# AMSI WINTERSCHOOL IN THE MATHEMATICAL SCIENCES ON CURVATURE

2-13 JULY 2018 THE UNIVERSITY OF QUEENSLAND

# **EVENT REPORT**







AMSI Winter School 2018 would like to thank the following partners for their support:



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### **AMSI Winter School 2018**

#### **On Curvature**

#### The University of Queensland 2–13 July 2018

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### FOREWORD

The AMSI Winter School is one of five premier flagship events hosted each year around Australia and forms part of the Securing Australia's Mathematical Workforce: 2016-2020 agreement between AMSI and the Department of Education and Training. Now in its 14<sup>th</sup> year, this key program has become an integral part of the events calendar for PhD and postgraduate students, as well as early-career researchers in the mathematical sciences and cognate disciplines.

Hosted over two weeks, this program offers a range of specialist topics with an overarching theme. The aim of the AMSI Winter School is to develop the next generation of mathematical scientists who can thrive in tomorrow's information age. This program draws upon the knowledge of national and international lecturers at the forefront of their fields, and attracts students from all around Australia.

The complete program, comprising course content and extra activities, is designed to align with the project objectives of the agreement to:

- Strengthen research training and the work-readiness of advanced mathematical sciences graduates;
- Promote university-industry collaborations that will encourage the private-sector employment of mathematical sciences graduates;
- Attract and improve the retention of senior undergraduate students in the mathematical sciences, with particular attention to women and Aboriginal and Torres Strait Islander students.

AMSI Winter School 2018 was jointly funded by the Australian Mathematical Sciences Institute (AMSI) and the Australian Government's Department of Education and Training, with support from the University of Queensland, the Australian Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS), the Queensland Cyber Infrastructure Foundation (QCIF), The Simulation Group, and the BHP Foundation through the Choose Maths program.

### **DIRECTOR'S REPORT**

#### Dr Phillip Isaac, AMSI Winter School 2018 Event Director



This year, the 14<sup>th</sup> AMSI Winter School was held at the St Lucia campus of the University of Queensland (UQ) in Brisbane. Since its inception, the Winter School has grown to become one of the most significant events in the Australian calendar for post-graduate students and early-career researchers in the mathematical sciences. Each year, the two-week program offers participants the opportunity to expand their skills and perspective, and to build collaborative networks.

The theme this year was Curvature. The selection of courses related to this theme attracted participants with a variety of mathematical backgrounds, although many were working on research projects related to at least one of the topics presented by the four lecturers. Participants were mainly from 12 different universities across Australia, with one participant from industry. The Winter Schools of the previous two years have attracted a diverse range of students and early-career researchers from cognate disciplines. By contrast, this year seemed to attract a more intimate and focused group with an interest in this specialised theme. The outcome was a strong cohort experience and an outstanding fortnight of growth for all participants.

Two series of lectures were run each week at this year's

Winter School, with each series comprising five lectures focused on a specially-chosen topic relating to curvature. The opening speaker for Week One was Professor Rod Gover from The University of Auckland, who spoke on the topic of Curvature in Conformal Geometry. Joining him in Week One was Associate Professor Mariel Sáez from Pontificia Universidad Católica de Chile, who presented a series of lectures on Curvature Flow of Networks. Week Two then saw Dr Paul Bryan from Macquarie University give lectures on Comparison Geometry, and Associate Professor Julie Rowlett present her short course on Heat Flow and Geometry. All lectures were given at the whiteboard in the Prentice Building (building number 42 on the St Lucia campus), Room 216.

All four lecturers had provided detailed summaries and pre-reading online in advance of the Winter School, and in some cases posted follow-up notes after the lecture. During the lectures, it was common for the lecturer to pose problems for the participants to attempt to solve. Many participants would take advantage of the informal tutorial sessions held in the Science Learning Centre (a contemporary collaborative learning space, ordinarily used by undergraduate students during semester) on Level Two of the Priestley Building (building number 67 on the St Lucia campus). It appeared to give rise to a very constructive learning environment with a collaborative atmosphere.

Participant talks were held on the Tuesday afternoon of the first week. As a peer-voted competition, these talks were managed in five groups, and a winner selected from each group. On the Monday afternoon of the second week, the finalists gave presentations to the entire group and a winner was elected. The quality of the talks was impressive, and the winner was Mark Bugden from the Australian National University (ANU) for his presentation

entitled "Light Orbiting a Five-Dimensional Black Hole". An honourable mention was given to Grace Garden from Boeing Research and Technology, Australia, who came a close second for her talk entitled "The Mathematics of Collision Avoidance".

