensland

Web Links

carma.newcastle.edu.au/mcoons/ECW2016.html

Other Sponsors

AustMS

Contact

michael.coons@newcastle.edu.au

3.10 WOMEN IN MATHEMATICS

Improving Gender Ratios in the Mathematical Sciences—AMSI's Approaches

The continued under-representation of women and girls remains a key threat to the health of Australia's mathematical sciences. Challenging traditional mathematical career narratives and championing gender equity at all stages of the discipline pipeline remains a core AMSI priority.

Less than 30 per cent of all undergraduate and postgraduate students in Australia are female; similarly, women account for fewer than 30 per cent of staff employed by mathematical sciences departments. This figure drops significantly with seniority, with fewer than 10 per cent of staff employed at the highest levels female.

AMSI is actively challenging the mathematical and general communities to address this issue. Embedded in all AMSI flagship programs, public Women in Mathematics (WIM) sessions/panels continue to generate critical discussion. Exploring key

challenges faced by women in the mathematical sciences, these sessions have helped foster a national support network.

AMSI is strongly leading this issue at the frontline, encouraging organisers of AMSI-sponsored workshops to

“We need to kill the stereotype that women are less talented than men at subjects such as mathematics and bioinformatics. In fact, often we are more precise and disciplined, powerful features for these fields.”

Daniela Gaoi, PhD student, University of Technology Sydney, Choose Maths Grant recipient

Choose Maths Travel Grants

Removing recognised social and economic barriers to participation, AMSI Choose Maths travel grants help empower Australian female mathematical sciences students and early career researchers to participate in AMSI's flagship programs (Winter and Summer Schools, BioInfoSummer, Optimise and the Vacation Research Scholarship program). Competitively awarded, these grants cover event attendance, travel/accommodation costs and financial support for partner and child travel/accommodation, and/or caring responsibility (childcare or temporary respite).

Delivered by AMSI, these grants are funded by BHP Billiton Foundation as part of the national Choose Maths project. This initiative aims to strengthen Australia's mathematics capability over the next five years. The team is working with schools in metropolitan and regional areas across Australia to implement strategies at key stages of the pipeline to strengthen mathematics education outcomes and to entice more girls and young women into mathematics.

Women in Mathematics Network

Also funded through the Choose Maths project, the Women in Maths Network has been established to inspire and support a new generation of female science, technology, engineering and

mathematics (STEM) students and professionals. This growing network of high-achieving academic and industry leaders is helping empower the future mathematical workforce by sharing their experience, wisdom and knowledge. This support is essential to increase the participation of Year 11 and 12 girls in maths and foster the long-term engagement of new generations of academic and industry researchers.

These mathematical communities provide support and inspiration while helping to expose emerging maths talent to a broad range of experience and opinions. Not only a chance to change lives, the experience provides mentors with a fresh perspective on their own careers, the impact and value of their work and why they chose a career in maths.

Choose Maths Careers Awareness Campaign

Understanding the value of mathematics as a career pathway is vital to strengthen engagement. Launched in 2017, the AMSI Choose Maths Careers Awareness campaign features the stories of 12 inspiring Australian maths professionals. With plans to expand in 2018, the campaign is already impacting nationally with classroom resources encouraging girls to keep their options open and study maths into Years 11 and 12. Free screenings of *Hidden Figures* in Melbourne, Sydney, Brisbane and Adelaide set



AMSI Summer School's Women in the Mathematical Sciences Event

PHOTO: VINCENT CHU

improve the participation of female researchers through a range of measures. Key recommendations include the appointment of at least one woman to each event organising committee, engagement of female speakers and supporting participation through provision of information such as childcare availability. The current goal for female attendees at AMSI-sponsored programs is 30 per cent. In 2016–2017, female mathematicians attending AMSI-sponsored workshops made up 17 per cent of the participants across the 23 funded workshops, slightly up on the previous year.

Reasons given by workshop organisers for lower than expected attendance vary, but include:

- A low level of female participation in specific fields of maths
- Difficulty in travelling/being away due to family commitments
- Over-commitment

WORKSHOPS STATS

Invited speakers receiving funding: **16%** female
Workshop participants: **17%** female
Female students/ECRs receiving travel funding from AMSI: **4%**

FLAGSHIP PROGRAM STATS

Overall, women accounted for almost **40%** of attendees across the five flagship training programs in 2016/2017.

