THE MAN WHO KNEW INFINITY

Film Review

One of the most interesting "real life" stories about mathematics is the Hardy-Ramanujan relationship. This was well described in the book *The Man Who Knew Infinity* by Robert Kanigel and this has now been transformed into the film under review. It stars Jeremy Irons (Hardy), Dev Patel (Ramanujan) and Toby Jones (Littlewood).

The film starts with a speech made towards the end of Hardy's life where he described Ramanujan "as the most romantic figure in the recent history of mathematics" and the whole film can be seen as a romance, if not a love story describing their relationship. As with any close relationship there are conflicts. Several scenes are about the need for proof. The film describes Ramanujan as finding his formulae through intuition and Hardy tries to tell him that he could not publish his results without proof, which is one of the major themes of the film and symbolic of the cultural clash between the two. He sends Ramanujan to some lectures given by people with far less talent, which causes conflict but finally, he does manage to prove his results and this led to publication by the London Mathematical Society, probably the first time the name of our Society has appeared in a film!

At a time when interest in mathematics is high, but the school-learned fear of it remains for many, it is welcome to have a film that depicts the love of mathematics in a very human way. Ramanujan is portrayed as being motivated by aesthetics, by form, and by a thirst for knowledge. Additionally, the themes of culture, class and race serve to humanise the material and the sometimes off-putting image of mathematicians comes out well. Hardy, in particular, while being depicted as awkward and lacking in social skills, is treated with real warmth by the end, and some scenes are put aside to briefly mention his anti-war politics, as well as those of Russell, but not in any heavy handed way. However, the idea that the motivation for learning mathematics is a very human one, and that mathematicians can come from all backgrounds is one that I think will be hugely

SOCIETY MEETINGS AND EVENTS

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resonant for audiences, as it has been with the interest in Turing in recent years.

One problem about any film about mathematics is how much of our subject to include. Any detail would put the general audience off. Here they get it about right, and some praise must surely go to Ken Ono, who was the mathematical advisor for the film. Of course, there are many formulae shown but these can be seen as mathematical wallpaper. They do describe the partition function p(n) and actually show that p(4)=5 but this should be accessible to everyone.

One point of comparison would be the film *Good Will Hunting*, which also depicted a – this time fictional – mathematical genius, and was received fairly positively. I think it fair to say that while that film had a lot of charm, this fim outshines *Good Will Hunting* in almost every way. The cultural gap is so much more acute and the historical foundation makes all elements of the film more grounded; from the characters, to the way it presents mathematics to the backdrop of the First World War. Most of all it is more uplifting, embracing the positivity of romance, albeit a platonic romance rooted in a love of mathematics.

The filming is quite beautiful, both in India and in Cambridge. They were allowed to actually film in Trinity College! Many well-known mathematicians are characters. Besides Hardy and Ramanujan we meet Littlewood, Russell and Major MacMahon. A nice scene is a discussion between MacMahon and Ramanujan concerning the partition function. At first, MacMahon doubts whether Ramanujan's formula for p(n) could be correct. MacMahon had computed p(200) by hand and then found that the analytic formula turned out to give an extremely accurate answer. MacMahon changed his mind!

Earlier in the film Ramanujan failed to be elected a fellow of Trinity and racism played a part here. Towards the end of the film, Hardy proposed that Ramanujan become an FRS and in a moving speech, he persuaded the other fellows to elect him. During his stay in Cambridge, Ramanujan develops tuberculosis and goes back to India where he dies at the age of 32.

The acting throughout is first class. Jeremy Irons is outstanding as Hardy and he even looks like him. Dev Patel is convincing as Ramanujan. Unfortunately, he doesn't look like him; Ramanujan was short and fat whereas Patel is quite tall. We particularly liked Toby Jones as Littlewood, providing some of the lighter moments. In short, this is perhaps the best film about mathematics ever made!

Armando Martino and David Singerman
University of Southampton

The Man Who Knew Infinity will be released in the UK on 8 April and in the US on 29 April.

CMI

LONDON MATHEMATICAL SOCIETY EST. 1865

Modern topics in Nonlinear PDE and Geometric Analysis

LMS-CMI Research School, Reading, 4-8 July 2016

Organisers: Stefanos Aretakis (Princeton, USA) and Nikos Katzourakis (Reading, UK). For further information please visit: http://ow.ly/VA0cK. The three main lecture (6+2)-hour courses will be:

- Course 1: Nonlinear PDE and Calculus of Variations
  Lawrence C. Evans (Berkeley, USA) - *Nonlinear PDE and optimisation*
  Jan Kristensen (Oxford, UK) - *Convexity notions in the Calculus of Variations*
- Course 2: Geometric Hyperbolic PDE, General Relativity & Fluid Dynamics
  Mihalis Dafermos (Princeton, USA - Cambridge, UK) - *The stability problem for black holes*
  Gustav Holzegel (Imperial College, UK) - *The formation of shocks in three dimensional fluid dynamics*
- Course 3: Geometric Nonlinear PDE
  Bernard Dacorogna (EPFL, Switzerland) - *The pull-back equation for differential forms*
  Spyros Alexakis (Toronto, Canada) - *On dynamical stability of singular Ricci solitons under Ricci flow*
- The distinguished guest lecturers are **Robert Jensen** (Chicago, USA) and **Juan Manfredi** (Pittsburgh, USA)

Applications should be made by 11 April using the form at http://ow.ly/VA0i0. Research students, post-docs and those working in industry are invited to apply. Numbers will be limited and those interested are advised to make an early application. *All applicants will be contacted within two weeks after the deadline.