There were several social highlights of the Winter School. On the Wednesday night of the first week was the Women in Maths Networking Event. This was a relaxed evening of wine and cheese with a panel discussion. The aim of the evening was to highlight the contribution of women in mathematics, with engaging discussions about career paths. The panel members this year were Ellie Hubbard (Senior Electrical Engineer, Aurecon Australasia), Mariel Sáez (Associate Professor, Pontificia Universidad Católica de Chile, and Winter School lecturer), Natalie Lawler (mathematics and science teacher, Kenmore State High School) and Kim-Anh Do (Professor, University of Texas MD Anderson Cancer Center).

Friday afternoon of the first week, Professor Geoff Goodhill from UQ's School of Mathematics and Physics and the Queensland Brain Institute (QBI), gave a lecture about his research conducted in his QBI lab, followed immediately by a guided tour of the lab and refreshments on the terrace at QBI. Many of the participants enjoyed this tour, having been given the chance to observe an environment in which leading-edge research is produced in the field of computational neuroscience. This was also a nice way to end the first week, and was followed by an informal dinner at St Lucy's restaurant on campus.

Monday evening of the second week was a public lecture by Associate Professor Julie Rowlett (Chalmers University of Technology, and Winter School lecturer). Her talk, entitled "The Spectrum: Incomputable yet Physically Tangible Numbers", was held in the Abel Smith Lecture Theatre on the St Lucia campus, and was well attended. The talk was engaging and inspired many questions at the end. Discussions continued over a light supper afterwards.

In the second week, Grace Garden, a participant currently employed by Boeing Research and Technology, offered to organise a tour of the Boeing labs on campus at St Lucia, for any interested participants. There was a great deal of interest, so we organised two impromptu tours on the Tuesday and Wednesday of the second week. This was a good opportunity for the participants to see the variety of activities undertaken in employment as R&D industrial mathematicians and by other STEM graduates.

Thursday night of the second week was the formal Winter School dinner, held at The Regatta Hotel in Toowong. In attendance was Bruce Olsson, Senior Partner of The Simulation Group, who presented the prize for best participant talk to Mark Bugden from ANU.

The Winter School attracted financial support from many sponsors: the Australian Mathematical Sciences Institute, the Australian Government Department of Education and Training, The University of Queensland, the Queensland Cyber Infrastructure Foundation, the Australian Research Council Centre of Excellence for Mathematical and Statistical Frontiers, and the Simulation Group. It should also be noted that BHP Billiton provided support by financing the Choose Maths Grants. These grants provide support for Australian female mathematical sciences students and early-career researchers.

I would like to express my sincerest thanks to many people who made this possible. In particular, Scientific Director Dr Julie Clutterbuck from Monash University, Event Coordinator Andree McFarlane, the team at AMSI, Head of the School of Mathematics and Physics (SMP) at UQ Professor Joe Grotowski, and the administrative staff in SMP and the Science Faculty office. Finally, thanks to all the participants, including the lecturers. I hope the experience at this Winter School stays with you throughout your careers.

#### Dr Phillip Isaac, 2018 AMSI Winter School Event Director

### **COURSE PROGRAM**

#### **PROGRAM THEMES:**

Geometric Analysis Curvature Flows Singularities

#### Course 1:

**Curvature in Conformal Geometry** 

Professor Rod Gover, The University of Auckland

#### Course 2:

#### **Curvature Flow of Networks**

Associate Professor Mariel Sáez, Pontificia Universidad Católica de Chile

#### Course 3:

#### **Comparison Geometry**

Dr Paul Bryan, Macquarie University

#### Course 4:

#### **Heat Flow and Geometry**

Associate Professor Julie Rowlett, Chalmers University of Technology

#### **Curvature in Conformal Geometry**

#### Professor Rod Gover, The University of Auckland



Lecture 1: Conformal problems in Riemannian geometry, pseudo-Riemannian geometry and mathematical physics

Beginning with the notation etc. in (pseudo-)Riemannian geometry, this lecture then covered some motivating problems including constructing invariants, invariant differential operators, curvature prescription and conformal compactification.

### Lecture 2: Conformal geometry, tractor calculus and the geometry of scale

We defined conformal manifolds and constructed on these the basic conformally invariant calculus. We then explained how (pseudo-)Riemannian objects should be treated in this picture.

#### Lecture 3: Hypersurfaces and their geometry

We developed the basic calculus for hypersurfaces in (pseudo-)Riemannian and conformal manifolds, arriving at the usual curvature quantities such as the second fundamental form, the mean curvature etc. We explained the place of these in conformal geometry. We saw how to use conformal geometry to describe e.g. minimal, CMC and totally umbilic hypersurfaces.