Winter School

42% female students **40%** female lecturers

BioInfoSummer

51% female participants, **43%** female speakers

Summer School

30% female students, **36%** female lecturers

Optimise

30% female participants, **24%** female speakers

Vacation Research Scholarships

28% female students, **8%** female supervisors

AMSI INTERN

To date, **35%** female participants in the program



AMSI Winter School's Women in Maths networking event

PHOTO: ANJANETTE WEBB

maths ambitions alight, with AMSI Careers Ambassadors giving 1700 students a sneak peak of the campaign during the popular events. choosemaths.org.au/careers/

Choose Maths Awards

The annual Choose Maths awards reward classroom teachers for excellence in the teaching and learning of mathematics. As well as awards (\$5000 for the recipient and \$5000 for the school) for Secondary Teacher of the Year and Primary Teacher of the Year, the Major Prize (\$10 000 for the recipient and \$10 000 for the school) goes to the teacher deemed to be a high achiever in the area of encouraging more girls to participate in mathematics.

Events in 2016–17:

- AMSI Winter School's Women in Maths networking event, held in July 2016, attracted more than 70 people to take part in an active discussion focused on highlighting the contribution of women in mathematics, raising awareness about issues for women, and promoting career pathways. Panel speakers included Professor Kerry Landman (The University of Melbourne), Julia Bruerton (Brisbane Grammar School) and Ellie Foxcroft (Biarri)
- In December 2016, 85 BioInfoSummer delegates attended

the Women in STEM Lunch, hosted by BioInfoSummer and WIMSIG to both raise awareness about issues faced by women in STEM and promote career pathways

- At AMSI Summer School in January 2017, a dinner featuring a panel of female Summer School lecturers provided an entertaining night for 74 summer school students and other guests. The Q&A style conversation was collated for a story in Sydney's *University News* (sydney.edu.au/news-opinion/news/2017/01/20/what-is-a-career-in-maths-really-like.html)
- A women's luncheon at The International Conference on Nonlinear PDEs, held at The University of Sydney in November 2016, featured talks by the University of New England's VC Professor Annabelle Duncan and keynote speaker Professor Angela Pistoia from the University of Rome. The event attracted both conference participants and local academics.
- In March, the International Conference in PDEs, Geometric Analysis, and Functional Inequalities held its Diversity Dinner and panel discussion on gender diversity and inclusion in mathematics
- The ACE forum on Women in Research and Higher Degrees in the Mathematical Sciences held at AMSI in June 2017 looked at the decline in interest amongst Australian female students in pursuing higher degrees in maths and stats

MENTORING THE NEXT GENERATION

Interview with Professor Asha Rao, Associate Dean Mathematical Sciences, RMIT University

Can you tell me a little about your background and how this influenced your pursuit of a career in mathematics?

I am of Indian origin and did all of my degrees in India. I got married a few months after I completed my Bachelor's degree, which was a combined degree in physics, chemistry and mathematics. I pursued a Master degree when my son was two years old. I had wanted to do a master's in analytical chemistry but chose pure mathematics instead because it did not have practicals! All I needed was paper, pencil and my brain!

Have you always been interested in maths?

Maths was always easy for me, growing up. As my mum tells me, I had to give an entrance exam for Grade 1 (this is common in India), in which I scored 98/100 in maths (and 2/100 for spelling). My parents encouraged me to study, with my mum being the main force—she always insisted that I did the best I could, and that usually meant I had to be near the top in class. Because maths was easy, it was not really a challenge. Though I did learn early that I needed to put effort into it, else I could not ace it. However, this was never a problem—I preferred doing maths to anything else, except drawing.

Who were your role models and mentors as a woman entering the mathematical sciences?

I did my master's degree at Bombay University (now Mumbai University). The faculty in the Department of Mathematics at Bombay University had a big gender imbalance—there were almost twice as many female lecturers as male! This meant that I didn't find it strange to be female entering mathematical sciences.

"I just thought it was natural to be female and doing maths."

How important is it for female mathematicians to mentor and act as role model for girls and women entering the discipline?

It is very important for female mathematicians to mentor and be role models for not only girls and women entering the discipline, but also the males. By being role models for both (all) genders, we will help girls and women to progress better. It will help boys and men to also have strong female role models, to recognise that their sisters and daughters, and female colleagues and students can be the same. This is what I have endeavoured in my career—to show all students what a strong female role model looks like.

