LONDON MATHEMATICAL SOCIETY
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# NEWSLETTER

*Issue: 504 - January 2023*

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NOTES OF A NUMERICAL ANALYST

MATHEMATICS NEWS FLASH

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LMS NEWS

## LMS Council 2022–23

The results of the 2022 LMS Elections to Council and Nominating Committee were announced at the LMS Annual General Meeting on 18 November 2022. Council membership for 2022–23 is as follows:

**President:**
Professor Ulrike Tillmann FRS (Isaac Newton Institute)

**Vice-Presidents:**
Professor Iain Gordon (University of Edinburgh)
Professor Catherine Hobbs (Coventry University)

**Treasurer:**
Professor Simon Salamon (King's College London)

**General Secretary:**
Professor Robb McDonald (University College London)

**Programme Secretary:**
Professor Chris Parker (University of Birmingham)

**Publications Secretary:**
Professor Niall MacKay (University of York)

**Education Secretary:**
Dr Kevin Houston (University of Leeds)

**Member-at-Large (Women and Diversity):**
Professor Sara Lombardo (Loughborough University)

**Members-at-Large of Council:**
Professor Peter Ashwin (University of Exeter) (re-elected to Council)
*Professor Elaine Crooks (Swansea University)
*Professor Andrew Dancer (University of Oxford)
*Dr Jessica Enright (University of Glasgow)
Professor Minhyong Kim (International Centre for Mathematical Sciences) (re-elected to Council)
Professor Jason D. Lotay (University of Oxford)
*Professor Frank Neumann (University of Leicester)
*Dr Rachel Newton (King's College London)
Professor Anne Taormina (University of Durham) (re-elected to Council)
Professor Amanda Turner (University of Leeds) (re-elected to Council)
Professor Sarah Whitehouse (University of Sheffield)

*Members elected in 2021 who are continuing with the second year of their two-year term.

**President Elect:**
Professor Jens Marklof (Bristol University) was voted by members to become President-Elect, taking office as President in November 2023.

**LMS Nominating Committee:**
Professor Laura Ciobanu (Heriot Watt University) and Professor Helen Wilson (University College London) were elected to the Nominating Committee for three-year terms of office. Continuing members of the Nominating Committee are Tara Brendle (Chair), Chris Budd, Nira Chamberlain, Philip Maini and Gwyneth Stallard. Council will also appoint a representative to the committee.

## Welcome from Simon Edwards, LMS Executive Secretary

I am really delighted to have joined the LMS as Executive Secretary at such a time of change in the mathematical sciences community. It is an honour to have the opportunity to manage an organisation that has such a rich history and a passion for advancing mathematics within the membership and the wider scientific community.

During my career, I have been involved with professional bodies and societies in science, technology, and medicine and understand the importance of the STEM sector in meeting many of the challenges of the twenty-first century. The Institution of Engineering and Technology, which I left at the end of September, has many of the same elements that the LMS has, including a successful venue, publishing operation and activities to support and engage the membership. I look forward to applying this knowledge and experience in supporting the Trustees to further the Society.

Throughout all my roles, I have enjoyed working with Presidents, Trustees, volunteers, and members in helping them grow and advance their professions and the role of their organisations in wider society. The LMS is no exception. I have seen for myself in my

first few weeks the breadth of activities the Society undertakes to deliver its mission.

I extend my thanks to the members and staff I have already met and the warm welcome and time they have given. The members and staff, working together as one team, are what makes the LMS successful. This engagement is crucial to understanding the issues in the mathematical sciences community and what the LMS can do to support and address the challenges.

I look forward to meeting as many members, and key partners of the LMS, as I can, at various online and in-person events over the coming months. Please do not hesitate to contact me: simon.edwards@lms.ac.uk.

Simon Edwards
LMS Executive Secretary

## LMS Committee Vacancies

The Society is seeking members to serve on the following committees:

- Research Policy Committee (RPC), which advises the LMS Council on developments in public policy affecting mathematics research. The Committee meets twice annually, via Zoom.
- Early Career Research Committee (ECRC). The Society is seeking a member with research interests neighbouring or in statistics or optimization. ECRC is responsible for awarding grants to early career researchers and providing financial support for events aimed at early career researchers. The ECRC meets three times a year via Zoom and once a year in person.
- Committee for Women and Diversity in Mathematics (CWDM), which promotes the objectives of the Society in as far as they concern gender and broader diversity practices.

Further information about LMS Committees, including full terms of reference, can be found at lms.ac.uk/about/committees.

If you are interested in joining an LMS committee, please send a brief statement of no more than half a page outlining your suitability for the role to Katherine Wright, katherine.wright@lms.ac.uk by 13 February 2023.

## Forthcoming LMS Events

The following events will take place in the forthcoming months:

**LMS South West and South Wales Regional Meeting**
17 January, Southampton (bit.ly/3QrQwvy).

**LMS Midlands Regional Meeting**
27 March, Warwick (bit.ly/3RW0GVj).

**LMS Meeting at BMC 2023**
4 April, Bath

**LMS Invited Lecture Series 2023**
19–23 July, Durham (tinyurl.com/2zm48prc)

A full listing of upcoming LMS events can be found on page 31.

# Members of Council 2022–2023

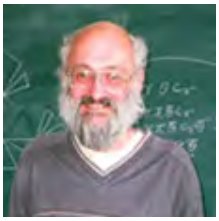
**Ulrike Tillmann**
President

**Cathy Hobbs**
Vice-President

**Iain Gordon**
Vice-President

**Simon Salamon**
Treasurer

**Robb McDonald**
General Secretary



**Chris Parker**
Programme Secretary

**Niall MacKay**
Publications Secretary

**Kevin Houston**
Education Secretary

**Sara Lombardo**
Member-at-Large (Women and Diversity)

**Peter Ashwin**
Member-at-Large

**Elaine Crooks**
Member-at-Large

**Andrew Dancer**
Member-at-Large

**Jessica Enright**
Member-at-Large

**Minhyong Kim**
Member-at-Large

**Jason Lotay**
Member-at-Large

**Frank Neumann**
Member-at-Large

**Rachel Newton**
Member-at-Large

**Anne Taormina**
Member-at-Large

**Amanda Turner**
Member-at-Large

**Sarah Whitehouse**
Member-at-Large

OTHER NEWS

## From the New President of the European Mathematical Society

As the new president of the European Mathematical Society (EMS) I am very happy to be given this opportunity to briefly address the members of the London Mathematical Society, one of the largest corporate members of the EMS. I am convinced that the connection between EMS and LMS is extremely important, in particular now, as the position of the UK in the European research landscape is being redefined.

I am pleased to say that I am taking over a thriving society that over the years has become more and more professional in its operation. Maybe the single most important activity of the EMS is its publishing house, the EMS Press, that is devoted to publishing high quality journals as open access through the 'subscribe to open' model. The revenue created by the EMS press goes entirely to support the EMS.

One of the fora for the interaction of the EMS with its corporate member societies is the EMS Presidents Meeting held approximately annually. Here the presidents of the member societies have an opportunity to discuss and exchange ideas with the EMS Executive Committee. As the EMS president elect, I participated in my first Presidents Meeting, held virtually on 10 September 2022. Several issues were discussed, e.g. how to increase the integration and participation within the EMS of all regions of Europe, in particular, in these difficult times of conflicts. The meeting also addressed the issue of how to operate the EMS in a sustainable way. Surely, in-person meetings are important to nurture true relationships, but the past years taught us to be less fearful of online meetings. While I very much hope to have an opportunity to meet many society presidents and representatives in person during my presidency, I believe the online Presidents Meeting in September was successful and had significant participation. The EMS will be discussing an appropriate balance between online and in-person meetings.

At the Presidents Meeting two new initiatives of the EMS were introduced: The European Mathematical Society Young Academy (EMYA) and the Topical Activities Groups (TAGs). In fact, the EMS is not only a society of societies. It also has individual members and these initiatives aim to increase the participation of our individual members. The vision of the EMS-TAGs is to integrate EMS members across Europe in diverse collaborative efforts. The goal with the creation of the young academy EMYA is to engage the younger generations of European mathematicians to be active within the EMS with the hope that it will also increase a sense of community among them. Member societies such as the LMS can nominate two members to the EMYA each year. The first deadline was this past September and the 30 inaugural members will be selected in the spring. The next deadline for nominations will be on 31 July 2023.

I believe a very important role of the EMS is to promote mathematics in all its wonderful diversity and to increase its visibility both towards the general public and towards important stakeholders. I hope many LMS members will choose to become individual members of the EMS and help me and the EMS achieve these goals. I encourage all of you to learn more from the EMS webpage and the quarterly EMS magazine.

Jan Philip Solovej
Professor of Mathematics, University of Copenhagen
President European Mathematical Society

## 10th Heidelberg Laureate Forum

The 10th Heidelberg Laureate Forum (tinyurl.com/2amkxv34) will take place in Heidelberg, Germany on 24–29 September 2023. All winners of the Fields Medal, the Abel Prize, the ACM A.M. Turing Award, the Nevanlinna Prize/IMU Abacus Medal, and the ACM Prize in Computing are invited to attend each HLF. In addition, young and talented computer scientists and mathematicians are invited to apply to participate. The previous HLFs have been an exceptional success. The HLF serves as a great platform for interaction between the masters in the fields of mathematics and computer science and young talent. Over the course of the week-long conference, young researchers will

be given the exclusive opportunity to profoundly connect with their scientific role models and find out how the laureates made it to the top of their fields. As described by a young researcher, "Meeting the humans behind some of the most formidable inventions and discoveries of our time was phenomenal. What was unexpected, perhaps, was how warm and approachable these individuals turned out to be. I am grateful to have been given this opportunity, and to have shared it with peers who I hope to soon call colleagues, collaborators and friends."

Applications for participation at the 10th HLF are open in three categories: Undergraduate/Pre-Master, Graduate PhD, and PostDocs. Young researchers at all any of these phases of their careers are encouraged to submit an application. The IMU Adhering Organisations and national mathematical societies can also nominate young researchers. Nominated persons get 'priority treatment', but, since there may be too many nominations, they have no acceptance guarantee. You may use the code IMU62851 when registering. See the webpage application.heidelberg-laureate-forum.org for the online application and nomination forms. The deadline for application is 11 February 2023.

For questions regarding requirements and the application process, please contact yr@heidelberg-laureate-forum.org. All applications that are completed and submitted by the deadline are meticulously reviewed by an international committee of experts to ensure that only the most qualified candidates are invited. There are 100 spaces available for each discipline of mathematics and computer science. All applicants will be notified by the end of April 2023 whether or not they are invited. For more information visit: heidelberg-laureate-forum.org.

## PROMYS Europe 2023: Call for Applications

PROMYS Europe a challenging mathematics summer programme, based at the University of Oxford, UK, is seeking applications from pre-university students from across Europe who show unusual readiness to think deeply about mathematics, as well as undergraduate students who would like to work with them as counsellors.

PROMYS Europe is designed to encourage mathematically ambitious students who are at least 16 to explore the creative world of mathematics. Participants tackle fundamental mathematical questions within a richly stimulating and supportive community.

The programme is dedicated to the principle that no one should be unable to attend for financial reasons. Most of the cost is covered by the PROMYS Europe partnership and by generous donations from supporters. In addition, full and partial financial aid is available, for those who need it. For more information and details of how to apply, visit the PROMYS Europe website promys-europe.org.

# EUROPEAN MATHEMATICAL SOCIETY NEWS

## EMS Call for Large Events

The EMS has announced a new call for large-scale scientific events, such as special semesters, interdisciplinary study groups, and large showcase events. This call has four deadlines per year: 1 February, 1 May, 1 September, 1 December. Proposals can apply for up to EUR 25K of funding, with one proposal being funded per quarter. For more details see euromathsoc.org/large-events .