All research students will be charged a registration fee of £150 and all early career researchers will be charged a registration fee of £250. There will be no charge for subsistence costs fro these groups. All other participants (e.g. those working in industry) will be charged a registration fee of £250 plus the full subsistence costs.

All UK-based participants must pay their own travel costs. For overseas participants, support will be available to contribute towards travel costs. Fees are not payable until a place on the course is offered but will be due by Friday 27 May 2016.

University of Reading

Heilbronn Institute for Mathematical Research

LONDON
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Inaugural Hirst Lecture & Society Meeting

St Andrews, 20 April 2016

3.30 pm: Opening of the meeting

3.45 pm: Mark McCartney (Ulster)
             Title TBA

4.45 pm: Tea

5.15 pm: Hirst Lecture, Edmund Robertson (St. Andrews)
             Title TBA

6.15 pm: Meeting closes. Wine reception.

The Inaugural Hirst Lecture & Society Meeting celebrates the joint award of the Hirst Prize & Lectureship, in the 150th Anniversary year of the London Mathematical Society, to Professor Edmund Robertson (St. Andrews) and the Dr John O'Connor (St. Andrews) for their creation, development and maintenance of the MacTutor History of Mathematics web site.

The prize and lectureship are named after Thomas A. Hirst, 5th President of the London Mathematical Society from 1872-1874. The prize is awarded in recognition of original and innovative work in the history of mathematics, which may be in any medium.

These lectures are aimed at a general audience. All interested, whether LMS members or not, are most welcome to attend this event. For further details and to register please email lmsmeetings@lms.ac.uk

There are funds available to contribute in part to the expenses of members of the Society or research students to attend the meeting and workshop. Requests for support, including an estimate of expenses, may be addressed to Elizabeth Fisher (lmsmeetings@lms.ac.uk).

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MATHEMATICAL SCIENCES RESEARCH DISPLAYED IN PARLIAMENT

Three mathematicians won medals and awards at a competition in the House of Commons on Monday 7 March 2016 for the excellence of their mathematical science research, walking away with a £3,000, £2,000 and £1,000 prize for Gold (sponsored by the Clay Mathematics Institute), Silver and Bronze (sponsored by the Bank of England) respectively.

Dr Philip Pearce (University of Manchester), Dr Tom Montenegro-Johnson (University of Cambridge) and Weijian Zhang (University of Manchester) each presented research to dozens of politicians and a panel of expert judges as part of the poster competition SET for Britain.

Dr Philip Pearce was awarded Gold for his research on building a virtual placenta, Dr Tom Montenegro-Johnson won Silver for his research on microrobotic swimming and Weijian Zhang won Bronze for his research on time-dependent network modelling for mining scientific literature.

The three winners were judged against 29 other shortlisted mathematicians and came out on top.

Sir Adrian Smith, Chair of the Council for the Mathematical Sciences (CMS) said: 'The CMS is delighted, once again, to showcase the importance of the mathematical sciences to a wider audience. It is paramount to encourage early-career research scientists, engineers, technologists and mathematicians and the SET for Britain event is a very effective way of doing this. We have been encouraged by the enthusiastic response from early-career researchers in the mathematical sciences and feel sure this will this continue in the future'.

Stephen Metcalfe MP, Chairman of the Parliamentary and Scientific Committee, said:

'This annual competition is an important date in the parliamentary calendar because it gives MPs an opportunity to speak to a wide range of the country's best young research-

(l to r) Dr Stephen Benn (Royal Society of Biology), Sylaja Srinivasan (Bank of England), Professor Nick Woodhouse (Clay Mathematics Institute), Weijian Zhang (Bronze Award Winner), Dr Philip Pearce (Gold Award Winner), Dr Tom Montenegro-Johnson (Silver Award Winner), Professor Sir Adrian Smith (CMS), Stephen Metcalfe MP

ers. These early career engineers, mathematicians and scientists are the architects of our future and SET for Britain is politicians' best opportunity to meet them and understand their work'.

The Parliamentary and Scientific Committee runs the event with support from the Royal Academy of Engineering, the Royal Society of Chemistry, the Institute of Physics, the Royal Society of Biology, The Physiological Society and the Council for the Mathematical Sciences.

The event was made possible this year by the prize sponsors, who are Essar, the Clay Mathematics Institute, Warwick Manufacturing Group (WMG), the Institute of Biomedical Science, the Bank of England and the Society of Chemical Industry.

VOICE OF THE FUTURE 2016

The Council for Mathematical Sciences (CMS) once again sent young mathematical scientists to this year's *Voice of the Future* event. The event is an opportunity for scientists aged 16-35 to put their questions to an assembled panel of MPs at the House of Commons. The event, organised by the Society of Biology, took place at Portcullis House on Tuesday 1 March 2016.