In what ways have you encountered gender bias within the mathematical sciences and how has it shaped your career?

One recent evidence of bias that I have found pertains to the recruitment process: I have found that recruitment panels are more willing to believe a male candidate who admits not having done something deemed necessary as per the Key Selection Criteria but feels that he can do it, rather than a female candidate who has provided evidence of having achieved the criteria.

In addition, when comparing research output, very little attention is paid to the fact that a researcher may have been working part-time, due to carer's responsibilities. As a result, personally, I have become very meticulous in reporting all my work by giving measures of impact with outcomes showing that the desired impact has been achieved. I suggest this to all the persons who seek advice from me, and I am very particular

to note these things when sitting on a panel, as well as when reading grant applications etc.

Why do you think mathematics in particular continues to have such a strong gender inequity issue? What are the barriers for women in mathematics?

The points I raised in the last answer probably account for this, as well. Women traditionally are more likely to do pastoral care of students in their early career, and this has a detrimental effect on their research output. In addition, women find it difficult to report on the other activities that they have undertaken, in an evidence based manner. Clearly, career paths are stymied, when raw numbers of research outputs are the only measures for career progression.

The important question that I want to raise is whether the traditional means of measuring success, by research outputs alone, has served us well. Is there some other way? If not, how can we improve the research outputs of our younger female mathematicians? Even when maths departments advertise female-only positions, these positions are immediately viewed with suspicion, by women as well as men, with many claiming that these positions are tainted by gender. As research shows, the gender bias within society's psyche is so deep that women are expected, and themselves expect, to be better than men—to be able to progress.

What changes have you seen since you began your career?


I have been in academia for almost 25 years and I have seen sporadic changes over that period. Often there are positive bias steps taken, but then there is lassitude within the discipline, and things are allowed to slide. It is almost as if every generation of women has to reinvent the wheel. Currently the SAGE initiative is causing universities to advertise and employ women – however this may not be achieving its stated aim of improving the actual number of women, with each university trying to attract females, especially those at higher levels, from other universities.

How can we improve female participation in mathematics in Australia, including higher-level academic positions?

As statistics show, the number of women graduating with PhDs almost equals the men, but the leaky pipe syndrome is causing us to lose women at every level. Being trained to recognise unconscious bias and also giving current academics, especially recruitment panels, the tools to attract women applicants will definitely help.

Mentoring past PhDs: it is important that academics realise that PhD students, especially female, need mentoring far beyond the successful completion of their PhD. The first two or three years after graduation are, I have found, the hardest for a newly minted PhD graduate to continue with their research. Add to this the imposter syndrome that females particularly suffer from. If each PhD supervisor could take the time to recognise opportunities and to encourage and support their graduated students, and any new staff in their departments, to take up these opportunities, then the pool of successful female academics would grow.

Higher-level female academics: One of the things that I realised when I took up my position as Associate Dean of Mathematical Sciences at RMIT was that I had no experience at department level. While men are always pushing to be given the leadership experience and positions, I found that I had waited for someone to tap me on the shoulder! This is something that needs to be addressed—women academics have to be tapped, and people need to be aware of the talent within their staff and encourage it.



“The important question that I want to raise is whether the traditional means of measuring success, by research outputs alone, has served us well. Is there some other way? If not, how can we improve the research outputs of our younger female mathematicians?”



Industry Research Programs 4

Dr Veelasha Moonsamy completed an APR.Intern placement commencing a Postdoc at Radboud University in the Netherlands

PHOTO: MICHAEL SHAW

4 | INDUSTRY RESEARCH PROGRAMS

AMSI's industry research programs aim to boost Australian industry engagement with mathematical sciences research. With 75 per cent of Australia's fastest growing employment areas requiring STEM, it is essential to ensure that Australia has the mathematical and statistical skills to remain internationally competitive and protect national security, population health and climate stability. Future mathematical literacy requires decisive policy action and reform today.

From July 2016 through June 2017, AMSI's industry internship program placed **51** interns from **8** disciplines with **25** industry partners across **10** industry sectors

“To support future research and development capability and secure Australia's innovation capacity, it is critical we equip the future research workforce to effectively apply their knowledge and expertise in industry settings.”