#### Lecture 4: The geometry of conformal infinity and boundary calculus

The use of conformally compact manifolds (following the initial ideas of Fefferman-Graham) as a tool in conformal geometry was explained and demonstrated. Motivated by this, the tools developed in the earlier lectures were applied to study the boundary at infinity of conformally compact manifolds.

#### Lecture 5: Higher Willmore invariants and energies

The final application was to understand how the Willmore energy and its functional gradient (with respect to variation of embedding) fit into the picture and then the generalisation of this to higher dimensions was explained, as well the link between these objects and Q-curvatures.

#### **Curvature Flow of Networks**

#### Associate Professor Mariel Sáez, Pontificia Universidad Católica de Chile

The study of geometric flows has gained a lot of attention in mathematics over the last few decades, both as a powerful tool in addressing problems in several branches of the discipline, as well as for its own interest. These flows can often be understood as non-linear quasi-parabolic equations with a geometrical meaning.

An important example is the extrinsic flow known as the "mean curvature flow" that has been extensively studied in the smooth setting (see for instance [10] and references therein). Particularly, when the evolution of curves is considered, the flow is known as "curve-shortening flow" and it is fully understood for closed embedded curves. Nonetheless, an early motivation for curve-shortening flow comes from the work of Mullins [7]



in the 1950s, where the evolving curves are interpreted as evolving interfaces that appear naturally in material sciences. However, in that context it is expected that certain natural "built-in" singularities (which are not present in the smooth case) appear through the evolution. Such behaviour is mathematically modelled by the evolution of networks under curve-shortening flow, which has proven to be more challenging to study than its smooth counterpart.

In these lectures I gave an overview of the classical theory for smooth curves and compared it to its counterpart in the network case. More precisely, I discussed the results of Gage-Hamilton and Grayson and more recent proofs of these theorems in [1, 2, 5], and then defined the flow of networks and possible different approaches to study this flow. I described existence results and long-time behaviour for networks with no loops (c.f. [9]) and some results in the case with loops (c.f. [8]).

"The organisation of the school was excellent, the lectures of really high standard, the city of Brisbane and the campus of UQ very beautiful... I enjoyed all of my time spent during the AMSI Winter School. I believe at last that the best part is having the possibility of meeting some really great people."

**Claudia Bucur, The University of Melbourne** 

#### **Comparison Geometry**

#### Dr Paul Bryan, Macquarie University



The role of curvature in geometry and topology is quite subtle but comparison geometry allows us to glimpse some of the hidden interactions between geometry and topology. The material is both classical and contemporary with classical fundamental results like the Bishop-Gromov volume comparison playing a very important role in contemporary research such as in the study of the Ricci flow. The theory is quite beautiful, exhibiting how powerful modern techniques in analysis may be used to expose geometric and topological phenomena and illuminate aspects of Gromov's little monster, namely the curvature tensor.

We developed comparison geometry as expressed by the Rauch comparison theorems through the Riccati equation, which is the linearisation of the geodesic equation, an innocuous-looking equation belying much complexity. In particular we saw how curvature affects distance, triangles volume and surface area, and discovered some topological implications. We also sketched the proof of the famous, classical topological sphere theorem of Berger-Klinenberg and discussed the contemporary differentiable sphere theorem of Brendle-Schoen as well as some open problems.

#### Heat Flow and Geometry

# Associate Professor Julie Rowlett, Chalmers University of Technology

#### Lecture 1

We began with the very basics.

Suggested reading for this lecture was *The Atiyah-Patodi-Singer Index Theorem* by Richard Melrose, Chapter 7

The heat kernel: what is it?

Explicit computation of the heat kernel in Rn

Heat spaces: what are they?

The heat space for Rn

Properties of the heat kernel on Rn



#### Lecture 2

Moving right along, we next considered compact smooth manifolds

Suggested reading was The Laplacian on a Riemannian Manifold, by Steve Rosenburg, Chapter 3

Duhamel construction of the heat kernel The short time asymptotic expansion of the heat trace Geometry captured by the heat trace

Spectral invariants and "hearing things"

#### Lecture 3

We continued with the notion of "hearing things" as well as increasing the geometric complexity. We considered smoothly bounded domains in Rn as well as heat kernels associated to Schrödinger operators on Rn with compactly supported L∞ potentials.