## EMS Magazine

The latest (and 126th) edition of the EMS Magazine is available online soon on the EMS webpage euromathsoc.org/magazine. Highlights include:

- Tensor Networks in Machine Learning — Richik Sengupta, Soumik Adhikary, Ivan Oseledets and Jacob Biamonte
- 100 Years of Acta Szeged — Lajos Molnár
- Interview with Caroline Series — Ulf Persson
- Research Networks for Women — Kristine Bauer, Erin Chambers, Brenda Johnson, Kristin Lauter and Kathryn Leonard

EMS News prepared by David Chillingworth
LMS/EMS Correspondent

OPPORTUNITIES

# LMS Grant Schemes

Applications are invited for the following grants to be considered by the Research Grants Committee at its February 2023 meeting. Applicants for LMS Grants should be mathematicians based in the UK, the Isle of Man or the Channel Islands. For grants to support conferences/workshops, the event must be held in the UK, the Isle of Man or the Channel Islands. The next closing date for research grant applications (Schemes 1,2,4,5,6 and AMMSI) is 22 January 2023.

**Conferences (Scheme 1)**

Grants of up to £5,500 are available to provide partial support for conferences. This includes travel, accommodation and subsistence expenses for principal speakers, UK-based research students, participants from Scheme 5 countries and Caring Costs for attendees who have dependents.

**Visits to the UK (Scheme 2)**

Grants of up to £1,500 are available to provide partial support for a visitor who will give lectures in at least three separate institutions. Awards are made to the host towards the travel, accommodation and subsistence costs of the visitor. Potential applicants should note that it is expected the host institutions will contribute to the costs of the visitor. In addition, the Society allows a further amount (of up to £200) to cover Caring Costs for those who have dependents.

**Online Lecture Series (Scheme 3)**

Grants of up to £1,000 are available per year to provide support to mathematicians, or groups of mathematicians, delivering online lecture series in mathematics. Applications for this element of the Scheme 3 grant is open to both Joint Research Groups (new and current) and to mathematicians who are not part of a Joint Research Group.

**Research in Pairs (Scheme 4)**

For those mathematicians inviting a collaborator, grants of up to £1,200 are available to support a visit for collaborative research either by the grant holder to another institution abroad, or by a named mathematician from abroad to the home base of the grant holder. For those mathematicians collaborating with another UK-based mathematician, grants of up to £600 are available to support a visit for collaborative research either by the grant holder to another institution or by a named mathematician to the home base of the grant holder. In addition, the Society allows a further amount (of up to £200) to cover Caring Costs for those who have dependents.

**Research Reboot (Scheme 4)**

Grants of up to £1,000 are available to provide support to mathematicians who have found themselves without the time to engage in research due to illness, caring responsibilities, increased teaching or administrative loads or any other factors. The grant offers funding to cover travel, accommodation, subsistence and caring expenses so the applicants can leave their usual environment to focus entirely on research for a period from two days to a week, in order to restart their research activity.

**Collaborations with Developing Countries (Scheme 5)**

For those mathematicians inviting a collaborator to the UK, grants of up to £3,000 are available to support a visit for collaborative research, by a named mathematician from a country in which mathematics could be considered to be in a disadvantaged position, to the home base of the grant holder. For those mathematicians going to their collaborator's institution, grants of up to £2,000 are available to support a visit for collaborative research by the grant holder to a country in which mathematics could be considered to be in a disadvantaged position. Applicants will be expected to explain in their application why the proposed country fits the circumstances considered eligible for Scheme 5 funding. In addition, the Society allows a further amount (of up to £200) to cover Caring Costs for those who have dependents. Contact the Grants team if you are unsure whether the proposed country is eligible, or check the IMU's Commission for Developing Countries definition of developing countries (tinyurl.com/y9dw364o).

**Research Workshop Grants (Scheme 6)**

Grants of up to £10,000 are available to provide support for Research Workshops. Research Workshops should be an opportunity for a small

group of active researchers to work together for a concentrated period on a specialised topic. Applications for Research Workshop Grants can be made at any time but should normally be submitted at least six months before the proposed workshop.

**African Mathematics Millennium Science Initiative (AMMSI)**

Grants of up to £2,000 are available to support the attendance of postgraduate students at conferences in Africa organised or supported by AMMSI.

The next closing date for early career research grant applications (Schemes 8-9 and ECR Travel Grants) is 22 February 2023. Applications are invited for the following grants to be considered by the Early Career Research Committee at its March 2023 meeting:

**Postgraduate Research Conferences (Scheme 8)**

Grants of up to £2,500 are available to provide partial support for conferences, which are organised by and are for postgraduate research students. The grant award will be used to cover the costs of participants. In addition, the Society allows the use of the grant to cover Caring Costs for those who have dependents.

**Celebrating new appointments (Scheme 9)**

Grants of up to £400-£500 are available to provide partial support for meetings to celebrate the new appointment of a lecturer at a university. Potential applicants should note that it is expected that the grant holder will be one of the speakers at the conference. In addition, the Society allows the use of the grant to cover Caring Costs for those who have dependents.

**ECR Travel Grants**

Grants of up £500 are available to provide partial travel and/or accommodation support for UK-based Early Career Researchers to attend conferences or undertake research visits either in the UK or overseas.

For full details of these grant schemes, and to find information on how to submit application forms, visit the LMS website: lms.ac.uk/content/research-grants. Queries regarding applications can be addressed to the Grants Administrator Lucy Covington (020 7927 0807, grants@lms.ac.uk), who will be pleased to discuss proposals informally with potential applicants and give advice on the submission of an application.

## David Crighton Medal 2023: Call for Nominations

The David Crighton Medal was established by the Councils of the LMS and IMA in 2002 in order to pay tribute to the memory of Professor David George Crighton FRS. The silver gilt medal is awarded to an eminent mathematician for services both to mathematics and to the mathematical community, who is normally resident in the mathematical community represented by the two organisations on the 1st January of the year of the award.

The award is considered biennially by the Councils of the IMA and LMS. The medal winner is normally presented with the award at a joint meeting of the IMA and the LMS, and is invited to give a lecture.

The most recent winner of the David Crighton Medal was Professor Caroline Series FRS, in 2021. Previous winners of the Medal are Professor Ken Brown CBE (2019), Professor I. David Abrahams (2017), Professor Frank Kelly CBE FRS (2015), Professor Arieh Iserles and Dr Peter Neumann OBE (2012), Professor Keith Moffatt FRS (2009), Professor Sir Christopher Zeeman FRS (2006) and Professor Sir John Ball FRS (2003).

Nominations are now invited. These should be made on the nomination form available at tinyurl.com/crighton2023 or from the Secretary to the David Crighton Committee (Emma-Jane.Wheal@ima.org.uk). Nominations must be received by 28 February 2023.

## Hirst Prize and Lectureship 2023: Call for Nominations

Originally launched in 2015 as part of the 150th anniversary celebrations of the London Mathematical Society, the Hirst Prize and Lectureship is now jointly awarded by the LMS and the British Society for the History of Mathematics (BSHM). The prize is named after Thomas Archer Hirst, who was the fifth President of the LMS (1872–1874).

The Hirst Prize and Lectureship is intended to recognise contributions to the study of the history of mathematics. The prize is awarded in recognition of original and innovative work in the history of mathematics, which may be in any medium.

The prize is open to any mathematician or historian of mathematics. In a given year, the members of the Hirst Prize Committee, and the members of the LMS

and BSHM Councils, are ineligible for the award of the prize. There is no requirement for the winner to be based in the UK.

The award will be considered by the Councils of the LMS and BSHM in March 2023, and the winner announced in summer 2023. The winner will be invited to give a lecture on the history of mathematics at a meeting of the LMS in 2024.

Nominations are now invited; download a nomination form at bshm.ac.uk/hirst-prize. Nominations should be sent to the Chair of the Hirst Prize Committee, Professor Sarah Hart (president@bshm.ac.uk), by 31 January 2023.

## LMS Research Schools and Research Schools in Knowledge Exchange 2024

Grants of up to £15,000 are available for LMS Research Schools, one of which will be focused on Knowledge Exchange. The LMS Research Schools provide training for research students in contemporary areas of mathematics. The Knowledge Exchange Research Schools will primarily focus on Knowledge Exchange and can be in any are of mathematics.

The LMS Research Schools take place in the UK and support participation of research students from both the UK and abroad. The lecturers are expected to be international leaders in their field. The LMS Research Schools are often partially funded by the Heilbronn Institute for Mathematical Research (Heilbronn.ac.uk) and UK Research and Innovation (ukri.org). Information about the submission of proposals can be found at tinyurl.com/ychr4lwm along with a list of previously supported Research Schools. Applicants are strongly encouraged to discuss their ideas for Research Schools with the Chair of the Early Career Research Committee, Professor Chris Parker (research.schools@lms.ac.uk) before submitting proposals. Proposals should be submitted to Lucy Covington(research.schools@lms.ac.uk) by 22 February 2023.

## LMS Undergraduate Research Bursaries in Mathematics 2023

The Undergraduate Research Bursary scheme provides an opportunity for students in their intermediate years to explore the potential of becoming a researcher. The award provides support to a student undertaking a 6–8 week research project over summer 2023, under the direction of a project supervisor.

Students must be registered at a UK institution for the majority of their undergraduate degree and may only take up the award during the summer vacation between the intermediate years of their course. Students in the final year of their degree intending to undertake a taught Masters degree immediately following their undergraduate degree may also apply. Applications must be made by the project supervisor on behalf of the student.

For further information contact Lucy Covington (urb@lms.ac.uk). Application deadline is Tuesday 1 February 2023.

## Clay Mathematics Institute Enhancement and Partnership Program

To extend the international reach of the Research School, prospective organisers may also wish to consider applying to the Clay Mathematics Institute (CMI) for additional funding under the CMI's Enhancement and Partnership Program. Further information about this programme can be found at tinyurl.com/y72byonb. Prospective organisers are advised to discuss applications to this programme as early as possible by contacting the CMI President, Martin Bridson (president@claymath.org). There is no need to wait for a decision from the LMS on your Research School application before contacting the CMI about funding through this programme.

## LMS Council Diary — A Personal View

Council's meeting on Friday 21 October 2022, held online, had its usual impressive breadth of topics, covering the Society's response to the war in Ukraine and its implications for mathematicians affected by the conflict and for the Russian translation journals that the LMS publishes jointly with the Institute of Physics Publishing, through to discussion and approval of the annual Trustees' report and the detailed financial statements therein. It was also the first Council meeting formally attended by the Society's new Executive Secretary Simon Edwards.

As usual the meeting began with President Ulrike Tillmann's report on her wide-ranging activities including her involvement with the *Black Heroes of Mathematics* conference and LMS/IMA/BSHM Joint Meeting 2022 *Women in Astronomy* held at De Morgan House. The President also reported on developments of the Society's *Levelling Up: Maths* scheme, now two years from its inception, and the Protect Pure Maths campaign.

Vice-President Cathy Hobbs gave a report on the European Meeting of Presidents of Mathematical Societies which she attended. Among the topics discussed was the European Mathematical Society establishment of a Young Academy and that nominations of early career mathematicians by member societies were sought. The Society has subsequently made two nominations on which we hope to report in a future edition of the *Newsletter*.

Council approved the Annual Report of the Trustees for 2021–22 and considered the Auditor's report into its finances which I am pleased to say was positive, and discussed preliminary stages in the planning for Council's biennial strategic retreat including themes for in-depth discussion. Council also considered at length the implication of the war in Ukraine on its publication of the Russian translation journals which are published jointly with the Institute of Physics Publishing.