Assoc. Prof. Yakov Zinder, University of Technology, Sydney

Industry Research Programs

4.1	APR.Intern.....	84
	APR.Intern A Step Forward for Innovation Company.....	84
	Advancing Defence Innovation With APR.Intern	85
	Mentor Honoured for Researcher Development	85
4.2	Mathematics in Industry Study Group (MiSG)	86
4.3	Parks Victoria Partnership.....	88

4.1 APR.INTERN

APR.Intern (formerly known as AMSI Intern) works at the interface between academia and industry, creating and strengthening linkages and awareness of the business value and impact of engaging high-level research capability to drive innovation.

Operating across all disciplines and sectors, the program delivers Australia's young and brilliant minds to industry, and enhances the postgraduate experience by providing opportunities for the practical application of research skills within a commercial context. This in turn provides a platform for industry to engage with and attract talent into organisations through short-term tightly focused research projects.

APR.Intern is Australia's leading PhD internship program placing over 200 postgraduate students from Australian universities into industry. More than 110 businesses and government agencies have hosted interns since the program's inception in 2007, and significantly, more than 30 per cent are repeat customers.

In 2017 the Australian Government confirmed its commitment to invest \$28.2 million to expand the Intern program on a national scale through the *National Research Internships Program* (NRIP), supporting the delivery of 1400 new internships over four years with access provided to all of Australia's universities.

Through the Intern program, PhD students have the opportunity to work with an industry partner on a research project of up to five months' duration. Projects have a focus on science, technology, engineering and mathematics (STEM) fields and an increased participation by women, indigenous, regional and disadvantaged Australians in STEM.

In late 2017, the expanded program was rebranded as APR. Intern to better reflect its scope and impact across the broader STEM environment, beyond mathematics. The NRIP program will officially launch in early 2018.

AMSI's Intern program is crucial in boosting business and university partnerships. Australia currently ranks 29th out of 30 countries in the OECD for business-university collaboration — a stark contrast to its ranking as 9th in research output per capita amongst OECD nations.

PROGRAM PARTICIPATION

From July 2016 through June 2017,
the program placed **51** interns
from **8** disciplines
with **25** industry partners
across **10** industry sectors

“Through our partnership with APR.Intern and industry innovators such as MEMKO, DSI is proud to open avenues for postgraduate researchers to directly apply their knowledge and specialist skills to solve real-world innovation challenges and strengthen Australia's defence industry capability”

Dr Regina Crameri, DSI Associate Director

APR.Intern A Step Forward for Innovation Company

AUTOMATED ORTHOTIC DESIGN SOFTWARE IS ALREADY helping Australian patients put their best feet forward.

Developed by Melbourne-based technology and industry specific engineering company MEMKO, the software was made possible thanks to specialist input from RMIT PhD student Jeffery Young.

With the process already underway, and with a local podiatric laboratory and a critical skill gap, the company was linked to Mr Young through APR.Intern.

“Jeffery's knowledge and problem-solving skills were just what we needed to bolster our development team and identify new solutions to outstanding complex issues”

Miro Miletic, Managing Director, MEMKO

For Jeffery, who has been developing an algorithm to measure gait parameters as part of his PhD, putting theory into practice provided understanding of industry needs and processes.

“I participated in every stage from initial brainstorming, analysis and development to application. As well as vital industry skills, I have more confidence communicating my knowledge and research with broad audiences and stakeholders”

Jeffery Young, RMIT PhD student

On hand to help to provide support as academic mentor, Dr Milan Simic proved a valuable sounding board as Jeffery developed a critical function of the software to allow improved design accuracy. The project also paved avenues to extend his research horizons.

“My research engagement with MEMKO will be ongoing. In particular, this experience has highlighted the synergy between academia, industry and APR.Intern,” he says.

Advancing Defence Innovation With APR.Intern

ACCESS TO SPECIALIST RESEARCH CAPABILITY is accelerating idea development and innovation within Australia's defence industry.

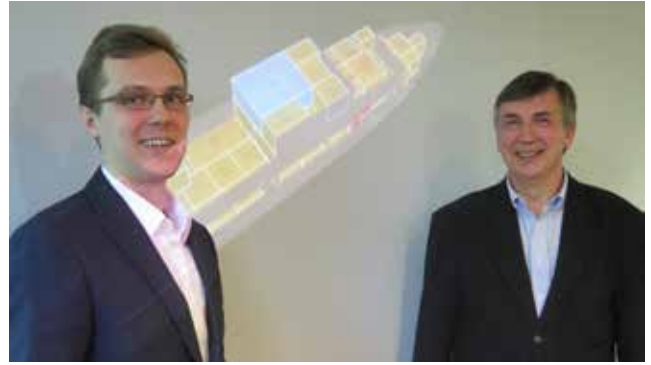
A project with APR.Intern and the Defence Science Institute recently showed independent engineering and project management consultancy BMT Design & Technology the benefits of having these skills onsite.