Suggested reading was Can One Hear the Shape of a Drum, by Mark Kac

Locality principles (generalisations of Kac's principle of "not feeling the boundary")

Kac's "hole"

#### Lecture 4

We finally arrived at non-smooth geometric settings: domains in Rn which have non-smooth boundary. We also looked at manifolds with singularities. In this context we investigated:

Locality principles

Hearing singularities

#### Lecture 5

In conclusion we learned about the dangers of heat, specifically:

Infinite speed of propagation

Randomness

"The Winter School as a whole was very well organised... The lecturers were not only extremely knowledgeable, but also easily approachable. Personally, I found the time set aside for tutorials/discussions after the lectures to be particularly helpful."

Sebastian Murk, Macquarie University

### **PARTICIPATION BREAKDOWN**

UNIVERSITY/INSTITUTION	
Australian National University	8
Boeing Research and Technology Australia	1
Curtin University of Technology	1
Macquarie University	1
Monash University	2
Queensland University of Technology	1
The University of Adelaide	3
The University of Melbourne	2
The University of New South Wales	2
The University of Queensland	3
The University of Sydney	1
The University of Western Australia	1
The University of Wollongong	1
TOTAL	27

"I enjoyed the atmosphere of learning in the Winter School—everyone was there to learn, share ideas, and collaborate. It was a great place to chat about maths."

Mark Bugden, Australian National University





Gender	Number	%
Male	24	89%
Female	3	11%

#### **Status**

<b>ATSI Status</b>	Number	%
Yes	0	0%
No	27	100%

State/Territory	Number	%
ACT	7	26%
NSW	6	22%
QLD	5	19%
NT	0	0%
SA	3	11%
TAS	0	0%
VIC	4	15%
WA	2	7%
International	0	0%

#### **Academic Status**



Academic Status	Number	%
Undergraduate	1	4%
Honours	4	15%
Masters	5	18%
PhD	16	59%
Academic	0	0%
Early-Career Researcher	1	4%

**Residency Status (only = 99%)** 



Academic Status	Number	%
Australian Citizen	16	59%
Permanent Resident	2	7%
Student Visa	7	26%
Other	2	7%

"The AMSI Winter School was a fantastic opportunity not only to learn about a broad range of topics from leading researchers, but in particular to connect with other postgraduate students with whom I would like to stay in contact and may be able to collaborate with in the future. The events were all well-organised and the free coffee was great! The organisers did a fantastic job of running the Winter School."

David Brook, The University of Adelaide

### GRANTS

#### **AMSI TRAVEL GRANTS**

AMSI Travel Grants are funded by AMSI, the Australian Department of Education and Training, and the University of Queensland. These grants allow students to travel interstate and from rural areas to attend the Winter School program. They offer both travel and accommodation support to students who would otherwise be unable to attend the event, and are awarded on a competitive basis. In 2018, AMSI Travel Grants were awarded to the following 19 Winter School participants:

David Brook, The University of Adelaide Mark Bugden, The Australian National University Daniel John, The University of Adelaide Simon Kitson, The Australian National University Yitao Lei, The Australian National University Jia Jun Gino Lu, The Australian National University Kobamelo Mashaba, Curtin University of Technology Nathan McMahon, University of Queensland (resides in NSW; PhD is under University of Queensland) Benjamin Metha, The University of Melbourne Benjamin Moore, The University of Adelaide Sebastian Murk, Macquarie University Jeremy Nugent, The University of New South Wales Lachlann O'Donnell, University of Wollongong Peter Olanipekun, Monash University Arturo Olvera, Monash University Cale Rankin, The Australian National University Christopher Rock, The University of New South Wales Kyle Wright, The Australian National University Erchuan Zhang, The University of Western Australia



"[I enjoyed] the atmosphere of being around so many mathematicians interested in a similar area. I found... that everyone, including the lecturers, was really easy to speak to and have a great time with. Rod Gover's course was by far the best take-away of the Winter School from an academic point of view. His course was thorough, organised and very inspiring."

Kyle Broder, Australian National University

#### **CHOOSE MATHS GRANTS**

Choose Maths Grants are designed to encourage female participants from the mathematical sciences and cognate disciplines to attend AMSI Flagship events. These grants offer travel, accommodation and carer support to those travelling from rural areas and interstate. At Winter School 2018, registration fees for grant recipients were also covered. Funded by AMSI and the BHP Foundation (out of the Choose Maths initiative), the following two students were awarded support to attend the 2018 Winter School program:

Claudia Bucur, The University of Melbourne Hadil Alhazmi, The Australian National University

"I enjoyed the extended opportunity to network with fellow PhD students, and make meaningful connections... I can't think of any substantial improvements that could be made."