New appointments to various LMS committees were considered and approved by Council, including an additional three new members to the Editorial Board of the Newsletter, and the appointment (from the 2022 Annual General Meeting) of the new Society Librarian, Deborah Kent of the University of St. Andrews. Council also approved new members to the Society which pleasingly included a sizeable number at associate, including undergraduate, level.

Finally, Council bade farewell to Lindsay Walsh, attending her last meeting of Council before stepping down as Head of Society Business in November. The President paid tribute to Lindsay for all her dedicated and excellent service to the Society and the wider mathematical community over many years including most recently with the *Levelling Up: Maths* scheme and with the Society's interaction with the Council of Mathematical Sciences.

Robb McDonald
General Secretary

## Maximising your Membership: Free Online Journal Access

Since the London Mathematical Society was founded in 1865, it has published high-quality peer-reviewed papers in a growing collection of esteemed journals. Beginning with the *Proceedings of the London Mathematical Society* in 1865, the portfolio of journals published by the Society now comprises 9 titles. LMS Members have free online access to the following journals from the Society's collection:

- *Bulletin of the London Mathematical Society:* Publishing leading research in a broad range of mathematical subject areas since 1969, the *Bulletin* features high-quality research articles with a maximum length of 20 pages, authoritative survey articles and obituaries of distinguished mathematicians.
- *Journal of the London Mathematical Society:* Since 1926, the *Journal* has welcomed papers on subjects of general interest that represent a significant advance in mathematical knowledge, as well as submissions that stimulate new interest and research activity. The *Journal* welcomes longer papers, of 18 pages or longer.
- *Proceedings of the London Mathematical Society:* The flagship journal of the LMS, the *Proceedings* publishes articles of the highest quality and significance across a broad range of mathematics, with no page length restrictions.
- *Mathematika:* Published by the LMS on behalf of its owner, UCL, *Mathematika* features both pure and applied mathematical articles, and has done so continuously since its founding by Harold Davenport in the 1950s. Its traditional emphasis has been towards a purer side of mathematics, but applied mathematics and articles addressing both aspects are equally welcome.

- *Nonlinearity:* Owned and published jointly with the Institute of Physics, *Nonlinearity* is aimed at mathematicians and physicists interested in research on nonlinear phenomena, with its coverage ranging from proofs of important theorems to papers presenting ideas, conjectures and numerical or physical experiments of significant physical and mathematical interest.

Members can sign up to free online access to any or all of these titles either by logging into their LMS user record at lms.ac.uk/user and going to the "My LMS Membership" tab, or by returning a completed subscription form for the current year (available at lms.ac.uk/membership/paying-your-subscription) or by email to (membership@lms.ac.uk) or by post (to: LMS Membership, De Morgan House, Russell Square, London WC1B 4HS).

In addition, the Society's fully open access journal, *Transactions of the London Mathematical Society*, is available to both members and non-members. It welcomes papers of general or specialised nature that represent a significant advance in mathematical knowledge, and the papers can be read online at londmathsoc.onlinelibrary.wiley.com/journal/20524986.

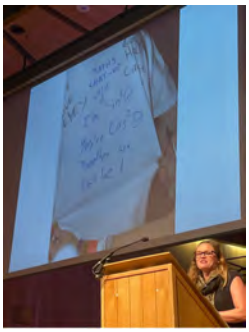
See lms.ac.uk/publications for more information.

Elizabeth Fisher
Membership & Grants Manager

REPORTS OF THE LMS

## LMS Popular Lecture 2022

**Lakes, rivers… and waterfalls? The surprising things maths can help us to understand about Antarctica**



Dr Sammie Buzzard might be based in the Geography Department at Cardiff University, but after her talk in Birmingham for the 2022 LMS Popular Lecture, it's clear she's a mathematician at heart.

The talk began with Sammie's backstory — from not knowing what to do at university, to accidentally ending up studying meteorology — with great emphasis on taking opportunities as they come. This sense of adventure continued throughout the talk, with the story of how she learned to shoot a rifle in Svalbard to protect the group from polar bears a particular highlight.

The maths itself was also very interesting, presented in the engaging and entertaining manner for which Sammie is known. We heard about recent developments in ice sheet modelling at both the North and South poles, including Dr Buzzard's own model for melt lake development on an ice shelf. Seeing fieldwork images of the predicted features really helped to bring the model to life.

As indicated by the title of the talk, waterfalls made a surprise appearance with some incredible footage of a 130 metre wide cascade atop the Nansen ice shelf in Antarctica. The images led to an interesting discussion during the Q&A about whether such features are good or bad in terms of their impact on the climate. However, as with most newly-discovered phenomena, the jury remains out on their precise impact.

To conclude the talk, Dr Buzzard presented a short summary of ice sheet data which led to the indisputable conclusion that we are in trouble (despite the disagreement of some audience members). It was very refreshing to see the clarity with which she spoke when discussing climate related issues, by simply presenting the data and allowing the audience to draw their own conclusions.

Fortunately, there was still time to enjoy a laugh at the expense of the scientists, with Sammie explaining how a group of Japanese high school students were able to make a more accurate prediction than several largescale operations (including NASA) about the extent of Arctic Sea Ice. This was of course presented in jest, but it did emphasise just how difficult a task climate scientists face.

Tom Crawford
St Edmund Hall, University of Oxford

# Superunification

RUTH E. LYONS

SUPERUNIFICATION is a new permanent public sculpture in Honeypark, Dun Laoghaire, Dublin by Irish artist Ruth E. Lyons. Ruth explains her inspiration from science in its design below.

From what we know about the composition of the universe, there are four fundamental forces. By acting on particles at a small scale, these forces shape the structure of the universe, defining every known thing from our bodies to stars and galaxies and informing the very nature of existence.

SUPERUNIFICATION is a dramatic standout sculpture which draws upon ideas from cosmology — the study of our universe. In its playful and aesthetically pleasing form, SUPERUNIFICATION firmly roots this cosmological outlook within the landscape of the everyday.

Fundamental to the design and thinking behind this public sculpture has been an emphasis on 'inclusivity' as expressed through the design and social fabric of the Honeypark development. The radial and networked layout of the roads is echoed in the sculpture's fluid crossovers and the looping movement of the two curved steel legs that twist around each other to ultimately join in a point at the top. There, this meeting point is also a departure at which the two members push away from one another, spiralling down to the ground again.

At 12 metres in height, SUPERUNIFICATION connects the sky to the ground. The colour gradient of the structure from black blue at the top through ultramarine to white at the base, appears as a seamless fade that draws the land and sky into conversation with it. Its elevation allows it to be seen from many perspectives and from a great distance. From an aerial view the curved form is a placeholder boldly marking this residential hub located between the sea and the mountains.

SUPERUNIFICATION links to similar forms within the lexicon of symbols in our culture, such as the double helix of a DNA strand and the looping figure eight of infinity. The curving structure of SUPERUNIFICATION, however, defies definition. From every perspective the curve appears to take on a different form, at once simple and surprisingly complex. The complexity of the curve is accentuated at different times of day as the form casts a shadow across the ground that is at times twisting and playful and at other times long and dramatic.

SUPERUNIFICATION forms a dialogue with the unknown, presenting a sense of the sublime in the fabric of the everyday. It is inspired by a consideration of entropy against the backdrop of domestic toils. SUPERUNIFICATION is about finding a space outside of entropy, or a space away from the chaos so that we can see it for a moment for what it is, the incredible unfolding of time.

In theoretical physics, unification is an elusive theory that brings together quantum mechanics and the theory of gravity — the theory of the very small with that of the very large. The development of such a theory would reveal the conditions at the very beginning of our universe! Rooted in the landscape of Honeypark, SUPERUNIFICATION gives these ideas that are at the forefront of human endeavour a central place within the motion of daily life.

## Ruth Lyons

Ruth has obtained awards and commissions from both within Ireland and abroad (ruth.ie). Some sculptures are on permanent display such as SALARIUM in the National Gallery of Ireland. Ruth was awarded the commission of SUPERUNIFICATION by Cosgrave Developments. The sculpture was put *in situ* in April 2022 (vimeo.com/744161124).

# Quantum Knot Invariants Via the Topology of Configuration Spaces

CRISTINA ANGHEL

The world of quantum invariants started with the discovery of the Jones polynomial and was expanded by Reshetikhin and Turaev via representation theory. Two sequences of such invariants are the coloured Jones and coloured Alexander polynomials. Is there a way to describe these quantum invariants through the topology of configuration spaces?

## Introduction: quantum invariants

Knot theory studies embeddings of the circle into three dimensional space. The first knot invariant, discovered in 1923, was the Alexander polynomial. Later on, the world of quantum invariants started in 1984 with the milestone discovery of the Jones polynomial [10]. Then Witten predicted the existence of a generalisation of the Jones polynomial for 3-manifolds, motivated from physics through the Chern-Simons topological quantum field theory. In 1989, Reshetikhin and Turaev established this and introduced a general method that gives quantum invariants for knots and $3$-manifolds using tools from representation theory. This method gives two important sequences of quantum invariants: coloured Jones polynomials $\{J_N(L,q)\}_{N\in\mathbb{N}}$ and coloured Alexander polynomials $\{\Phi_N(L,\lambda)\}_{N\in\mathbb{N}}$, which recover the original Jones and Alexander polynomials at the first terms. Furthermore, for any level $\mathcal{N}\in\mathbb{N}$, one can use linear combinations of coloured Jones polynomials with colours less than $\mathcal{N}$ in order to get the Witten-Reshetikhin-Turaev $3$-manifold invariant $\tau_{\mathcal{N}}$.

## Topological information encoded by quantum invariants

Jones and Alexander polynomials originated in different areas of maths, but later on they could both be described through so-called skein theory and also through representation theory. On the other hand, it is still an open question to find a common geometric perspective. More specifically, the Alexander polynomial is well-understood in terms of the knot complement. However, the connection between the Jones polynomial and the topology of the knot complement is still mysterious. Also, there are predictions from physics stating that the limit of coloured Jones polynomials contains topological information about the complement, such as the simplicial volume of the complement. (This is the Volume Conjecture, stated by Kashaev and generalised by Murakami-Murakami.)

## Topological models for quantum invariants

On the homological side of the story, Lawrence [9] introduced a sequence of representations of the braid group $B_n$ on the homology of $\mathbb{Z}\oplus\mathbb{Z}$-coverings of the configuration spaces in the $2n$-punctured disc $\mathscr{D}_n$. Kohno [8], and later on Ito [6] and Martel [10], worked on identifications between quantum and these homological representations of braid groups. Bigelow (based on Lawrence's work [5]) showed that the Jones and HOMFLY-PT polynomials are given by intersection pairings in coverings of configuration spaces. They used skein theory for the proof. We call such a description a topological model.

One of my main research directions concerns the construction of topological models for quantum invariants, via intersections of Lagrangian submanifolds in configuration spaces ([1],[2],[3],[4]). This creates a new topological framework permitting one to explore topological and geometric information encoded by these invariants.

In [4] it is shown that $J_N(L,q)$ and $\Phi_N(L,\lambda)$ are specialisations of a state sum of graded Lagrangian intersections in a configuration space of the punctured disc. A globalised result, which uses a single graded intersection between two submanifolds and does not involve any state sum, is proved in a sequel paper [3].

More specifically, it is proved there that the $N^{th}$ coloured Jones and $N^{th}$ coloured Alexander polynomials of the closure of a braid with $n$ strands can be read off from a *graded intersection between two Lagrangians in the* $(n-1)(N-1)^{th}$ *symmetric power of a punctured disc*, as presented in formula (4). In the next part we describe the main construction of this model.