This year's CMS nominated participants were Rosanna Cretney (Open University), Ellen Dowie (University of Kent), Hannah Muit (Ernst & Young) and Maria Sudell (University of Liverpool).

MPs attending the event included the Minister for Universities and Science, Jo Johnson MP; Shadow Minister for Science, Yvonne Fovargue MP; Nicola Blackwood MP and members of the House of Commons Select Committee for Science & Technology; and Sir Mark Walport the Government Chief Scientific Adviser. A video message was also received from Tim Peake aboard the International Space Station.

More information about the event is available at https://www.rsb.org.uk/policy/policy-events/voice-of-the-future. The event was also broadcast on Parliament TV http://tinyurl.com/zcpgtmj.

MATHEMATICS POLICY ROUND-UP
March 2016

HIGHER EDUCATION

BIS Committee publishes assessing quality in HE report

The Business, Innovation and Skills Select Committee has published its report - *The Teaching Excellence Framework: Assessing quality in Higher Education*. 'The Committee supports the Universities Minister's desire to improve teaching quality at universities, widen participation, and increase the focus on graduate employability but the Committee's report recognises genuine concerns about the implementation of the new teaching framework and the pace of its introduction'. The full report is available at http://tinyurl.com/h6xavd8.

RESEARCH

Consultation on Mathematics for Horizon 2020

The European Commission has launched an open consultation on *Mathematics in H2020*. The objective is to collect a large quantity of concrete proposals that can subsequently be used to inform the future work programmes (2018-19-20) with innovative mathematical content. The consultation is open until 30 April 2016. More information is available at http://tinyurl.com/h8n6xt2.

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SCHOOLS AND COLLEGES

OECD Report

A report published by OECD - *Low-performing Students: Why they Fall Behind and How to Help them Succeed* - examines low performance at school by looking at low performers' family background, education career and attitudes towards school. The report also analyses the school practices and educational policies that are more strongly associated with poor student performance. The evidence provided in the report reveals what policy makers, educators, parents and students themselves can do to tackle low performance and succeed in school. More information is available at http://tinyurl.com/gu6ba48.

Tough Choices Report

Your Life has launched a report titled - *Tough Choices: The real reasons A-level students are steering clear of science and maths*.

The skills gap is set to grow not diminish, demonstrating that huge challenges remain. This report aims to help inspire change by providing an insight into students' thinking and the choices they face. The report looks at the decision-making process of those students that choose to move away from science and mathematics before A-level. The full report is available at http://tinyurl.com/gshcqmk.

OTHER

New Director General Business and Science

Gareth Davies has been appointed to the role of Director General for Business and Science, at the Department for Business, Innovation and Skills (BIS). More information is available at http://tinyurl.com/za89jwd.

Dr John Johnston
Joint Promotion of Mathematics

CLAY RESEARCH FELLOWS 2016

The Clay Mathematics Institute is pleased to announce that Simion Filip and Tony Yue Yu have been appointed Clay Research Fellows.

Simion Filip will receive his PhD in June 2016 from the University of Chicago under the supervision of Alex Eskin. Simion is interested in the connections between dynamical systems and algebraic geometry, in particular between Teichmüller dynamics and Hodge theory. His recent interests also involve K3 surfaces and their special geometric properties. Simion has been appointed as a Clay Research Fellow for a term of five years beginning 1 July 2016.

Tony Yue Yu received his PhD in 2016 from Université Paris Diderot under the supervision of Maxim Kontsevich and Antoine Chambert-Loir. Tony works on non-archimedean geometry, tropical geometry and mirror symmetry. He aims to build a theory of enumerative geometry in the setting of Berkovich spaces. Such a theory will give us a new understanding of the enumerative geometry of Calabi-Yau manifolds, as well as the structure of their mirrors. It is also intimately related to the theory of cluster algebras and wall-crossing structures. Tony has been appointed as a Clay Research Fellow for a term of five years beginning 1 September 2016.
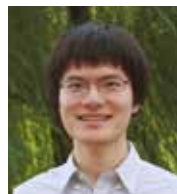
For more information visit www.claymath.org.

EUROPEAN NEWS

The following items are from the European Mathematical Society (EMS) webpage www.euro-math-soc.eu/recent-news.

Meeting of presidents in Budapest
The next meeting of presidents of member societies of the European Mathematical Society will take place in Budapest, Hungary, during the weekend 2 to 3 April 2016. The meeting is hosted by the János Bolyai Society and the Alfréd Rényi Institute of Mathematics. Among other issues, problems of mathematical education throughout Europe will be a focal point for the meeting.

Crafoord Prize
The Royal Swedish Academy of Sciences has awarded the 2016 Crafoord Prize in Mathematics to Yakov Eliashberg, Stanford University, USA, *"for the development of contact and symplectic topology and groundbreaking discoveries of rigidity and flexibility phenomena"*. Yakov was born in 1946 in St Petersburg, Russia, obtaining a PhD at Leningrad State University in 1972. He is the Herald L. and Caroline L. Ritch Professor of Mathematics at Stanford University.