"While BMT already values and actively invests in research and development, the APR.Intern program has shown us how effective a dedicated project-focused researcher can be," senior BMT Design and Technology engineer Aidan Depetro said.

The defence, maritime and industry leader was matched to Swinburne University of Technology PhD student Sergei Chichin to optimise development of an in-house design tool.

"Sergei's specialist optimisation and software design knowledge helped us overcome major hurdles in the automation of compartment arrangement and incorporation of in-house knowledge into the design tool," explains Aidan.

The results speak for themselves, with the company considering the design tool as an opportunity for future business enterprises.



"At this stage, the tool will be used internally to rapidly generate and evaluate designs for a range of clients but commercial ventures are a possibility down the track," says Aidan.

This internship was co-funded by the Defence Science Institute as part of its ongoing partnership with APR.Intern to give Australian business the leading edge in defence.

Mentor Honoured for Researcher Development

PERHAPS ONE OF THE BIGGEST QUESTIONS facing postgraduate research students—industry or academia?

As Australia seeks to strengthen industry-led university research engagement, researchers such as University of Technology Sydney's (UTS) Associate Professor Yakov Zinder are helping students see how they can have a career that includes both.

Having led research in quantitative management science and operations research, Yakov is drawn to real-world industry research challenges.

"For applied mathematicians, industry poses some of the most interesting questions. Engagement with industry is essential in my field," he says.

He has used mentor roles with both APR.Intern and the Australian Technology Network Industry Doctoral Training Centre (ATN IDTC) to champion the benefits of industry engagement to his students.

Given his passion, it will surprise few to learn that he has set the bar high for academic supervision of postgraduate interns, working on more projects than any other APR.Intern academic mentor. His research has helped drive innovation with, among others, ANC, Fleet Flyers, CSIRO, Energy Australia and Intelligent Energy Systems Pty. Ltd.

Yakov's success and impact as a mentor for both programs recently saw him jointly honoured with a UTS Vice-Chancellor's Award for Research Excellence in the category Research Development (including Supervision) with colleague Professor Alex Novikov.

With Australia trailing the OECD in university-industry collaboration, Yakov believes national scale programs such as APR.Intern are critical in building such linkages.

"To support future research and development capability and secure Australia's innovation capacity, it is critical we equip the future research workforce to effectively apply their knowledge and expertise in industry settings," he says.

The fostering of new talent remains the biggest driver in his passion for mentoring students into industry. His involvement in programs such as APR.Intern, he believes, allows him to elevate his students' learning experience.

"Industry collaboration enriches my teaching and research by deepening my understanding of specific industry needs, while also helping my students develop critical soft skills such as cross-discipline communication,"

**Associate Professor Yakov Zinder,
University of Technology Sydney (UTS)**

The intense research challenges posed by APR.Intern are, he admits, hard work, with the projects designed to deliver fast-tracked industry-specific solutions within tight deadlines. Involved at all stages of the project, his role is to guide postgraduate interns through what is usually their first taste of industry innovation.

"The workload is high with constant student contact and engagement with the industry partners—it can be intense. However, it is rewarding to be able to watch your students mature and develop during these collaborations," he explains.

Personally, Yakov has benefited as much as his students with access to industry opening opportunity to build long-term collaborations.

4.2 MATHEMATICS IN INDUSTRY STUDY GROUP (MiSG)

The University of South Australia, 13–17 February 2017

AMSI partners with ANZIAM to support the annual Mathematics in Industry Study Group. Applied mathematicians, statisticians, physical scientists and engineers apply cutting edge mathematical science to provide practical working solutions to real-life industry challenges facing multinational and small to medium businesses within Australia and New Zealand and globally.

The MiSG creates business linkages to high-calibre professionals, tools and technologies to improve capacity and capability in problem solving and decision-making. Each year, 100 applied mathematicians, statisticians and physical scientists attend, using the opportunity to apply their skills to business participant challenges.