Kyle Wright, Australian National University



### **PROGRAM EXTRAS**

#### Welcome BBQ

Students convened at Emmanuel College in the evening of Sunday 1 July for an informal barbeque. This was a chance for students to register for the program, settle into their on-campus accommodation and meet one another before the official commencement of the program the next day.

#### **Opening Ceremony**



The Winter School program officially commenced with the Opening Ceremony, which was hosted on Monday 2 July in the Science Learning Centre at the University of Queensland (UQ). Students, lecturers and distinguished guests were welcomed to Brisbane and the UQ campus by Event Director Dr Phillip Isaacs. Keynote speaker Professor Joseph Grotowski (Head of School, Mathematics and Physics, the University of Queensland) welcomed students and urged them to use the Winter School as an opportunity to learn and network with world-renowned experts and peers alike. Distinguished guests at the event included Professor Geoff Prince

(AMSI Director), Troy Farrell (Head of School, Science and Engineering Faculty, Mathematical Sciences), as well as prominent members of the University of Queensland science faculty including Margaret Mayfield, Tony Roberts and Phil Pollett.

The Opening Ceremony concluded with morning tea. Students were also invited to attend a campus tour to get acquainted with the facilities at UQ's St Lucia campus.

#### **Queensland Brain Institute**

Students were invited to attend a special lecture given by Professor Geoffrey Goodhill about the Queensland Brain Institute and the computational neuroscience research being conducted there.

This lecture was followed by a tour of the Institute where students got a first-hand view of the facilities and were given the opportunity to take part in some of their interactive research activities.

#### Women in Maths

In collaboration with WIMSIG (Women in Maths Special Interest Group), a Women in Maths event was hosted to celebrate women's contribution to the mathematical sciences and encourage diversity



in the sector. The event invited panel members to talk about their career experiences as well as changes they have observed in the industry over the years. The audience also had the opportunity to engage in a lively Q&A discussion delving into panel members' experiences more closely as well as sharing tips on how to encourage more diversity within the mathematical sciences in future generations. Panel members included Ellie Hubbard (senior electrical engineer, Aurecon Australasia), Associate Professor Mariel Sáez (Pontificia Universidad Católica de Chile and 2018 Winter School lecturer), Natalie Lawler (mathematics and science teacher, Kenmore State High School) and Professor Kim Anh Do (University of Texas MD Anderson Cancer Center). Julia Collins from AMSI also spoke to guests about the AMSI Choose Maths project and the positive long-term impacts on encouraging more diversity in the mathematical sciences.

Over 50 guests were in attendance to learn about the wonderfully diverse mathematical journeys of these panellists and participate in lively discussion over supper.

#### **Participant Talks**



The Participant Talks are an opportunity for students to share their research with their peers and see the broad scope of study for mathematics in their general field. All attendees were asked to give a 15-minute presentation on their thesis or topic of specialisation, with an added five minutes to field any questions from the audience. Students were first separated into five groups and asked to vote for the best presentations in their respective groups. Speakers from this short list went on to present to the whole cohort. Mark Bugden (Australian National University) was voted as the Best Speaker, with Kyle Broder (Australian

National University), Claudia Bucur (The University of Melbourne), Grace Garden (Boeing), and Kyle Wright (Australian National University) being nominated as short list finalists.

#### **Friday Night Social**

Students attended the Friday Night Social at the end of the first week. This was an informal opportunity for students to socialise over pizzas with peers, lecturers and Winter School organisers in a relaxed atmosphere. This was hosted on Friday 6 July at St Lucy's at the University of Queensland. It was an excellent chance for the cohort to mix and mingle and get to know each other better outside of classes.

#### **Public Lecture**

The Public Lecture was hosted on Monday 9 July at the Abel Smith Lecture Theatre at the University of Queensland. This event is an occasion for members of the public to interact with the mathematical sciences community and be exposed to the broad range of applications and positive impacts that mathematics has on everyday life. The 2018 Winter School Public Lecture was presented by Associate Professor Julie Rowlett

(Chalmers University of Technology, Sweden) who talked about eigenvalues and their role in creating sound, heat flow and the energy in quantum particles. This event was attended by 100 guests including Winter School students, academics and members of the general public. A light supper was served to guests afterwards.



#### **Boeing Tour**

Students were given the rare opportunity to tour the Boeing offices located on the University of

Queensland campus, and get a sneak peek into their research activities. Our thanks go to Grace Garden, Winter School 2018 participant and early-career researcher at Boeing, for making the arrangements for these tours.