Professor Yakov Eliashberg

Turkish academics persecuted
Turkish academics who have openly criticized Turkey's military crackdown on ethnic Kurdish communities are now feeling the wrath of their government. In recent days the government arrested 33 academics. Although all have since been released, 15 have been fired from their university posts. The course of action started on 11 January, when a letter protesting violence in Turkey's ethnically Kurdish Southeastern region, and calling on the government to make peace with Kurdish rebels, was posted online. Meanwhile, more than 2,200 academics in Turkey and more than 2,300 abroad signed the letter (see http://tinyurl.com/z968vqj).

Horizon 2020 consultation
In 2014 the European Commission organized an online consultation *Mathematics and Digital Science* that was followed up by a workshop in Brussels in November that same year and resulted in a report with recommendations for the incorporation of various mathematical areas and methodologies into future programmes within the HORIZON 2020 programme. The EMS participated in both the consultation and the workshop very actively. This year, a similar online open consultation has been started and has received a number of reactions already. The EMS urges its members (both societies and individuals) to take up the challenge and thus give mathematicians better options for applications in future work programmes under HORIZON 2020. The consultation will stay open until 30 April 2016. For further information see http://tinyurl.com/h8n6xt2.

Hermann Weyl Prize
The 2016 *Hermann Weyl Prize* has been awarded to Vasily Pestun of IHES (France) for his ground breaking results in the study of supersymmetric gauge theories, such as his ingenious computation of partition functions that led to the discovery of rich connections between four-dimensional and two-dimensional quantum field theories. The award ceremony will take place during the *International Colloquium on Group Theoretical Methods in Physics* to be held in Rio de Janeiro, Brazil, from 19 to 25 June 2016. For further information see http://icgtmp.blogs.uva.es/.

David Chillingworth
LMS/EMS Correspondent

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Heilbronn Institute for Mathematical Research

The Heilbronn Institute for Mathematical Research has just celebrated its first 10 years in operation. It is a national institute that supports mathematics across the UK. Its members split their time between their own personal research and fundamental mathematical problems suggested by the UK Government Communication Headquarters in Cheltenham.

At any one time the Institute typically has over 40 members, ranging from highly distinguished senior mathematicians to early career Research Fellows; it supports over 25 postdoctoral Research Fellowships.

The Heilbronn Institute is based in Bristol and London. Fellows are currently hosted in seven UK Mathematics Departments, and this number is set to increase. Over the past 10 years over 150 mathematicians have been members, including over 60 Research Fellows. These members have come from more than 20 universities in the UK.

As well as supporting mathematicians through sabbatical secondments and Research Fellowships, the Institute funds a range of conferences, workshops and focused research events. For example, it funds an Annual Distinguished Lecture Series, which in 2016 will be given by Professor Peter Sarnak (IAS, Princeton), and an Annual Conference at which recent speakers include Professors Nalini Anantharaman, Jean-Francois Le Gall, Bryna Kra, Kristin Lauter, Henrik Lenstra, Wendelin Werner and Don Zagier. It also supports many other mathematical events across the UK.

For more information about the work of the Institute see heilbronn.ac.uk.

CHALKDUST

Chalkdust Issue 3 is now available. It includes an interview with Professor Ian Stewart, the legacy of Fibonacci, an article about fractional calculus and much more. If you would like to read your maths-horoscope or find out what the half derivative of a function is, you can read it online for free at www.chalkdust magazine.com, where you can also order a printed copy of the magazine, read a weekly blog and subscribe to a monthly newsletter.

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General Society Meeting & Hardy Lecture 2016

Friday 8 July 2016
JZ Young Lecture Theatre, UCL, Gower Street (nearest tube stations: Euston and Euston Square)

3.30	Opening of the meeting and LMS business, including the announcement of the 2016 Prize winners (open to all)
	Tony Scholl (Cambridge)
	TITLE TBA
4.45	Tea/Coffee
5.15	Jacob Lurie (Harvard) – Hardy Lecture
	Weil's Conjecture for Function Fields

Abstract: *Let q be a positive definite quadratic form with integer coefficients. We say that another such quadratic form q' is in the genus of q if, for every positive integer n, the quadratic forms q and q' differ by a change of variable when reduced modulo n. Up to a change of variables, there are only finitely many quadratic forms in a genus. Moreover, there is a formula (the "mass formula" of Smith-Minkowski-Siegel) which counts the number of quadratic forms within a genus. This mass formula was reformulated by Tamagawa and Weil as a statement about the volume of certain adelic homogeneous spaces for the special orthogonal group SO(n). This led Weil to conjecture an analogous statement for the volumes of homogeneous spaces for other groups, which he verified in a number of cases and has subsequently been proven by Langlands, Lai, and Kottwitz. In this lecture I'll describe joint work with Dennis Gaitsgory which establishes the function field analogue of Weil's conjecture, using techniques inspired by algebraic topology*

6.30	Reception at De Morgan House
7.30	Society Dinner to be held at VENUE TBC

These lectures are aimed at a general mathematical audience. All interested, whether LMS members or not, are most welcome to attend this event. To register for your place at the meeting, please email Elizabeth Fisher (lmsmeetings@lms.ac.uk). If you would like to attend the Society Dinner, please email Elizabeth Fisher (lmsmeetings@lms.ac.uk). The cost to attend the Society Dinner is £35.00 per person (inclusive of wine).