The program receives acclaim from industry partners as a low-cost, high-yield investment in problem solving. Some partners have implemented MiSG practices directly following the workshops, while others have expanded their investment into collaborative research partnerships to solve even larger business challenges.

Every participating industry partner receives a brief summary report immediately following the MiSG workshop. These reports capture the essence of what was achieved during the workshop and summarise the ongoing work to be discussed in full technical detail in a final report.

MiSG 2017 was opened by Emeritus Professor John Ockendon (University of Oxford), who was instrumental in setting up similar study groups around the world.

EVENT PARTICIPATION

62	Attendees
26	Students
11	Female participants
12	International participants

Projects

MiSG 2016 tackled four industry problems, delivering a range of challenges for mathematical statistics, operational mathematics, applied and computational mathematics researchers.

Analysis of Train Lateness

Rail operators around the world are using driver advice systems to provide train drivers with driving advice to help them keep trains on time and minimise energy use. TTG Transportation Technology provides driver advice systems to several railways in the UK. These advice units also capture detailed information about the operation of the railway, including the location and speed of each train at ten-second intervals. A typical UK operation will have 200–300 train services per day.

Preliminary analysis of train logs is showing that, on some railways, trains are unable to meet their timetables 50–75% of the time. This is limiting the scope for on-time running and for energy savings. The aim of this project is to analyse the data from train logs to determine where and when trains are losing time, to determine factors that contribute to time loss, and to develop new reporting methods that will assist with on-going monitoring of network and driver advice system performance.

Partner: TTG Transportation Technology

Summary report: mathsinindustry.com/about/misg-2017/2017-projects/ttg-summary-report/

Estimating Transonic Drag

The drag coefficient function of transonic projectiles rises gradually as speed drops, then drops sharply as the speed drops through Mach 1. DST Group wishes to estimate the drag coefficient function for various projectiles, to match empirical data. Empirical data for a projectile may contain observations of several trajectory parameters, including range, firing angle, muzzle velocity, maximum height and final velocity. Other data may contain very limited information, such as maximum range only; in this case, determining whether particular model parameters give a result that matches the data requires an

expensive calculation of the optimal firing angle. Furthermore, when searching for an optimal trajectory, range does not vary smoothly with firing angle due to accuracy variations in the numerical methods used to calculate trajectories. Finding the best fit drag coefficient function reduces the global optimisation of a jump discontinuous multidimensional scalar function.

The aim for MiSG is to investigate and develop methods that can efficiently find the globally optimal values of drag function parameters when evaluating a set of candidate parameters is expensive.

Partner: DST Group

Summary report: not available at the time of publication

Do Road Safety Cameras Reduce Crashes?

The Royal Automobile Association (RAA) in South Australia has data on expiation notices issued by police, and road crash data. They are also a major insurer in South Australia, and have access to car insurance data.

RAA is interested in creating a *dashboard* that can be updated annually to summarise how safety cameras are being used in South Australia, and their effectiveness at reducing road crashes. Currently in South Australia there are 172 fixed cameras in operation, and in 2015–16 there were 1287 unique mobile camera locations used. In the last financial year, fines totalled almost \$88 million. Out of the top thirty intersections that recorded casualty crashes between 1996 and 2010, 17 now have fixed safety cameras. Casualty and injury crashes have reduced, but how does this compare to intersections where cameras have not been installed? RAA has access to road crash data since 1996 and expiation data from July 2012. RAA wishes to establish which camera sites have been most and least effective so that it can advocate on behalf of its members to ensure that cameras are used effectively.

Partner: Royal Automobile Association, South Australia (RAA)

Summary report: mathsinindustry.com/about/misg-2017/2017-projects/raa-summary-report/



Dr Belinda Chiera, The University of South Australia and Dr Jonathan Tuke, University of Adelaide at MiSG workshop

PHOTO: Prof. Mark J. McGuinness

Electricity Pricing and Control Mechanisms for Microgrids

Future communities will feature embedded electricity microgrids with low-capacity connections to the wider supply network. Within a community, customers will use rooftop photovoltaic systems to supply energy, and energy storage systems and demand management to control their energy use.

Control of electricity use within a community is required to manage peak power flows (which determine infrastructure capacity requirements) and to maximise the use of local energy from renewables. This control can be achieved using a combination of:

- centralised control of generation, energy storage and loads including water heating, air conditioning, pool pumps and electric vehicle charging
- decentralised control based on real-time price signals

The cost of imported electricity and the price paid for exported electricity should be low when there is an oversupply of energy

in the community, and high when there is insufficient supply. However, sudden changes in price could lead to sudden changes in behaviour, and introduce instability into the system.