#### **Conference Dinner**

The Conference Dinner was hosted at the Regatta Hotel on 12 July. This was a formal sit-down dinner for students, lecturers and event organisers to celebrate the conclusion of the Winter School program. Distinguished guest Bruce Olsson from Winter School sponsor The Simulation Group presented the prize for Best Participant Talk to winner Mark Bugden.

The catering was universally praised, and it was a very successful and enjoyable final dinner to close out the conference.



"[I enjoyed most of all] the external social events, it was a good opportunity to hear more about what some of my peers are doing, and how they got there."

#### **Grace Garden, Boeing**

### **FEEDBACK ANALYSIS**

Seventy-eight percent of attendees of the 2018 Winter School completed the post-event feedback survey. Once again, the data illustrates the importance of this flagship event in assisting students to collaborate with peers and extend their knowledge by providing them with access to the world leaders in their chosen field. This data points to both immediate benefits as well as potential ongoing benefits in the long term for both innovation and career development. In rating their overall experience, with 1 being poor and 10 being excellent, participants rated the event an average of 9.4. This is an increase year-on-year from the average event rating in both 2016 and 2017.

Of those who completed the survey, 57 per cent of students stated that they attended Winter School because the theme was related to their overall research interests, and an additional 33 per cent indicated that their main motivation for attending was to broaden their knowledge base. A further 5 per cent noted that they had attended to help their career prospects. This data suggests that students attending this event are future-focused and keen to pursue mathematical sciences in the long term. It also suggests that there is an appetite to deepen their already expert knowledge and learn from the most eminent minds leading the world on this topic.

There was positive feedback among attendees who reported that they came away from the program with a wider skill set that could be applied to their everyday mathematical activities (43 per cent agreed; 10 per cent strongly agreed), including the strengthening of their ability to conduct individual research outside of the program (33 per cent agreed; 24 per cent strongly agreed).

The data also revealed the program's importance in giving attendees an opportunity to network and form friendships and professional relationships with others in their cohort (in an environment that can otherwise be isolating). Thirty-three percent strongly agreed that they had made useful contacts with whom they would potentially collaborate, and an additional 33 per cent agreed with this statement.

Attendees found the Winter School program informative and useful. Most felt that the course had strengthened their mathematics credentials (53 per cent strongly agreed; 33 per cent agreed), and that it had exposed them to other research fields that they may not have otherwise known about (33 per cent strongly agreed; 29 per cent agreed). All students completing the feedback survey unanimously said that they would recommend AMSI Winter School to their friends and colleagues.

### OVERALL, THE SCHOOL WAS OF A HIGH STANDARD

Strongly Agree	86%	
Agree	14%	
Neutral	0%	
Disagree	0%	
Strongly Disagree	0%	

### OVERALL, THE SCHOOL WAS WELL-ORGANISED

Strongly Agree	86%
Agree	14%
Neutral	0%
Disagree	0%
Strongly Disagree	0%



### THE WOMEN IN MATHS EVENT WAS A REWARDING EXPERIENCE

Strongly Agree	24%
Agree	66%
Neutral	0%
Disagree	0%
Strongly Disagree	5%
Not Applicable	5%

### THE SCHOOL STRENGTHENED MY MATHEMATICAL CREDENTIALS

Strongly Agree	33%
Agree	53%
Neutral	14%
Disagree	0%
Strongly Disagree	0%



### THE PUBLIC LECTURE WAS INTERESTING AND INFORMATIVE



Strongly Agree	57%
Agree	24%
Neutral	5%
Disagree	0%
Strongly Disagree	5%
Not Applicable	9%

### I WOULD RECOMMEND THE WINTER SCHOOL TO OTHERS

Strongly Agree	81%
Agree	19%
Neutral	0%
Disagree	0%
Strongly Disagree	0%



"I loved the courses—especially Julie's!—and meeting so many cool maths people."

Benjamin Metha, The University of Melbourne

### **STUDENT PROFILES**

#### Winter School an Inspiration for Emerging Maths Talent

Choose Maths Grant recipient Dr Claudia Bucur



University of Melbourne Research Fellow and AMSI Winter School 2018 attendee Dr Claudia Bucur came to maths later in life. Her love for the subject, however, began much earlier thanks to an inspiring teacher.

"I had the fortune of having a very good maths teacher through high school. Having her for an example, it never occurred to me that men could be more inclined or better at maths than women," says Bucur.

Given her introduction to maths, it seems fitting that her Winter School 2018 experience was made possible thanks to a Choose Maths grant. It was crucial to meeting the cost of attending.