### Links via braids and the punctured disc

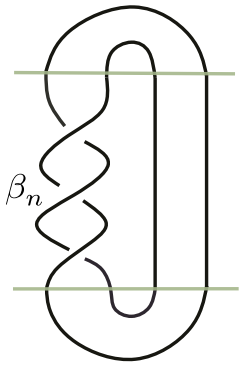



Figure 1. A link $L$ as a closure of a braid

We consider links as being closures of braids. Let us fix $n \in \mathbb{N}$ to be the number of strands of such a braid. Once we have fixed the number of strands of the braid, we denote by $\mathscr{D}_{3n-1}$ the disc with $(3n-1)$-punctures.

We use the property that the braid group is the mapping class group of the punctured disc, so each braid induces a homeomorphism of the disc, as in figure 1.

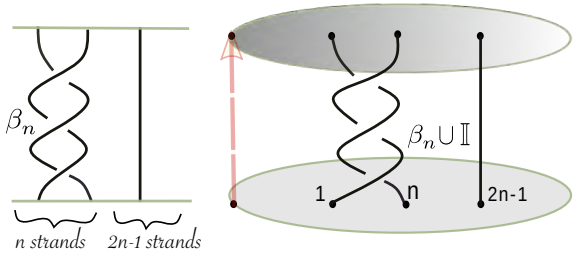



Figure 2. Braid group action

Our recipe will obtain the colour $N$ Jones and Alexander invariants from a graded intersection in a symmetric power of the punctured disc. For the particular case given by $N = 2$, we get a model which can be constructed from a graded intersection in a configuration space, which recovers the Jones and Alexander polynomials.

In the next sections we will use a dictionary: we draw collections of curves in the punctured disc and they will encode Lagrangian submanifolds in the configuration space. Here, by Lagrangian we mean a submanifold of half of the top dimension (for further work the model can be viewed in a symplectic geometry setting, where we have Lagrangian submanifolds in a symplectic manifold).

| Collection of $n$ curves in the punctured disc $\mathscr{D}$ | Dictionary | A Lagrangian in the configuration space of $n$ points in $\mathscr{D}$ |
|---|---|---|

We use two such collections of curves, which we colour in red and green, and through this dictionary they encode two Lagrangian submanifolds in the configuration space. We will then define a graded intersection between these Lagrangians. The grading procedure uses certain extra punctures and curves in the punctured disc which connect the two collections of arcs (but for simplicity these are not shown in figure 3).

### Example: Jones and Alexander invariants of the trefoil knot

We start with the example of the intersection model for the trefoil knot $T$, seen as the closure of the braid $\sigma^3 \in B_2$. We will motivate this construction after we have finished presenting the example, and explain how it sits in a wider setting. In this situation $n = 2$, and we choose two Lagrangians in the punctured disc $\mathscr{D}_5$: the red arc $\mathscr{S}_2$ and the green circle $\mathscr{T}_2$, which are drawn in the picture below.

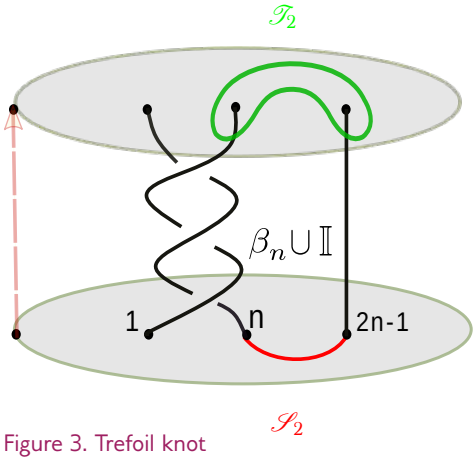



Figure 3. Trefoil knot

Now, we act with the braid on the red curve and obtain the red Lagrangian $(\sigma^3 \cup \mathbb{I}_3)\mathscr{S}_2$, which we intersect with the fixed green Lagrangian:

$$(\sigma^3 \cup \mathbb{I}_3)\mathscr{S}_2 \cap \mathscr{T}_2$$

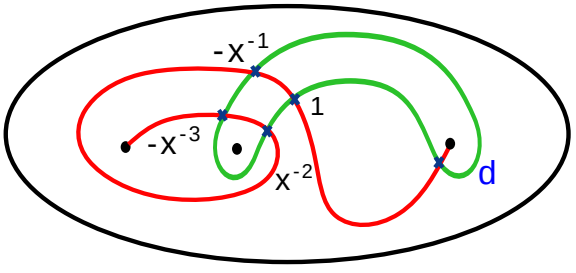
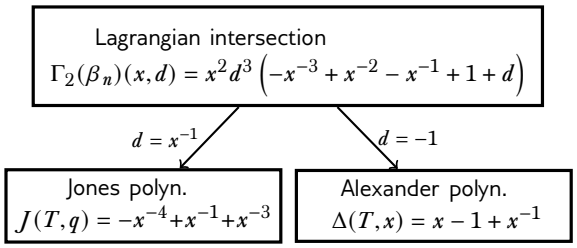



Figure 4. Graded intersection for the trefoil knot

The graded intersection is parametrised by the intersection points between these two submanifolds. The gradings that are associated to the intersection points are presented in the above picture. Using them, we obtain an intersection form in two variables, which recovers the Jones and the Alexander polynomial of the trefoil knot, as below:




### Topological set-up for the model for Jones and Alexander invariants

In this case, we work in the configuration space of $n-1$ points in the $(3n-1)$-punctured disc $Conf_{n-1}(\mathscr{D}_{3n-1})$. In the next part, we describe the definition of two Lagrangian submanifolds in this configuration space. Following our dictionary, the submanifolds will be constructed by drawing a collection of $(n-1)$ arcs and $(n-1)$ circles in the punctured disc. The first Lagrangian submanifold will be given by the product of all the red arcs quotiented by the action of the symmetric group. For the second submanifold we follow the same procedure using the set of green circles.

This method gives us two Lagrangians $\mathscr{S}_n$ and $\mathscr{T}_n$ in the configuration space $Conf_{n-1}(\mathscr{D}_{3n-1})$, encoded by the collections of red arcs and green circles respectively (see figure 5):

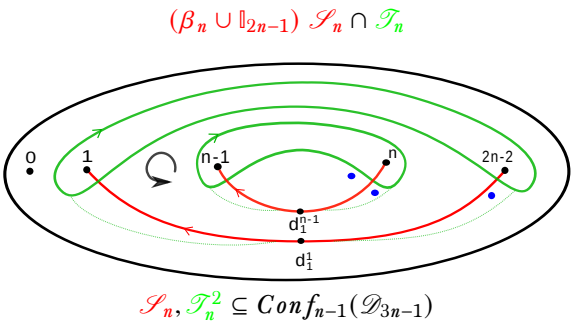



Figure 5. Jones and Alexander polynomials from the same graded intersection

So far, these two submanifolds are intrinsic and do not encode any information from the link $L$. Now, the link (seen as the closure of the braid) comes into play. Using that the braid group $B_{3n-1}$ is the mapping class group of the $(3n-1)$−punctured disc, we construct a well-defined Lagrangian

$$(\beta_n \cup \mathbb{I}_{2n-1})\ \mathscr{S}_n \subseteq Conf_{n-1}(\mathscr{D}_{3n-1})$$

associated to the braid $\beta_n \in B_n$.

Finally, we define a *graded intersection pairing* between this Lagrangian and $\mathscr{T}_n$, which will be a Laurent polynomial:

$$\langle (\beta_n \cup \mathbb{I}_{2n-1})\ \mathscr{S}_n, \mathscr{T}_n \rangle.$$

It will be indexed by the set of intersection points between these two Lagrangian submanifolds:

$$I_{\beta_n} = (\beta_n \cup \mathbb{I}_{2n-1})\ \mathscr{S}_n \cap \mathscr{T}_n.$$

Then, we grade these intersection points by *monomials*, which count the winding of certain associated loops around the punctures of the punctured disc and also a relative winding, using a local system. The formula for the graded intersection will be given by the sum of all of these gradings.

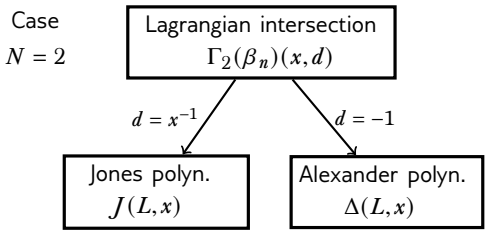
### Jones and Alexander polynomials from the same picture

Now we present the intersection model for the Jones and Alexander invariants. Let $L$ be an oriented link and $\beta_n \in B_n$ such that $L$ is the closure of this braid $\beta_n$. Let $w(\beta_n)$ be the writhe of the braid $\beta_n$, given by the number of positive crossings minus the number of negative crossings. We consider the following polynomial $\Gamma_2(\beta_n)(x,d) \in \mathbb{Z}[x^{\pm\frac{1}{2}}, d^{\pm 1}]$:

$$\Gamma_2(\beta_n)(x,d) = (d^2x)^{\frac{w(\beta_n)+n-1}{2}} \cdot d^{-(n-1)} \langle (\beta_n \cup \mathbb{I}_{2n-1}) \mathscr{S}_n^2, \mathscr{T}_n^2 \rangle. \quad (1)$$

It is proved in [3] that this intersection model recovers the Jones and Alexander polynomials of the closure of the braid, through the following specialisations of coefficients:

$$\Gamma_2(\beta_n)(x,d)|_{x=d^{-1}} = J(\hat{\beta}_n, x)$$
$$\Gamma_2(\beta_n)(x,d)|_{d=-1} = \Delta(\hat{\beta}_n, x). \quad (2)$$




This gives a picture which provides a framework for constructing geometric categorifications for Jones and Alexander polynomials and a further perspective on how to relate these.

### Topological set-up for the quantum generalisations of colour $N$

Let us fix $N \in \mathbb{N}$ to be the colour of our invariants. In this case, we start with the $(3n-1)$-punctured disc and consider $\Sigma^{n,N}$ to be its $(n-1)(N-1)$-symmetric power. In the next part, we describe the definition of two Lagrangian submanifolds in this symmetric power of the punctured disc. Similar to the previous case, the submanifolds will be also encoded by collections of $(n-1)$ arcs and $(n-1)$ circles in the punctured disc. The difference is that now we will consider the symmetric powers of order $N-1$ on each curve from the collection.

More specifically, for the definition of the first Lagrangian submanifold we consider the products of $(N-1)$-symmetric powers on each red arc, take their product and quotient it by the action of the symmetric group, to get a submanifold in the symmetric power $\Sigma^{n,N}$. We call this set of curves in the punctured disc the "geometric support" of the submanifold. For the second submanifold we do the same procedure using the set of green circles.