SA Power Networks is interested in investigating electricity pricing and control mechanisms that will:

- minimise the cost of electricity for the community
- share the costs fairly between customers within the community
- empower customers to further reduce their bills by changing their behaviour
- reward customers who behave in ways that benefit the community
- ensure reliability and quality of electricity supply

Partner: SA Power Networks

Summary report: mathsinindustry.com/about/misg-2017/2017-projects/sapn-summary-report/

Web Links

mathsinindustry.com/about/misg-2017/

Other Sponsors

ANZIAM, University of South Australia

Contact

Assoc. Prof. Peter Pudney, University of South Australia, peter.pudney@unisa.edu.au

4.3 PARKS VICTORIA PARTNERSHIP

Protecting Australia's Iconic Flora and Fauna, Sustained with Statistics

Through a partnership program established in 2010, AMSI provides statistical support to Parks Victoria's environmental monitoring, evaluation and reporting processes.

The AMSI-Parks Victoria partnership continues to provide mutual benefits to both organisations. Parks Victoria obtains specialist statistical support, enabling better understanding to help solve

real-life land management problems, while AMSI, through its Intern program, gains valuable exposure to an industry partner and staff ranging from scientists to rangers.

Through AMSI's support, Kally Yuen works as a research partner to Parks Victoria research teams.

AMSI acknowledges Parks Victoria for their continuing support of this important research collaboration.

Kally Yuen, AMSI Statistician

Kally is an experienced biostatistician, having worked at the Peter MacCallum Cancer Centre and Centre for Youth Mental Health at The University of Melbourne.

Accredited by the Statistical Society of Australia in 2004, Kally's qualifications include a Master of Science degree in Statistics and a Bachelor of Science degree with First Class Honours in Statistics and Computer Science. She received the Maurice H. Belz Prize in Statistics while she was an undergraduate at The University of Melbourne.

Kally specialises in survival analysis, generalised linear models and relational database management systems. She is experienced in statistical consulting, research study design, study protocol and research database development, statistical analyses of research data, protocol review for research and ethics committees and grant assessment. Highly published, she has been a co-author in more than 30 research publications, 14 as a senior author. She has nurtured new talent as an instructor in statistics training courses and supervisor for research students.

Projects

Maintenance Program for Control of English Broom in Alpine National Park

Introduced in the nineteenth century, English broom is now widespread in Victoria's eastern alps, including the Alpine National Park. It is a weed of national significance due to its invasiveness, potential for spread and severe impacts on Australia's environment and primary industry. In 2004, Parks Victoria launched an adaptive experimental management program to evaluate the effectiveness of a number of herbicide treatments to control the weed. The results indicated that all treatments were able to reduce broom cover to a low level by the seventh year. A second phase of the program was launched in 2013 to investigate the best approach to maintain the low level achieved previously. This second phase indicated that active treatment targeted at residual broom plants and new growth is necessary, and the use of spot spraying on a biennial basis is sufficient to prevent the increase of broom level and preserve other plant species. However, annual treatment with spot spraying is not recommended as it tends to reduce the number of native plant species in the area treated.



English Broom, weed of national significance, regenerating post-fire in Alpine National Park in 2003 (photo Parks Victoria)

Weed Monitoring in the Dandenong Ranges

At the 6th Biennial Weed Society Victorian Conference in June 2016, Dr Marie Keatley, environmental scientist at Parks Victoria, presented the results of weed mapping undertaken in Dandenong Ranges National Park. In addition to publication of the work in the Conference proceeding, it was selected for publication in the peer-reviewed journal *Plant Protection Quarterly*. This joint work with AMSI identified Sweet Pittosporum as the most persistent weed in Dandenong Ranges National Park. Results have assisted planning for weed control in the region and enabled the community weed action group *StopPitt* to obtain funding for weed control. It has also led to collaboration between Parks Victoria and a PhD student from Monash University to investigate how long it would take plant communities to recover once Sweet Pittosporum is removed.