"[Without the grant] it would have been quite challenging for me to attend Winter School. It allowed me to fully focus on the mathematics," she says.

Focused on mathematics related to the theme of curvature, Winter School 2018 proved very relevant to Bucur's work in the field of integro-differential equations.

"Some of the courses were quite close to my area of research, some a little bit further away. It was thus challenging and very useful at the same time. I would definitely like to pursue studying and working on some of the subjects I got to know during Winter School," she says.

Previously based at Italy's University of Milan, Bucur returned to mathematics studies in 2012 after working in the industry as a Statistical Analysis System Developer for six years. Now at the University of Melbourne, she is interested in issues related to existence, regularity, quantitative and geometric properties of solutions in problems involving fractional nonlocal operators of integral type.

"This type of operators and problems give rise to a beautiful theory and to a lot of work. The applications are numerous, for instance in models describing anomalous diffusion, geomorphology, viscoelasticity, signal processing and materials sciences or fractals," she explains.

As she continues her new journey in mathematical science, AMSI Winter School offered not only exposure to new subjects and field areas but powerful networking opportunities to build ties in her field.

"[It was valuable] to meet and exchange opinions with some great mathematicians, setting the basis for future collaborations."

This rare access to add her voice to discussion in her field and foundational ties for future collaboration is why Bucur sees Choose Maths as such an enormous opportunity for women in mathematics.

"The Choose Maths grant provides a valid support for women mathematicians in their early career to access amazing courses. For me, meeting the women lecturers and the Women in Maths ambassadors was really inspiring," she enthuses.

AMSI Winter School 2018 was hosted by the University of Queensland. Event sponsors included AMSI, the Department of Education and Training, UQ, the BHP Foundation, ACEMS, QCIF and the Simulation Group. For more information visit <u>ws.amsi.org.au</u>.

#### **The Cosmos of Maths**

#### Choose Maths Grant recipient Mark Bugden



As a theoretical physicist with a passion for string theory, Mark Bugden knows the importance of understanding space and how things fit together.

"String theory helps us to increase our understanding of the fundamental laws of the universe, and in doing so helps us understand our place in the cosmos," he explains.

While not quite the cosmos, AMSI Winter School 2018 gave the Australian National University PhD student the opportunity to "understand a larger part of the tapestry of mathematics, which is especially important in an interdisciplinary field."

The chance to explore new ideas beyond his PhD also provided insight into their impact and significance in relation to his field.

"This year's theme of curvature helped clarify a lot of hazy ideas and solidify my knowledge."

The two-week residential school also provided a compelling platform to network and exchange ideas, something often missing from the PhD experience in a country plagued by the tyranny of geographical isolation.

"The event provides opportunity to meet students from other universities, as well as academics outside your area. This is essential to maintain competitiveness in an ever-demanding academic environment," says Bugden.

Instrumental to his capacity to attend, Bugden knows he wouldn't have made it to Winter School without support from AMSI. Something he is very grateful to have received.

"Without travel and accommodation costs covered, I wouldn't have been able to attend. In that sense, the travel grant was vital," he says.

Bugden, who won the AMSI Winter School 2018 participant talks, says the event was a perfect mix of opportunities to build knowledge and communication skills. Just don't ask him what he liked best.

"It is an even split between the mathematical content and networking. The student talks, in particular, were a chance to present research and compete in a relatively stress-free environment."

As for what comes next, Bugden hopes to take up a permanent university position and a place in the rich tapestry of the mathematical sciences. Where that leads is anyone's guess.

"Who knows, perhaps in 50 or 100 years there will be some practical application nobody could have foreseen. As we've seen, Einstein's general theory of relativity led to the development of GPS satellites and quantum theory to the development of computers," he says.

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### **MEDIA RELEASE**

#### Why Strings Pluck at Our Hearts: Maths and Australia's Pink Passion

She's touring Australia this month and we can't get enough of her music, but is there a maths factor to the nation's Pink passion?

Maths definitely plays a role, according to Associate Professor Julie Rowlett who will deliver the 2018 Australian Mathematical Sciences Institute (AMSI) Winter School public lecture from 6pm, at the University of Queensland on 9 July.

This maths factor, says the Chalmers Institute of Technology Mathematician and sometimes singer, is down to a group of numbers, also known as eigenvalues.

"Relatives of pi, eigenvalues are known collectively as the spectrum, these mysterious numbers are responsible for how the music we love sounds. They are responsible not only for the sounds made by string instruments like guitar and piano, but also for the unique sound of Pink's voice!"