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LMS LIBRARY AT UCL

Registering, Renewing, Visiting

Members of the Society are reminded that they may register as users of the University College London (UCL) Library, where the London Mathematical Society Library is held and which contains a collection of:
• periodicals published by other mathematical societies which are received in exchange for the Society's publications
• copies of books and journals published by the Society
• items acquired by the Society as review copies or gifts

The Society's Library is housed in the UCL Science Library. Members may also use all the material available in the reading rooms and stores of the UCL family of libraries. These privileges include:
• borrowing up to ten items at any one time
• placing up to three concurrent reservations on material already on loan.
• borrowing books by post without service charge (costs for returning the books must be covered by the user)
• access to MathSciNet and specific electronic journals from designated terminals in the Science Library
• use of the Explore access points to search for and view electronic publications and save single copies of articles (no more than one article per journal issue) for your own personal use – you can save articles to standard USB sticks, note that USB sticks containing encrypted software do not work on the Explore access points
• use of photocopying facilities at UCL libraries (charged at the same rate as UCL staff)
• rapid photocopying service by post - Photocopy Request and Copyright Declaration Form

For licensing reasons, use of the Library at UCL does **not** include remote electronic access to journals and articles. To check the listings of electronic journals available to visitors, before your visit to the Library, use Explore (http://sfx.ucl.ac.uk/sfx_local/az/walkin).

To Register/Renew (in person)

Complete the application form (download from www.ucl.ac.uk/library/docs/borrower-form) and bring the following items with you:
• passport-size photograph
• proof of identity e.g. passport, photocard driving licence
• proof of address e.g. utility bill, recent bank statement, valid photocard driving licence
• proof of membership – a letter of confirmation can be obtained from the Society
  – email membership@lms.ac.uk

To Register/Renew (by post)

To register by post, complete the application form (download from www.ucl.ac.uk/library/do–cs/borrowerform) and return it with:
• a passport-size photograph
• proof of membership – a letter of confirmation can be obtained from the Society – email membership@lms.ac.uk

To: Head of Membership, UCL Library Services, University College London, Gower Street, London WC1E 6BT (tel: 020 7679 7953, fax: 020 7679 7373, email: lib-membership@ucl.ac.uk).

When registering by post, library cards will be posted back to the address given on the application form.

Library cards are valid for 12 months from date of issue and will need to be renewed each year.

No charge is made for the initial registration or for renewing expired library cards or cards which are within one calendar month of expiring.

Reminders to renew - to receive reminders to renew by email from the Library at UCL, remember to include an email address on the form when registering and renewing. The UCL Library will send out reminders two weeks before your library card is due to expire. Forgotten cards – if you forget your library card, you will **not** be admitted to any UCL Library. This rule is strictly applied.

Visiting the Library

New: checking seat availability
You can now check online for the availability of seats in the reading rooms and computer cluster at the Science Library: www.ucl.ac.uk/library/sites/science/#current

New: self-guided tour
You can now familiarise yourself with the layout of the Science Library by viewing the self-guided tour online: http://www.ucl.ac.uk/library/docs/floor-plans/science-self-guide.

24 hour opening
The Science Library is open 24 hours for UCL Library card holders and has extended the opening hours of the assistance desk.

Opening hours

	Help Point and Collection Point	Self Service	Reading Rooms
Monday	09:30 – 21:00	Open from 08:45	Open from 08:45
Tuesday	09:30 - 21:00	24 hour opening	24 hour opening
Wednesday	09:30 - 21:00	24 hour opening	24 hour opening
Thursday	09:30 - 21:00	24 hour opening	24 hour opening
Friday	10:00 - 21:00	24 hour opening	24 hour opening
Saturday	11:00 - 18:00	Close at 20.45	Close at 21:00
Sunday	Closed	11:00 - 20:45	11:00 - 21:00 (holders of UCL Library Cards only)

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- During the weekends and evenings, the Library is open principally to offer book loans and to handle related queries. For all other queries, please contact a member of staff during office hours (www.ucl.ac.uk/library/help)

- During the year, the opening hours may change. Please check the Science Library website before travelling (www.ucl.ac.uk/library/sites/science#open)

Visit www.lms.ac.uk/library/lms-library for further information about the Society's Library.

LMS GRANT SCHEMES

Next Closing Date for Research Grant Applications: 15 May 2016

Applications are invited for the following grants:

Conferences (Scheme 1)
Grants of **up to £7,000** are available to provide partial support for conferences held in the United Kingdom. This includes a maximum of £4,000 for principal speakers, £2,000 to support the attendance of research students who are studying at universities in the UK, and £1,000 to support the attendance of participants from Scheme 5 or former Soviet Union countries.

Celebrating new appointments (Scheme 1)
Grants of **up to £600** are available to provide partial support for meetings held in the United Kingdom to celebrate the new appointment of a lecturer at a UK university.