PHOTO: PARKS VICTORIA

Sweet Pittosporum, the most persistent weed in Dandenong Ranges National Park (photo taken by Ben O'Leary, Monash University)



PHOTO: MARGO BROWN

APR.Intern Program

Parks Victoria is a long-term APR.Intern industry partner, providing opportunities for postgraduate students to gain industry experience and apply their research in the context of real-world projects. In May 2016, Deakin University postgraduate student Yongqing Jiang, gave a presentation of his intern project to a group of engaging staff at Parks Victoria. Yongqing has created an efficient database system to capture data collected by remote cameras used to monitor fauna in parks. As a result of this successful collaboration, Yongqing was selected to embark on a new APR.Intern project to develop an automated system to detect whether an image has fauna in it or whether it is the result of a false trigger. This project has now been completed and Yongqing successfully presented his work to Parks Victoria staff in mid-December 2016.

ACRONYMS

ABACBS	Australian Bioinformatics and Computational Biology Society
ACE	Advanced Collaborative Network
ACEMS	ARC Centre of Excellence for Mathematical and Statistical Frontiers
ACOLA	Australian Council of Learned Academies
AGR	Access Grid Room
AMSI	Australian Mathematical Sciences Institute
AMSSC	Australian Mathematical Sciences Student Conference
ANU	The Australian National University
ANZAMP	Australian and New Zealand Association of Mathematical Physics
ANZIAM	Australian and New Zealand Industrial and Applied Mathematics
ARC	Australian Research Council
AustMS	Australian Mathematical Society
BIS	BioInfoSummer
CARMA	The Priority Research Centre in Computer Assisted Mathematics and Applications, The University of Newcastle
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DST Group	Defence Science Technology Group
ECR	Early Career Researchers
EMBL Australia	European Molecular Biology Laboratory Australia
ERA	Excellence in Research for Australia (Australian Research Council)
FAA	Fellow of the Australian Academy of Science
FAAAS	Fellow of the American Association for the Advancement of Science
FAMS	Fellow of the American Mathematical Society
FAustMS	Fellow of the Australian Mathematical Society
FRSC	Fellow of the Royal Society of Canada
HDR	Higher Degrees by Research
IMPA	Instituto Nacional de Matemática Pura e Aplicada
ISI	The Institute for Scientific Information
MathSciNet	Mathematical Reviews Database, maintained by the American Mathematical Society
MATRIX	Mathematical Research Institute (jointly administered by The University of Melbourne, Monash University with support from ACEMS)
MCMC	Markov chain Monte Carlo
MiSG	Mathematics in Industry Study Group
MSI	Mathematical Sciences Institute, Australian National University
NSF	National Science Foundation (USA)
OECD	Organisation for Economic Co-operation and Development
PDE	Partial Differential Equation
QCIF	The Queensland Cyber Infrastructure Foundation
QUT	Queensland University of Technology
RHE	Research and Higher Education
RHEC	Research and Higher Education Committee
SPCM	South Pacific Conferences in Mathematics
SAC	Scientific Advisory Committee
SSA	Statistical Society of Australia
STEM	Science, Technology, Engineering and Mathematics
UCLA	University of California, Los Angeles
UNE	The University of New England
UniSA	University of South Australia
UNSW	The University of New South Wales
UOM	The University of Melbourne
UON	The University of Newcastle
UOW	University of Wollongong
UQ	The University of Queensland
USQ	University of Southern Queensland
USYD	The University of Sydney
UTas	University of Tasmania
UTS	University of Technology Sydney
UWA	The University of Western Australia
UWS	Western Sydney University
VRS	Vacation Research Scholarships
WEHI	The Walter and Eliza Hall Institute of Medical Research
WIMSIG	Women in Mathematics Special Interest Group

AMSI MISSION

The radical improvement of mathematical sciences capacity and capability in the Australian community through:

- The support of high quality mathematics education for all young Australians
- Improving the supply of mathematically well-prepared students entering tertiary education by direct involvement with schools
- The support of mathematical sciences research and its applications including cross-disciplinary areas and public and private sectors
- The enhancement of the undergraduate and postgraduate experience of students in the mathematical sciences and related disciplines

A complex, three-dimensional mathematical surface, possibly a hyperboloid of two sheets, rendered with a fine grid pattern. The surface is colored with a gradient from light yellow to dark brown, with a bright white highlight on the left side. It is set against a plain grey background.

www.amsi.org.au

Australian Mathematical Sciences Institute
Building 161, c/- The University of Melbourne
Victoria 3010 Australia
Tel: +61 3 8344 1777
email: enquiries@amsi.org.au