Following this procedure, we define two Lagrangians $\mathscr{S}_n^N$ and $\mathscr{T}_n^N$ in the symmetric power $\Sigma^{n,N}$, given by the collections of red arcs and green circles respectively (see figure 5):

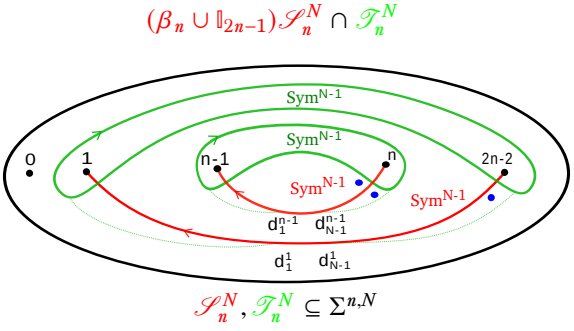



Figure 6. Lagrangian submanifolds for the colour $N$ quantum invariants

The action given by the braid leads to a well-defined Lagrangian

$$(\beta_n \cup \mathbb{I}_{2n-1})\ \mathscr{S}_n^N \subseteq \Sigma^{n,N}.$$

Then, we define a *graded intersection pairing* between this Lagrangian and $\mathscr{T}_n^N$, which will be a Laurent polynomial:

$$\langle (\beta_n \cup \mathbb{I}_{2n-1})\ \mathscr{S}_n^N, \mathscr{T}_n^N \rangle.$$

This pairing is indexed by the set of intersection points between these two Lagrangian submanifolds:

$$I_{\beta_n}^N = (\beta_n \cup \mathbb{I}_{2n-1})\ \mathscr{S}_n^N \cap \mathscr{T}_n^N$$

Then, to each intersection point we associate a grading which is a polynomial, counting the winding of certain associated loops around diagonals of this symmetric power using a local system. The above graded intersection will be given by the sum of all of these gradings.

### Coloured Jones and Alexander polynomials unified through the intersection of two Lagrangians in a symmetric power of a surface

We consider the Lagrangian submanifolds $\mathscr{S}_n^N, \mathscr{T}_n^N \subseteq \Sigma^{n,N}$ and define

$$\Gamma_N(\beta_n)(u,x,y,d) \in \mathbb{Z}[u^{\pm 1}, x^{\pm 1}, y^{\pm 1}, d^{\pm 1}]$$

to be the following polynomial:

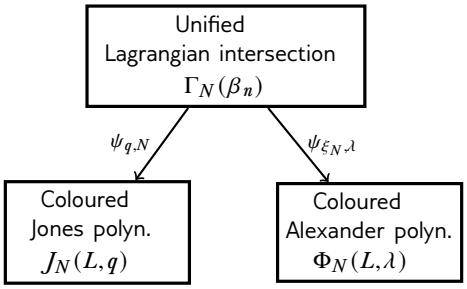
$$\begin{aligned}\Gamma_N(\beta_n)(u,x,y,d) :=& u^{-w(\beta_n)} u^{-(n-1)} (-y)^{-(n-1)(N-1)} \\ & \langle (\beta_n \cup \mathbb{I}_{2n-1})\ \mathscr{S}_n^N, \mathscr{T}_n^N \rangle.\end{aligned} \tag{3}$$

Then it is shown in [3] that $\Gamma_N$ recovers the $N^{th}$ coloured Jones and $N^{th}$ coloured Alexander invariants through the following specialisations of coefficients:

$$\begin{aligned} J_N(L,q) &= \Gamma_N(\beta_n)|_{\psi_{q,N}} \\ \Phi_N(L,\lambda) &= \Gamma_N(\beta_n)|_{\psi_{\xi_N,\lambda}}. \end{aligned} \tag{4}$$

Here $\psi_{q,N}$ and $\psi_{\xi_N,\lambda}$ are two specialisations given by morphisms from Laurent polynomials in 4 variables to Laurent polynomials in one variable.

The feature of this formula is that the Lagrangian submanifolds are explicit and their geometric support in the surface is a multi-pointed Heegaard diagram for the knot. Also, the colour $N$ of the invariants can be seen directly in this geometric picture by the number of particles chosen on a fixed geometric support given by the diagram.




### Categorifications

In recent years, there has been increased interest in studying deeper invariants, given by categorifications. This procedure starts with a polynomial invariant and aims to produce a sequence of groups which encode more information. One of the first categorifications was introduced by Khovanov for the Jones polynomial, through combinatorial techniques. On the other hand, Ozsváth, Szabó and Rasmussen defined a geometric categorification of the Alexander polynomial, called knot Floer homology, using symplectic geometry.

Recently Dowlin proved a conjecture due to Rasmussen and constructed a spectral sequence that relates these two categorifications for Jones and Alexander polynomials: Khovanov homology and knot Floer homology. Currently there are still questions about the geometry of such categorifications and spectral sequences.

The story is different for the analogous invariants for $3$-manifolds. There is an important open question about the existence of categorifications for Witten-Reshetikhin-Turaev invariants.

### Topological model for the Witten–Reshetikhin–Turaev invariants

In this part, we discuss a topological model for quantum invariants for $3$-manifolds. The main result from [2] shows that the level $\mathcal{N}$ Witten-Reshetikhin-Turaev (WRT) invariant is a state sum of graded intersections between Lagrangian submanifolds in a fixed configuration space.

Let us fix a level $\mathcal{N} \in \mathbb{N}$. We will use the description of closed oriented $3$-manifolds as surgeries along framed oriented links. In turn, we will look at links as closures of braids. Suppose that the corresponding link has $l$ components and the braid has $n$ strands.

In [2] it is shown that the $\mathcal{N}^{th}$ WRT invariant $\tau_{\mathcal{N}}(M)$ comes from a state sum of specialisations of graded intersections between explicit Lagrangian submanifolds in the configuration space $Conf_{n(\mathcal{N}-2)+l+1}(\mathcal{D}_{3n+3l+1})$.

In this way, we conclude that the WRT invariant at level $\mathcal{N}$ is completely encoded by the set of intersection points between certain Lagrangian submanifolds in the configuration space of $n(\mathcal{N}-2)+l+1$ points in the $(3n+3l+1)$-punctured disc. The number of particles is fixed and is determined by the level of the invariant $\mathcal{N}$, the number of components of the link $l$ and number of strands of the braid $n$.

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Cristina is a postdoc in mathematics at the University of Geneva. Her area of expertise is quantum topology and her research is on the interaction between representation theory, low dimensional topology and symplectic topology. Cristina was born in Romania. She likes very much the landscape of the Carpathian mountains.

Notes of a Numerical Analyst

# Analytic Continuation

NICK TREFETHEN FRS

Analytic continuation starts from a paradox: it is perfectly exact, yet impossible. It is exact in that the values of an analytic function in a set $\Omega \subseteq \mathbb{C}$ are determined by its values in any subset $E \subseteq \Omega$. (We assume $\Omega$ and $E$ are nonempty, simply-connected continua.) It is impossible in that it is ill-posed: if we know $f$ to accuracy $\varepsilon > 0$ on $E$, then nothing whatsoever can be inferred about its values at any point $z_0 \in \Omega \backslash \overline{E}$.

Somewhere between these extremes lies a terrain where useful things can be done. Suppose we know that $|f(z)| \le 1$ in $\Omega$. Then analytic continuation to a point $z_0 \in \Omega \backslash E$ is *well-posed* but with *infinite condition number* in the sense that as $\|f-g\|_E \to 0$, $|f(z_0) - g(z_0)| \to 0$ sublinearly. This goes back to the Hadamard three-circles theorem.

For example, suppose $f$ is analytic with $|f(z)| \le 1$ in the half-strip $\mathrm{Re} z \ge 0$, $-1 \le \mathrm{Im} z \le 1$ and we know it to accuracy $\varepsilon$ on the interval $[-i, i]$. Then it is determined to accuracy $\varepsilon^{\alpha(x)}$ at any $x \in [0, \infty)$ with $\alpha(x) \sim (4/\pi) e^{-\pi x/2}$. If you know $f$ to $d$ digits at the end of the strip, you know it to $d/10$ digits at $x \approx 1.47$, $d/100$ digits at $x \approx 2.94$, and so on (since $(2/\pi)\log 10 \approx 1.47$). Figure 1 shows a memorable variation on this estimate.

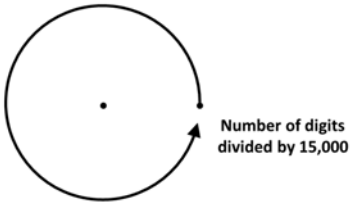


Figure 1. Suppose $f$ can be analytically continued around the origin for $0 < |z| < 2$ and is bounded by 1. If $f$ is known to $d$ digits of accuracy near $z = 1$, then after one circuit around the origin, it is determined to about $d/(\pi/4)\exp(\pi^2)$ digits.

Such results seem impossibly gloomy, yet analytic continuation is established numerical practice based on rational approximations. Traditionally Padé approximation is used, working from Taylor series coefficients, and a more recent alternative is AAA approximation, based on function values as in Figure 2. Ultimately such methods work because functions arising in practice tend to be simpler than worst-case bounds allow.

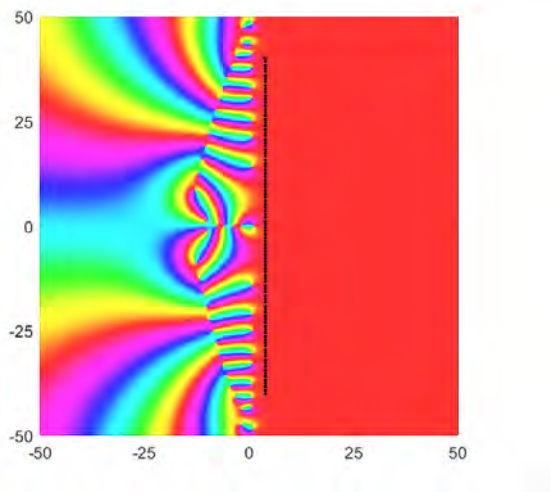


Figure 2. Phase portrait, showing complex arguments by colours, of a numerical analytic continuation of the Riemann zeta function. Here $\zeta(z)$ has been evaluated at 100 points with $\mathrm{Re} z = 4$ and then approximated by a rational function $r(z)$ by the AAA method. The region of good accuracy $r(z) \approx \zeta(z)$ encompasses about 20 zeros on the critical line $\mathrm{Re} z = \frac{1}{2}$.

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**Nick Trefethen**
Trefethen is Professor of Numerical Analysis and head of the Numerical Analysis Group at the University of Oxford.

# Mathematics News Flash

Jonathan Fraser reports on some recent breakthroughs in mathematics.

**Polynomials that vanish to high order on most of the hypercube**

AUTHORS: Lisa Sauermann, Yuval Wigderson
ACCESS: https://arxiv.org/abs/2010.00077

If a polynomial $P \in \mathbb{R}[x_1,\dots,x_n]$ with $P(0,\dots,0) \neq 0$ vanishes at all points $\{0,1\}^n \setminus \{(0,\dots,0)\}$ then the degree of $P$ must be at least $n$. (Can you construct an example showing that this degree bound is sharp?) This elegant result is the content of the Alon-Füredi theorem based on *Alon's Combinatorial Nullstellensatz* and has many useful applications in combinatorics and beyond.

This paper, published in *Journal of the London Mathematical Society* in 2022, considers a natural generalisation of this problem. Fix an integer $k$ (and $n$ sufficiently large in terms of $k$) and ask how small the degree of $P$ can be if we insist that $P$ has zeroes *of multiplicity* $k$ at all points $\{0,1\}^n \setminus \{(0,\dots,0)\}$. An elegant (and sharp) solution is obtained which finds immediate applications to problems in enumerative geometry. For example, the authors generalise a result of Clifton and Huang which provides lower bounds for the size of a collection of hyperplanes in $\mathbb{R}^n$ satisfying certain combinatorial constraints.

**On a problem of Lang for matrix polynomials**

AUTHORS: Alina Ostafe
ACCESS: https://arxiv.org/abs/2105.07705

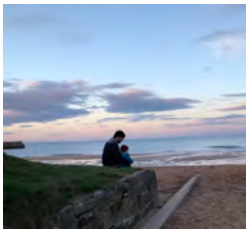
A celebrated conjecture of Serge Lang from the 1960s, which was later proved (independently) by Ihara, Serre and Tate, states that there can only be finitely many *torsion points* on certain algebraic curves, that is, points with all coordinates being roots of unity. This paper, published in 2022 in *Bulletin of the London Mathematical Society*, makes progress towards a matrix analogue of this result. In particular, a complete result is proved in the case of planar rational curves for $2 \times 2$ complex matrices. Partial results are also given in higher dimensions under certain commutativity assumptions.