Postgraduate Research Conferences (Scheme 8)
Grants of **up to £4,000** are available to provide partial support for conferences held in the United Kingdom, which are organised by and are for postgraduate research students.

Research in Pairs (Scheme 4)
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. Grants of **up to £600** are available to support a visit for collaborative research either by the grant holder to another institution within the UK, or by a named mathematician from within the UK to the home base of the grant holder.

International Short Visits (Scheme 5)
Grants of **up to £3,000** are available to support a visit for collaborative research by a named mathematician from a country in Africa (or countries where mathematics is in a similar position) to the home base of the grant holder. Grants of **up to £2,000** are available to support a visit for collaborative research by the grant holder to a country in Africa (or countries where mathematics is in a similar position).

For full details of these grant schemes, and to download application forms, please visit the LMS website: www.lms.ac.uk/content/research-grants.
• Applications received by **15 May 2016** will be considered at a meeting in June.
• Applications should be submitted well in advance of the date of the event for which funding is requested.
• Normally grants are not made for events which have already happened or where insufficient time has been allowed for processing of the application.

Queries regarding applications can be addressed to the Grants Administrator Anthony Byrne (0207 927 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.

LMS COUNCIL DIARY
5 February 2016
A personal view

As the new Council Diarist, this entry marks my first contribution to the *LMS Newsletter* in that role. I would like to begin by expressing my sincere thanks on behalf of all Council members to Francis Clarke, who recently stepped down as Diarist, for his excellent service in that regard.

The February meeting of Council marked the first meeting for our new President Simon Tavaré in his role as Chair. The President made some introductory remarks based on his experience observing previous meetings in the role of President-Designate, including an expression of enthusiasm about the

Society's support for young mathematicians. The President updated Council on his activities undertaken on behalf of the Society since the previous meeting; these included a visit to Fudan University in China and a House of Commons launch event for the Council for Mathematical Sciences (CMS).

The Council also heard the First Quarter Financial Review from the Treasurer, who noted a large donation from an individual to the Society as a result of its development work. A few possible uses for these funds had been carefully considered, and at a later stage in the meeting Council agreed to use

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the gift to support Undergraduate Research Bursaries.

According to usual practise, the Council heard several committee reports. The Programme Committee proposed, and Council agreed, to seek to host a 'London Mathematical Society Lecture' as part of future programmes of the International Congress of Mathematicians (ICM). Vice-President Brown updated the Council on Research Policy Committee activities, including efforts to gather data about the lack of funding for mathematical sciences postdoctoral fellowships and about the allocation of funding within institutions for Doctoral Training Programmes (DTPs) in the mathematical sciences. He also noted the completion of a survey about departmental views on the Research Excellence Framework (REF), with data yet to be processed. He also reported that the matter of gender balance of EPSRC fellowships would be raised at the next Strategic Advisory Team (SAT) meeting.

The results of the 2015 elections were noted, and the Scrutineer presented his report and review of these elections. Council also agreed several appointments to various committees, and noted that the Presidential Search Panel would be initiating its search for the next President.

The Council also agreed a list of 54 new members to be elected at the Society meeting later in February.

A final item of note was a proposal to support mathematicians outside of academia, for example retirees, or early career mathematicians who have not yet secured a post; Council agreed that this is an important area of activity and that the idea should be developed further.

Tara Brendle

LMS FUNDING FOR UNDERGRADUATE MATHEMATICAL SOCIETY MEETINGS 2016

In 2016, the LMS Research Meetings Committee has supported one Undergraduate Mathematical Society Meeting: Varsity Event between the Mirzakhani Society (Oxford) and the Emmy Noether Society (Cambridge) (see report on page 22).

Applications for Future Undergraduate Mathematical Society Meetings

The LMS considers requests from Undergraduate Mathematical Societies to host a meeting and offers funding of **up to £500** for either full or partial support for travel and subsistence of a speaker(s), and reasonable costs for catering.

Applications can be made at any time but the deadline for applications in the current financial year is **Friday 1 July 2016**. There is limited funding and applications will be considered on a first-come, first-served basis.

Applicants should contact Elizabeth Fisher (lmsmeetings@lms.ac.uk) for an application form. Applications should be countersigned by the LMS Departmental Rep. For a list of LMS Representatives, visit the website www.lms.ac.uk/membership/lms-represent atives. If your department does not have a LMS Rep, please contact Elizabeth Fisher (lmsmeetings@lms.ac.uk).

LMS-sponsored Undergraduate Mathematical Society Meetings 2014 & 2015

In 2014 and 2015, the LMS supported the following Research Workshops Undergraduate Mathematical Society Meetings:
- *Application of Fluid Dynamics to Atmosphere and the Ocean,* Durham
- *Juggling: Theory and Practice,* St Andrews
- *Mathematics in the World of Gaming,* King's College London

SIR ANDREW WILES AWARDED 2016 ABEL PRIZE

The Norwegian Academy of Science and Letters has awarded the 2016 Abel Prize to Professor Sir Andrew Wiles, University of Oxford, 'for his stunning proof of Fermat's Last Theorem by way of the modularity conjecture for semi-stable elliptic curves, opening a new era in number theory'. Wiles will receive his award from His Royal Highness Crown Prince Haakon at the University of Oslo on 24 May 2016.