Calculations using these numbers are used to explain a range of phenomena such as how waves travel, the flow of heat and the energy of quantum particles. In music, says Rowlett, they allow us to tell the "real story" behind vibrating frequencies and sounds.

"Understanding these vibrations and how they can be used provides insights into how we make music and why we like it. For example, why a rock guitarist who wants to play high notes holds the strings way down close to the base of the guitar," says Associate Professor Rowlett.

Originally from the US but now based in Sweden, Rowlett is also one of four field specialists leading short courses for Australia's brightest mathematics postgraduates and early-career researchers during the 2018 AMSI Winter School on Curvature.

Free to attend, Associate Professor Julie Rowlett's public lecture, "The Spectrum: Incomputable Yet Tangible Numbers", will run from 6pm on 9 July at The University of Queensland, St Lucia Campus. Bookings essential, visit: <u>ws.amsi.org.au/public-lecture-2018/.</u>

Incorporated into each of the Institute's flagship training schools, AMSI Director Professor Geoff Prince said public events are an important platform to strengthen community engagement with mathematics.

"Julie Rowlett's lecture offers the public a powerful opportunity to engage with mathematics and its value as a tool to deepen understanding of the world," says Professor Prince.

Hosted in 2018 by The University of Queensland, AMSI Winter School is a two-week residential program for graduate students, postdoctoral fellows and early-career researchers in the mathematical sciences and cognate disciplines, providing the opportunity for participants to expand their skills and build collaborative networks with their peers.

AMSI Winter School 2018 is sponsored by AMSI, UQ, the Department of Education and Training, the BHP Billiton Foundation, ACEMS, QCIF and, the Simulation Group. For more information visit <u>ws.amsi.org.au.</u>

### **MEDIA REPORT**

Harmonics and its role in bridge construction and music were at the heart of the media coverage for AMSI Winter School 2018. Centred around Associate Professor Julie Rowlett's Public Lecture topic, "The Spectrum: Incomputable yet Physically Tangible Numbers", the media campaign received strong coverage across news channels nationally reaching a total reach of over **13 million**.

A News Limited article achieved national reach of approximately **12 million** with the piece published on news.com.au and syndicated through websites for all major News Limited national dailies—*Daily Telegraph, Herald Sun, Courier Mail, Adelaide Now, NT News, Townsville Bulletin, news.com.au, Gold Coast Bulletin, Geelong Advertiser, The Mercury.* An article was also published for national paper *The Australian* which had a reach of over **one million**. While not measurable, strong social media integration of many of these sites also significantly added to reach with a presence in popular news feeds associated with key platforms such as Facebook and Twitter.

"This year's Boeing tour was very interesting and enjoyable. It is a great motivation for maths students or researchers to understand the power of mathematics when they are exposed to such industry directly."

Erchuan Zhang, The University of Western Australia

### **EVENT COMMITTEES**

AMSI would like to acknowledge and thank all the individuals who contributed their time and expertise to making Winter School 2018 a resounding success:

#### **STANDING COMMITTEE**

Dr Phillip Isaac (Chair and Event Director)—The University of Queensland Julie Clutterbuck (Scientific Director)—Monash University Joseph Grotowski—The University of Queensland Troy Farrell—Queensland University of Technology Ian Turner—Queensland University of Technology Geoff Prince—Australian Mathematical Sciences Institute Markus Hegland—The Australian National University Chloe Pearse—Australian Mathematical Sciences Institute Aurore Delaigle—The University of Melbourne Artem Pulemotov—The University of Queensland Andree McFarlane—The University of Queensland Andree McFarlane—The University of Queensland

#### **EVENT ORGANISING COMMITTEE**

Phillip Isaac (Event Director)—The University of Queensland
Joseph Grotowski—The University of Queensland
Andree McFarlane—The University of Queensland
Chloe Pearse—Australian Mathematical Sciences Institute
Anna Muscara—Australian Mathematical Sciences Institute

"Above all it was clear just how proficient the event organisers have become at running the Winter School. The professionalism and ease with which every aspect of the Winter School was taken care of was unprecedented. My sincere thanks to Andree, Phil and all others involved for running an event of absurdly high quality."

Cale Rankin, Australian National University

## AMSI WINTERSCHOOL IN THE MATHEMATICAL SCIENCES ON CURVATUR 2-13 JULY 2018 THE UNIVERSITY OF QUEENSLAND

**THEMES INCLUDE** GEOMETRIC ANALYSIS CURVATURE FLOWS SINGULARITIES

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