**Simultaneous approximation in Lebesgue and Sobolev norms via eigenspaces**

AUTHORS: Charles Fefferman, Karol Hajduk, James Robinson
ACCESS: https://arxiv.org/abs/1904.03337

This paper, published in 2022 in *Proceedings of the London Mathematical Society*, provides a powerful method for approximating functions defined on smooth bounded domains by elements of the eigenspaces of the Laplacian or the Stokes operator. The approximations converge in both Lebesgue spaces and Sobolev spaces. Part of the motivation for this comes from the well-known difficulties in finding eigenfunction approximations in bounded domains that are bounded in $L^p$.

The novel approximation method is motivated by interesting examples. In particular, the authors prove energy conservation for the 3D convective Brinkman-Forchheimer equations under suitable conditions. These equations describe the evolution of an incompressible fluid flow in a saturated porous medium, although the authors stress that their main motivation to study these equations is mathematical. Indeed, these equations provide a 'tamed' model for the notorious Navier-Stokes equations.

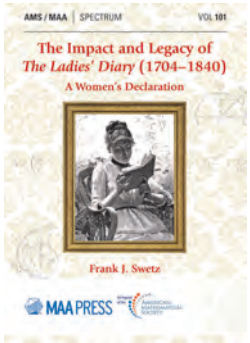


**Jonathan Fraser** is a Professor at the University of St Andrews and an Editor of this Newsletter. He is pictured here discussing the horizon with Dylan.

# The Impact and Legacy of *The Ladies' Diary* (1704–1840): A Women's Declaration

by Frank J. Swetz, MAA Press, 2020, US$55, ISBN: 978-1-4704-6266-6

Review by Sloan Evans Despeaux




During the eighteenth century in Britain, almanacs were the place that mathematics enthusiasts looked for information, challenges, and community. One of the first such almanacs was *The Ladies' Diary*. It was initially established in 1704 as *The Ladies Diary: or, The Womens ALMANACK,. . . Containing many Delightful and Entertaining Particulars Peculiarly adapted for the Use and Diversion of The FAIR-SEX*, an almanac with articles for homemakers. However, shortly after a male reader submitted a mathematical question to the editor in 1707, the editor replaced many of the *Diary*'s domestic features (such as cooking recipes) with mathematical ones. Interestingly, in spite of the title, from 1707 onwards, both men and women read and responded to the mathematical questions of the *Diary* posed one year then answered the next.

*The Ladies' Diary* has been the subject of several studies over the past few decades. In the book under review, Frank Swetz provides a succinct and entertaining compilation of the results of these studies. As historian of mathematics Amy Ackerberg-Hastings writes in her foreword to the book, Swetz has made *The Ladies' Diary* 'accessible to a non-academic audience' by providing a 'lively biography of the periodical' (pp. xi–xii).

Swetz opens his book with a fictional coffeehouse encounter surrounding a group of men reading and responding to the mathematical problems they found in *The Ladies Diary*. The rest of the book is organized into chapters, each of which is guided by a 'probing question' (p. xv). In Chapter 2, in response to the question 'For those unfamiliar with this publication, just what was *The Ladies' Diary*?' he introduces the format of British almanacs and *The Ladies' Diary* in particular. The next chapter tackles the question 'How did the editors shape and control the direction in which the *Diary* developed and progressed?' Here, Swetz gives a very good summary of the complicated editorial succession of the *Diary* over the decades.

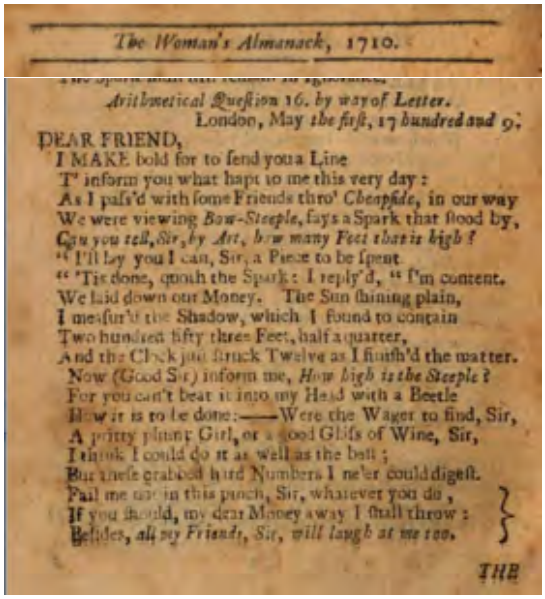
Chapter 4 explores 'Why enigmas and mathematical problems?' Swetz points out that women's explicit engagement (that is, activity under their real names and not pseudonyms, which was a common practice) with the mathematical questions declined in response to the increased difficulty of the problems, and it was exacerbated by the bawdy mathematical problems posed by Robert Heath during his term as editor (1745–1753). However, Swetz makes a very good point that even during this decline, women's engagement with the enigma section of the almanac remained strong. He then gives examples of mathematical questions under each editor, noting how the tenor of the questions changed over time.

For many of these sample questions, Swetz uses a reprint collection of the *Diary*'s mathematical questions from 1704 to 1816, compiled by the mathematician and journal editor Thomas Leybourn (*c.* 1769–1840). While the early mathematical problems were written in rhyming verse, Leybourn translated these problems into 'plain but perspicuous prose' because he judged that the mathematical poetry 'in almost every case was bad, and often hardly intelligible' [2, p. vi]. By relying mainly on Leybourn's translations, Swetz obscures important changes described by Costa in her 2002 study of *The Ladies Diary* [1]. Costa describes a process beginning in the 1720s that changed the *Diary* 'from a forum where women's "geometrical, algebraical, astronomical and philosophical" skills were displayed and praised to one nominally dedicated to women and to mathematics, but in which polite banter had been displaced by an increasingly skill-oriented, even confrontational, discourse' [1, p. 70]. Questions posed in rhyming verse were displaced by those presented with prose and equations.

For example, Swetz gives Leybourn's translation of Prize Problem 16 from 1710:

> Walking through Cheapside, London, on the first day of May, 1709, the sun shining brightly, I was desirous to know the height of the Bow steeple. I accordingly measured its shadow just as the clock was striking twelve, and found its length to be $253\frac{1}{8}$ feet; it is required from thence to find the steeple's height. (Leybourne, quoted in Swetz, p. 43)

However, in its original form, the problem appeared as below:



*The Woman's Almanack, 1710.*

*Arithmetical Question 16. by way of Letter.*

London, May *the first*, 17 *hundred and* 9.

DEAR FRIEND,

I MAKE bold for to send you a Line
T' inform you what hapt to me this very day:
As I pass'd with some Friends thro' *Cheapside*, in our way
We were viewing *Bow-Steeple*, says a Spark that stood by,
*Can you tell, Sir, by Art, how many Feet that is high?*
"I'll lay you I can, Sir, a Piece to be spent.
"'Tis done, quoth the Spark: I reply'd, "I'm content.
We laid down our Money. The Sun shining plain,
I measur'd the Shadow, which I found to contain
Two hundred fifty three Feet, half a quarter,
And the Clock just struck Twelve as I finish'd the matter.
Now (Good Sir) inform me, *How high is the Steeple?*
For you can't beat it into my Head with a Beetle
How it is to be done:——Were the Wager to find, Sir,
A pritty plump Girl, or a good Glass of Wine, Sir,
I think I could do it as well as the best;
But these grabbed hard Numbers I ne'er could digest.
Pair me me in this punch, Sir, whatever you do,
If you should, my dear Money away I shall throw:
Besides, *all my Friends, Sir, will laugh at me too.*

THE

While the mathematics required remains the same, the important context surrounding the problem is lost.

Chapter 5 explores the question 'What were women's opportunities to study and know mathematics?' by giving a brief history of education in Britain from the sixteenth to nineteenth centuries, including women's exposure to mathematics. Chapter 6 discusses the intellectual value of the *Diary* by exploring more mathematical problems as well as the more general scientific content of the almanac. Chapter 7 asks 'Did the *Diary* reflect and support the mathematical reforms taking place during the span of its publication?' Chapter 8 approaches the question 'Did the *Diary* really serve the needs of women?' Swetz focusses on the early years of the *Diary* here, but he reminds us that while women soon dropped out of the mathematical problem section, their participation in the enigmas remained strong. In Chapter 9, the final one of the book, he examines the societal impact of the *Diary*.

In his Epilogue, Swetz presents us with several open questions, such as one about women's activity in other periodicals with mathematical problem sections like *The Ladies Diary*. He closes out the book with three appendices with selections from *The Ladies' Diary*. He also includes an extensive bibliography. In her forward, Ackerberg-Hastings writes that his 'bibliography can serve double duty as a list of recommended sources for those readers who want to learn more about any of the many topics addressed in the story he tells' (p. xii).

This book would be a good introduction to *The Ladies Diary* for those new to the history of mathematics. Although a distracting number of typographical errors remain in the text, Swetz nonetheless writes in an engaging style and condenses an immense amount of existing scholarship into a slim volume.

## FURTHER READING

[1] S. Costa. The 'Ladies Diary': Gender, Mathematics, and Civil Society in Early Eighteenth-Century England, Osiris 17 (2002), 49–73.

[2] T. Leybourn, Preface, The Mathematical Questions, Proposed in the Ladies' Diary, and their original answers, together with some new solutions, from its commencement in the year 1704 to 1816, vol. 1, J. Mawman, London, 1817, vi.

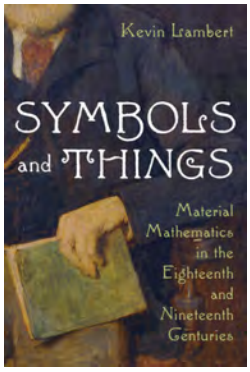
**Sloan Evans Despeaux**

Sloan Evans Despeaux is Professor of Mathematics at Western Carolina University. Her research interests centre on the history of mathematics (especially the mathematics, mathematicians, and scientific journals in nineteenth-century Britain). She is secretary of the International Commission of the History of Mathematics and serves on the American Mathematical Society HMATH Editorial Committee. She is deputy editor of the *American Mathematical Monthly*, and she co-directs the North Carolina Network of Math Teachers' Circles.

# Symbols and Things: Material Mathematics in the Eighteenth and Nineteenth Centuries

by Kevin Lambert, Pittsburgh Press, 2021, £39.50, US$55, ISBN: 9780822946830

Review by Sam A. Mutter




What equipment does a scientist need in order to do their research? A microbiologist might have a hard time without a microscope, and observational astronomers would be in the dark without a telescope. But what about a theoretical scientist? Which tools are essential for a mathematician to perform their craft?

Kevin Lambert argues that a Victorian mathematician was just as much a labourer as they would have been an academic, with a tool belt comprising textbooks, diagrams, notepads and museums. In *Symbols and Things*, he talks us through each of these items, upon which every eighteenth- and nineteenth-century British theoretician came to rely.

Each chapter brings into focus a different advancement: a thing, and explores how it changed the academic landscape: the symbols. Chapter 1 recounts how the rise of mass-printing allowed for specialist texts to be made available for the amateur or junior mathematician. Displayed at this point and throughout the book are several beautiful scans of first edition texts, such as *Cocker's Arithmetic*, which serve to immerse the reader in history. Indeed, Lambert chooses *Cocker's* as an example marking the invention of the publishing house, explaining how every printer (bootleg or otherwise) was trying to outdo their rivals by putting their own spin on the text. I enjoyed reading these stories of the evolution of publishing; it all seems so long ago, but at the same time it's easy to find parallels to the present. After all, how many different editions of *Euclid's Elements* might we all find on our bookshelves today?