Wiles is one of very few mathematicians – if not the only one – whose proof of a theorem has made international headline news. In 1994 he solved Fermat's Last Theorem, which at the time was the most famous, and long-running, unsolved problem in the subject's history.

His proof was not only the high point of his career but also the culmination of a remarkable personal journey that began three decades earlier. Wiles recalls that he was intrigued by the problem that he as a young boy could understand, and yet it had remained unsolved for three hundred years. 'I knew from that moment that I would never let it go', he said. 'I had to solve it'.

The Abel Committee said, 'Few results have as rich a mathematical history and as dramatic a proof as Fermat's Last Theorem'.

Sir Andrew was awarded an LMS Whitehead Prize in 1988 and was elected an Honorary Member of the LMS in 2001.

On behalf of the LMS, and the UK mathematical community more broadly, Professor Simon Tavaré FRS, the President of the LMS, congratulates Sir Andrew on his remarkable achievements that have led to the 2016 Abel Prize.

More information is available at www.abelprize.no/

Institute of mathematics & its applications

LONDON MATHEMATICAL SOCIETY EST. 1865

The David Crighton Lecture

Professor Frank Kelly CBE FRS

Thursday 12 May 2016 at 6.15 p.m. followed by a reception

at The Royal Society, Carlton House Terrace,

London, SW1Y 5AG

Registration will open at 5.45 p.m.

Mathematics and Financial Markets

Abstract: *A substantial proportion of mathematics graduates, at both first degree and doctoral level, enter the financial services sector. This is hardly surprising given the importance of the sector to the economy, and the role of mathematical modelling in the valuation of instruments and the assessment of risk. What is striking is that, with some notable exceptions, few mathematicians have been actively engaged in the design of financial markets. This is undoubtedly a serious challenge with parallels from other large-scale complex networks: to design a distributed system, linking self-interested and intelligent agents, so that the outcome is effective and efficient.*

How would an ideal market operate, to allow liquidity between long-term investors to be provided by short-term traders? In the second part of the talk I outline some preliminary work, joint with Elena Yudovina, on this question. I describe a simplified and analytically tractable model of a limit order book where the dynamics are driven by stochastic fluctuations between supply and demand. The model has a natural interpretation for a highly traded market on short time scales where there is a separation between the time scale of trading, represented in the model, and a longer time scale on which fundamentals change.

There has been considerable discussion recently of the effects of competition between multiple high-frequency traders, and of proposals aimed to slow down markets. A key issue is that traders may compete on the speed with which they can snipe an order rather than compete on price, and a proposed regulatory response is to use frequent batch auctions. Our model is clearly a caricature of a real limit order book, but it does provide insight into various high-frequency trading strategies (for example market-making, sniping and mixtures of these) and the impact on Nash equilibria when a market in continuous time is replaced by frequent batch auctions.

Professor Frank Kelly will be presented with the David Crighton Medal which is awarded biennially, for services both to mathematics and to the mathematical community, by the Institute of Mathematics and its Applications, and the London Mathematical Society.

Admission to the lecture and reception is by ticket only.
For tickets please contact Alison Penry at the IMA, Catherine Richards House, 16 Nelson Street, Southend-on-Sea, SS1 1EF or email alison.penry@ima.org.uk by 24 April 2016. Tickets are free of charge and will be allocated on a first come, first served basis.
Please confirm whether you wish to attend the lecture and reception, or the lecture only.

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CECIL KING TRAVEL SCHOLARSHIP

The London Mathematical Society annually awards a £5,000 Cecil King Travel Scholarship in Mathematics, to a young mathematician of outstanding promise. The Scholarship is awarded to support a period of study or research abroad, typically for a period of three months. Study or research in all areas of mathematics is eligible for the award.

The award is competitive and based on a written proposal describing the intended programme of study or research abroad, and the benefits to be gained from such a visit. A shortlist of applicants will be selected for an interview during which they will be expected to make a short presentation on their proposal.

Applicants must be nationals of the UK or the Republic of Ireland, either registered for or having completed a doctoral degree within 12 months of the closing date.

Applications should be made using the form available on the Society's website (**www.lms.ac.uk/prizes/cecil-king-travel-scholarship**) or by contacting education@lms.ac.uk. The closing date for applications is **Monday 6 June 2016**. It is expected that interviews will take place in London in late June or early July.

The Cecil King Travel Scholarship was established in 2001 by the Cecil King Memorial Fund. The award is made by the Council of the London Mathematical Society on the recommendation of the Cecil King Prize Committee, nominated by the Society's Research Meetings Committee.

The London Mathematical Society is a registered charity for the promotion of mathematical knowledge.

UNIVERSITY OF CAMBRIDGE

**UNIVERSITY OF CAMBRIDGE
FACULTY OF MATHEMATICS**

ADAMS PRIZE

Statistical Analysis of Big Data

The University of Cambridge has announced the subject for one if its oldest and most prestigious prizes. The Adams Prize is named after the mathematician John Couch Adams and was endowed by members of St John's College. It commemorates Adams's role in the discovery of the planet Neptune, through calculation of the discrepancies in the orbit of Uranus.