Not only does the author focus on his chosen 'things', but he also explains how contemporary affairs in the UK, Ireland and mainland Europe had affected the technological landscape. For example, he mentions how the Glorious Revolution of 1688 affected the publishing wars mentioned above, and how in-vogue Kantian philosophy fuelled research into imaginary numbers, and even electromagnetism. Thus *Symbols and Things* would not only interest the scientifically-minded, but also anyone with an enthusiasm for eighteenth-century history and philosophy. It would, of course, be beneficial to be both, since the book mentions a lot of names from a lot of fields, which could be overwhelming for someone not so familiar with them.

Lambert's writing style is particularly enjoyable. His attention to detail is astounding, with hundreds of notes in which he allows himself to be a bit more personal, and which open up whole new rabbit holes of discussion. The segues from thought to thought are gracious and compelling:

*"The finite nature of [the law of excluded middle] is beautifully captured by Boole's mathematical expression for the categories of things left after such an operation has been carried out* $(1 - x)$*. It might as easily stand for the material finitude of the resources left immediately after a book* $(x)$ *has been borrowed from a library."*

and it is generally a pleasure to read something written by someone so clearly knowledgeable and passionate about a topic.

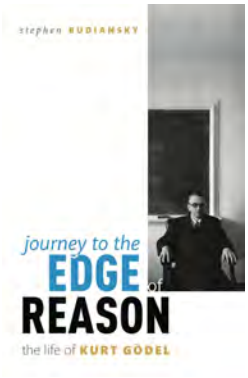
I would recommend this book for anyone who is fascinated by the way legendary (and obscure) mathematicians used to think, and how physics, philosophy and mathematics evolved together, with the help of some Steam-Age innovation.

**Sam A. Mutter**
Sam is a PhD student at Newcastle University, UK. He mainly works in buildings, but is also fond of trees. His interests include learning languages (dead and alive), designing board games, and eating.

# Journey to the Edge of Reason: The Life of Kurt Gödel

by Stephen Budiansky, Oxford University Press, 2021, £20,
ISBN: 9780-198866336

Review by David E. Dunning




Kurt Gödel is among the most famous mathematicians of the twentieth century—not only in the sense of the renown of his mathematical accomplishments, but also in the more ambivalent sense that he, the mathematician himself, is a highly mythologized tragic figure. His long struggle with mental illness is well known. And even at his most lucid, notes of tragedy surround him. He was born in the waning days of the Hapsburg empire, and hit his mathematical peak in a Vienna that would soon see abstraction vilified as 'Jewish mathematics' under Nazi rule. Mathematically, he was a man out of step with his time, resolutely adhering to unapologetic Platonism in an era of modern logicist, formalist, and intuitionist alternatives. And of course it is not difficult (though not inevitable!) to read tragedy in his most famous results, with their rigorous demonstration that despite our best efforts, consistent formal systems of any depth must remain incomplete. It is not easy to tell this story with sensitivity and nuance, depicting the real entanglement of Gödel's difficult life with his monumental work, yet avoiding caricature and the cliche of the mad genius. To do so for a general audience, to convey a meaningful sense of the stakes of Gödel's mathematics while assuming no familiarity with logic or set theory, is more difficult still.

Stephen Budiansky's magnificent new biography of Kurt Gödel accomplishes all of this, and offers a thoroughly engaging read throughout. An effective and affecting prologue introduces the subject through his psychiatrist's eyes in the later years of his life, establishing a mature Gödel's values and anxieties, while also depicting the general rhythm of the life he found in Princeton. The chapters then tell his story chronologically, offering rich contextual detail at every stage. After nicely setting the late Hapsburg scene into which Gödel was born in 1906 in Brünn, Budiansky follows the young Gödel through his school days to his youthful involvement with the Vienna Circle philosophical group. In 1928 Gödel met Adele Nimbursky; their enigmatic relationship (and, from 1938, marriage) would be at once a protective and a dominating force that did much to shape his daily life from then on. Budiansky succinctly presents some background on the search for foundations in mathematics, and in particular Hilbert's formalist approach, before describing the monumental theorems by which Gödel demolished that programme and forever established himself as one of history's great logicians.

Despite his enormous mathematical stature, Gödel appears perpetually young and unsure of himself. His character in this portrayal is above all naïve. Late summer 1939 found him preoccupied with lectures and colloquia in a manner that his friends sometimes considered endearing, but by then was mostly maddening as their world unraveled. Catastrophe eventually became all too undeniable, of course, and in 1940 Kurt and Adele escaped the Reich, traveling around the world to Princeton the long way to avoid the frequent arrest of German passengers on Atlantic crossings. Gödel's political naïveté and frequent myopia did not preclude an ability to confront disaster with wry humor. Upon his arrival in the United States, his friend the economist Oskar Morgenstern 'asked him how things were in Vienna. "The coffee is terrible," Gödel deadpanned' (p. 215). Gödel's deep friendships—with Morgenstern, and even more closely with Albert Einstein—are touchingly rendered. They offered strong, steady support through the ups and downs of his unsteady mental (and later also physical) health during the postwar decades in Princeton.

Budiansky artfully conjures the places and times of Gödel's life—early twentieth-century industrial Brünn, Vienna in the interwar and after the Anschlüss, Princeton and the Institute for Advanced Study following the surge of world-renowned European émigrés—giving always the right amount of background to establish a rich context without letting the prose become academic.

Readers of this *Newsletter* will find the mathematical content thin. That is no criticism, merely a note of emphasis that the book is a beautifully written narrative biography, not an exposition of Gödel's work. That said, readers with no mathematical background at all are nonetheless likely to find the limited discussions of mathematics non-trivially demanding—even an admirably accessible explanation of what Gödel was up to in his incompleteness theorems requires considerable background and is necessarily quite abstract. Budiansky judiciously relegates a slightly more extensive discussion of Gödel's proof to an appendix. This offers the curious reader a bit more detail while remaining basically non-technical.

Naturally anyone with an interest in Gödel or the history of logic ought to waste no time obtaining a copy of this book. But beyond that most obvious audience, any reader with a taste for twentieth-century history in general will appreciate the engrossing portraits of the story's European and American backdrops. And moving nervously through all these settings, at once astutely perceptive and naïvely bereft of worldliness, is the subject of the central portrait, a man whose brilliance, hardships, and warmth emerge vividly.

**David E. Dunning**

David E. Dunning is a Lecturer in the Integrated Studies Program at the University of Pennsylvania. He is a historian of science, technology, and mathematics, whose research focuses on the material and social dimensions of abstract knowledge. Recently he is enjoying the sleep-deprived joys of new parenthood.

# Obituaries of Members

## A. Geoffrey Howson: 1931–2022

Professor A. Geoffrey Howson, who was elected a member of the London Mathematical Society on 19 March 1970, died on 1 November 2022, aged 91.

*Tony Gardiner writes:* Geoffrey made his mark in the early 1950s, when he proved that the intersection of two finitely generated subgroups of a free group is also finitely generated (a result that is now memorialised as the Howson property of a group). Later he became a significant player in international mathematics education 1960–2000, although he operated quietly and so his contributions were not always widely appreciated.

Geoffrey's life provides insights into how the UK and mathematics education has changed since 1931 when he was born — the seventh of seven children — in the village of Kippax, four miles north of Castleford. He always remained faithful to these roots: solid Yorkshire, from a deprived, but proud, mining community. Yet he came to excel in mathematics and in international mathematics education, as well as in the world of opera, Bauhaus design and embroidery, and medieval church architecture.

No one in Geoffrey's family had ever been to secondary school. He attended Castleford Grammar School, and was the first from that school to study mathematics (in Manchester). He was Graham Higman's second PhD student. On completion in 1955 he faced National Service, so invitations from Baer (Illinois) and Maclane (Chicago) were put on ice. During his National Service he taught RAF trainees at the RAF Technical College in Henlow about guided missiles, before moving to the Royal Naval College, Greenwich in 1957, where he taught the new generation of future naval commanders about similar things.

In 1962 he went to Southampton to manage the School Mathematics Project (SMP). This was the UK equivalent of 'new math', but more humane and less abstract. At its height SMP materials were used in around 60% of UK secondary schools. But SMP remained a Teachers' Cooperative, with no government support. Geoffrey's original job was to edit and to manage the program of new textbooks. In practice, he had to coordinate the writing (devised and completed by a remarkable group of full-time teachers), the production/revision process, and negotiate with publishers and exam boards. He was an SMP Trustee from 1967, and Chairman 1984–96.

Geoffrey became a representative for 'modern maths' developments in the UK, and interacted with those similarly placed in other countries, in both East and West. He published and edited numerous books and papers, all written in a thoughtful style. His goal was to enlighten, rather than to engage in 'theoretical research'. He became a leader in Mathematics Education internationally, but was less appreciated by the new breed of 'Maths Education' researchers. He contributed pragmatic comparisons, surveys, histories and analyses, designed to inform and allow improved judgements to be made.

Geoffrey served as Secretary-General of ICME (1983–90) under Jean-Pierre Kahane as President and helped to give ICMI/ICME a new lease of life. Shortly before retirement he was Head of Department in Southampton and Dean 1990–92, and helped to strengthen the department. He also chaired the LMS/IMA/RSS committee that produced the 1995 report *Tackling the Mathematics Problem* — an early instance of the three scholarly societies acting together on a matter of mutual concern, and having a significant impact on subsequent policy-making.

## David Monk 1932–2022

Dr David Monk, who was elected a member of the London Mathematical Society on 19 December 1957, died on 3 October 2022, aged 90.

*Adam McBride writes:* David Monk will be remembered by many as a doyen of mathematics competitions, national and international, with which he was involved for over 50 years.

Having won a scholarship to Trinity College, Cambridge, David went up in 1951, gaining his BA degree in 1954 and his doctorate in 1958, for a thesis entitled *The Geometry of Flag Manifolds* supervised by J.A. Todd. He was an Assistant Lecturer at the University of Hull until 1960 when he moved to the

University of Edinburgh, where he remained until his retirement in 1992.

In 1967 the UK took part in the International Mathematical Olympiad (IMO) for the first time. David was involved from the start, being Deputy Leader of the UK team in 1968. He went on to attend the IMO four times as Team Leader and four more times as Deputy Leader. In the late 70s and 80s he ran a correspondence course for potential team members. When the British Mathematical Olympiad Committee (BMOC) was set up in 1991, David was a founder member. The BMOC was then subsumed into the United Kingdom Mathematics Trust (UKMT) after the latter was established in 1996.

David was probably best known for his extraordinary creativity and ingenuity in composing interesting and challenging problems. As recently as 2016, two of his problems were used in the British Mathematical Olympiad. Some of his problems have been used in the Balkan Mathematical Olympiad, the Romanian Master of Mathematics and the Gulf Mathematical Olympiad. However, it was in the arena of the IMO that David achieved international renown. He was the author of 13 problems that were chosen to appear on IMO papers, making him the most prolific composer of IMO problems in the world. (To put this in context, as many as 200 problems are proposed by participating countries in any year but only 6 are used in the competition.) David's achievements were recognised in 2018 by the receipt of a Paul Erdős Award from the World Federation of National Mathematics Competitions.

David kept a meticulous record of his problems in a little pocket book, all in his own neat handwriting. One section contains his famous 'Background Problems' which were used at the annual UKMT camp at Trinity College, Cambridge. David attended these camps regularly and he loved being back at his old college. However, perhaps the most remarkable section is headed 'Problem Ideas', of which there are no fewer than 203(!). Some of these ideas might lead to IMO problems in the future so that David's legacy can live on.

David's marriage to Isobel brought him many years of happiness. Together they indulged his love of travel which stemmed from his trips to IMOs all over the world. Isobel died in 2019 and David's last years were spent in a care home. Although Covid restrictions made life difficult, he showed great resilience and remained as sharp as a tack right up to the end. He loved tackling sudoku puzzles in his daily paper and watching Countdown and The Repair Shop on television. He was a true gentleman and the essence of kindness.

On a personal note, David gave me my very first mathematics lecture at the University of Edinburgh in 1964. His lectures were a model of clarity, with the utmost attention to detail. Little did I realise that I was to be taught by a future giant of the Olympiad scene.

## Death Notices

We regret to announce the following death:

- Jan Nekovár, of the Pierre et Marie Curie University, who was an LMS Reciprocity Member from 1995–2017, and was awarded an LMS Whitehead Prize in 1998, died on 13 November 2022, aged 59.
- Rex Dark, of the University of Galway, who was elected an LMS Member on 16 June 1978, died on 5 December 2022, aged 79.

## LMS Obituaries

The following obituary has recently been published in the LMS *Bulletin*:

Gordon Douglas James (1945-2020)
tinyurl.com/46uwu2j9

Obituaries (both recent and historical) published in the Bulletin are free to read and can be accessed at tinyurl.com/bduxhkhe.

## Quivers, Clusters, Moduli and Stability

Location: University of Oxford
Date: 9–13 January 2023
Website: tinyurl.com/3aak7rz9

The primary aim of this meeting is to foster interaction between geometers and algebraists, so that problems and methods can be shared between these communities. It also serves to celebrate the 60th birthday of Professor Alastair King. Registration is via the conference website above. The meeting is supported by an LMS Conference grant, Foundation Compositio Mathematica and the EPSRC.

## New Perspectives in Pure Mathematics

Location: University of Bristol
Date: 27–29 March 2023
Website: tinyurl.com/5e6z2snn

Taking place over three days, this international conference features a distinguished line-up of speakers, covering a range of recent advances in number theory, combinatorics, algebra, geometry and logic. This is the last in a series of conferences being held to celebrate the move of the School of Mathematics at the University of Bristol to the recently refurbished (Grade II listed) Fry Building at the heart of the university campus. The meeting is supported by an LMS Conference grant, the Heilbronn Institute for Mathematical Sciences and the Clay Mathematics Institute.

## Graph Rigidity and Applications

Location: Lancaster University
Date: 17–21 April 2023
Website: tinyurl.com/dd5nsc7k

This workshop will focus on advances in graph rigidity and its applications. Geometric and combinatorial rigidity theory is an interdisciplinary field which aims to provide techniques for identifying rigidity and flexibility properties of discrete geometric structures. The invited talks will be given by Sean Dewar (Bristol), Ioannis Emiris (Athens), Derek Kitson (Mary Immaculate, Limerick), Kaie Kubjas (Aalto), Isabella Novik (Washington), Ben Smith (Manchester), Klara Stokes (Umea) and Nelly Villamizar (Swansea). The meeting is supported by an LMS Conference grant.

## Python for A-Level Mathematics and Beyond

Location: Online
Date: 20–21 January 2023
Website: tinyurl.com/39zeej4m

This is a hands-on IMA workshop and will introduce delegates to the freely available, open-source and general-purpose programming language Python — which is one of the most popular programming languages in the world. Python will be used to enhance the teaching and learning of Mathematics at A-Level and beyond. Delegates need no prior knowledge of programming to benefit from this workshop.

## Kings and Queens of Gravity

Location: QMUL and De Morgan House
Date: 29–31 March 2023
Website: tinyurl.com/4ufjacay

This workshop will focus on recent advances in mathematical general relativity (GR) in the UK. We will bring together researchers studying general relativity from different angles, with talks in analysis and nonlinear PDE theory, differential geometry, mathematical physics and numerical relativity. Given the interdisciplinary nature of the workshop, the goal is for talks to be at an accessible level for graduate students. There will also be a poster session for junior researchers and students. Registration necessary.

## IMA and OR Society Conference on Mathematics of Operational Research

Location: Birmingham
Date: 27–28 April 2023
Website: tinyurl.com/bdd2cvyv

Building on the success of the three previous conferences held in 2017, 2019 and 2021, this fourth conference will aim to draw together the considerable community of researchers and practitioners who use/develop innovative mathematics, relevant to the applications and theory of Operational Research. The conference will showcase activities from across OR, and will welcome both contributions which have a clear application focus as well as those which are theoretically driven.

## Scottish Combinatorics Meeting

Location: University of Strathclyde, Glasgow
Date: 22–23 May 2023
Website: tinyurl.com/SCMMay2023

This two-day meeting provides an occasion for researchers from across Scotland and beyond to get together to hear talks on a variety of topics in combinatorics. There will be an opportunity for several research students and junior researchers to present short talks. Some funding is available for travel expenses and accommodation of UK research students. The meeting is supported by an LMS Conference grant.

## Probabilistic Group Theory CMI–HIMR Summer School

Location: University of Bristol
Date: 19–23 June 2023
Website: tinyurl.com/3rkk6xyu

In recent years, probabilistic methods have been at the heart of many spectacular advances in group theory and related areas, finding a diverse range of applications. This summer school will introduce a wide audience of graduate students and early career researchers to some of the most exciting recent developments. The programme will feature four short courses from world-leading experts in the area, together with tutored problem sessions for participants. The event is supported by the LMS Celebrating New Appointments Scheme.

## Gregynog Welsh Mathematics Colloquium 2023

Location: Gregynog Hall, Tregynon, Powys
Date: 22–24 May 2023
Website: gregynogwmc.github.io

The Wales Mathematics Colloquium is a long-standing annual event aimed at bringing together mathematicians at Welsh HEIs, although others are also welcome to attend. It plays an important role in fostering mathematical discussion and collaboration between staff and postgraduates in Wales. This year's keynote speakers are: Professor Sir John Aston (Cambridge), Professor Gianne Derks (Surrey) and Professor Roger Heath-Brown FRS (Oxford). The meeting is supported by an LMS Conference grant.

## Remembering Victor Snaith: Topology, Number Theory and Interactions

Location: University of Bristol
Date: 10–14 July 2023
Website: tinyurl.com/mrwttbhx

This conference will bring together homotopy theory, cohomology of groups, algebraic K-theory and number theory. The aim is to feature important developments, paying special attention to synergies between these areas. Speakers have been asked to spend a substantial part of their talk describing their area for non-experts so we encourage early career researchers to attend. Funding deadline 17 March. The conference is supported by the Heilbronn Institute, the Snaith family and an LMS Conference grant.

## Algebraic Groups and their Representations: LMS Research School

Location: University of Birmingham
Date: 24–28 July 2023
Website: https://sites.google.com/view/agrt23

Participants will learn about this core area of mathematics, from its origins through to cutting-edge developments. The three lecture courses will be Representation Theory of Reductive Groups and Categorification, Jonathan Brundan (Oregon), Geometry Arising from Algebraic Groups, Martina Lanini (Rome) and Modular Representation Theory of Reductive Algebraic Groups, Simon Riche (Clermont Auvergne). See the website for how to apply. The closing date for applications is 10 March 2023, though early applications are encouraged. This workshop is aimed at graduate students and early career researchers who wish to learn more about this core area of mathematics.

# Society Meetings and Events

## January

17 LMS South West and South Wales Meeting and Workshop, University of Southampton

## March

27-30 LMS Midlands Regional Meeting, University of Warwick

## April

4 LMS Meeting at the BMC 2023, University of Bath

# Calendar of Events

This calendar lists Society meetings and other mathematical events. Further information may be obtained from the appropriate LMS Newsletter whose number is given in brackets. A fuller list is given on the Society's website (www.lms.ac.uk/content/calendar). Please send updates and corrections to calendar@lms.ac.uk.

## January

9-13 Quivers, Clusters, Moduli and Stability, University of Oxford (504)

20-21 Python for A-Level Mathematics and Beyond, Winter 2023, Online Workshop (504)

## March

27-29 New Perspectives in Pure Mathematics, University of Bristol (504)

29-31 Kings and Queens of Gravity, Queen Mary University of London and LMS De Morgan House (504)

## April

3-6 British Mathematical Colloquium, University of Bath (503)

17-21 Graph Rigidity and Applications, Lancaster University (504)

27-28 4th IMA and OR Society Conference on Mathematics of Operational Research, Birmingham (504)

## May

22-23 Scottish Combinatorics Meeting, University of Strathclyde, Glasgow (504)

22-24 Gregynog Welsh Mathematics Colloquium 2023, Gregynog Hall, Tregynon, Powys (504)

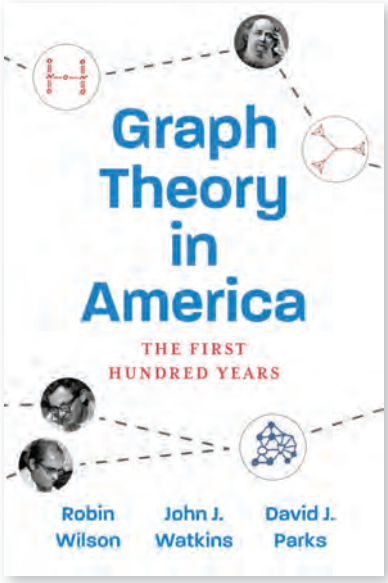
## June

19-23 Probabilistic Group Theory CMI-HIMR Summer School, University of Bristol (504)

## July

10-14 Remembering Victor Snaith: Topology, Number Theory and Interactions, University of Bristol (504)

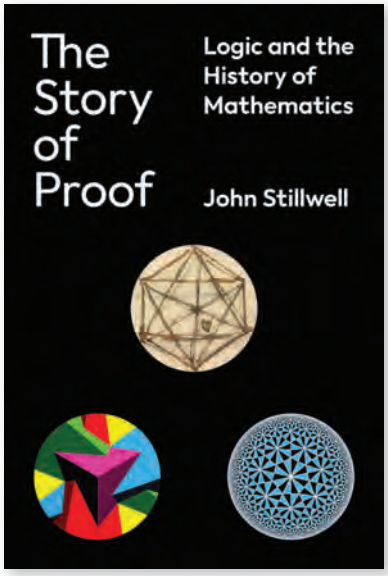
24-28 Algebraic Groups and their Representations LMS Research School, University of Birmingham (504)




## Graph Theory in America: *The First Hundred Years*

Robin Wilson, John J. Watkins, and David J. Parks

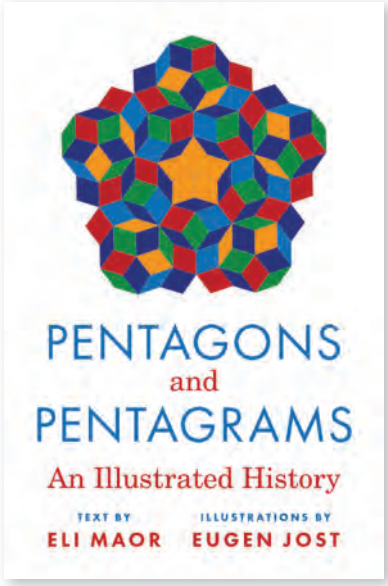
**How a new mathematical field grew and matured in America**




## The Story of Proof: *Logic and the History of Mathematics*

John Stillwell

**How the concept of proof has enabled the creation of mathematical knowledge**




## Pentagons and Pentagrams: *An Illustrated History*

Eli Maor and Eugen Jost

**A fascinating exploration of the pentagon and its role in various cultures**