The Chairman of the Adjudicators for the Adams Prize invites applications for the 2016-17 prize which will be awarded this year for achievements in the field of Statistical Analysis of Big Data.

The prize is open to any person who, on 31 October 2016, will hold an appointment in the UK, either in a university or in some other institution; and who is under 40 (in exceptional circumstances the Adjudicators may relax this age limit). The value of the prize is expected to be approximately £15,000, of which one third is awarded to the prize-winner on announcement of the prize, one third is provided to the prize-winner's institution (for research expenses of the prize-winner) and one third is awarded to the prize-winner on acceptance for publication in an internationally recognised journal of a substantial (normally at least 25 printed pages) original article, of which the prize-winner is an author, surveying a significant part of the winner's field.

Applications, comprising a CV, a list of publications, the body of work (published or unpublished) to be considered, and a brief non-technical summary of the most significant new results of this work (designed for mathematicians not working in the subject area) should be sent to the Secretary of the Adams Prize Adjudicators via email to adamsprize@maths.cam.ac.uk.

The deadline for receipt of applications is 31 October 2016.

FROM SYMBOLIC DYNAMICS TO APPROXIMATION METHODS AT LSD & LAW 2016

Report

A part of the annual two-day *London Stringology Day & London Algorithms Workshop* (LSD & LAW 2016) was dedicated this year to the LMS sponsored research meeting *From Symbolic Dynamics to Approximation Methods* (SDAM). The meeting was intercalated with the workshop's schedule, taking place on both Thursday 4 and Friday 5 February 2016.

Its programme included three invited talks and other short informal talks and attracted all participants of the LSD & LAW 2016 meeting. The number of researchers that attended the workshop this year was over 60 coming from more than 15 countries. The ratio of female researchers among the participants was of about 25%, five of them presenting their work.

The SDAM meeting had as its focus the space discretization of general dynamic systems which complemented the interests of the research community present at LSD & LAW 2016.

The invited talk given by Marie-Pierre Béal (University of Marne-la-Vallée, France) discussed shifts of sequences which are sets of bi-infinite sequences of symbols defined by a given set of forbidden patterns. The speaker presented how rational expressions may be obtained for the zeta functions of these classes of shifts of sequences and showed formulas of the zeta functions for some shifts defined by non-regular constraints (zeta functions

Marie-Pierre Béal talks about an example of Zeta functions for sub-shifts

Fatima Vayani gives an example of q-grams present in a DNA sequence

Ritu Kundu talks about the background of the Superbubble problem

Tiziana di Matteo gives examples of different levels of mathematical models considered on network filtering for big data

have been computed for Dyck shifts, Markov-Dyck shifts, and sofic-Dyck shifts). Some of the presented applications of symbolic dynamics referred to coding for constrained channels.

Filippo Mignosi (University of L'Aquila, Italy) explored in his invited talk Sturmian Words, or "Sturmian Trajectories", which are a classical topic of Symbolic Dynamics. The talk consisted of both old and recent "semantic" relationships between combinatorial properties of Sturmian words and classical approximation results.

Michael Soltys (California State University Channel Islands, USA) proposed in his invited talk several open problems. Among these, a relatively recent result shows that Square Shuffle is NP-complete. This is one of the syntactically simplest NP-complete problems. However, this result was proven for an alphabet of six symbols and the question remains open for non-unary alphabets of no more than five elements. He also discussed an open problem related to repetitions in strings over alphabet lists and an open problem related to the minimality of a universal alphabet for these lists to fulfil certain intersection properties.

Several shorter contributing talks discussed various problems falling into the intersection between symbolic dynamics, combinatorics and algorithms. Gabriele Fici (University of Palermo, Italy) presented some new results related to algorithms on the previously mentioned forbidden words, which have direct applications in bioinformatics (one of the traditional focus areas of the LSD & LAW meetings). The talk of Tiziana Di Matteo, King's College London, presented a mathematical modeling of network filters with applications in the evaluation of stock markets, an area representative for the "big data challenge".

The SDAM meeting was supported by an LMS Conference grant and the Department of Informatics at King's College London, which also provided additional support for the overall LSD & LAW 2016 workshop.

The next LSD & LAW meeting will be held at King's College London in February 2017 (exact dates to be announced soon).

<div align="right">

Maxime Crochemore
Robert Mercas
King's College London

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MIRZAKHANI SOCIETY
Report

The Mirzakhani Society of the University of Oxford was established in October 2014 to promote the welfare of those identifying as female or non-binary studying mathematics. The Society is named after Maryam Mirzakhani, the first woman to win the Fields Medal.

On Saturday 27 February 2016, we held a Varsity event with the Emmy Noether Society of the University of Cambridge. It was a great experience where we were able to discuss the issues surrounding gender equality in mathematics from a perspective stretching beyond our own universities. This event involved three speakers; the first was Anne Davis, a Professor of Mathematical Physics and the University Gender Equality Champion for STEMM subjects at Cambridge; the second speaker was Perla Sousi, a Lecturer in the Statistics Laboratory at Cambridge; and the third speaker was Christie Marr, Deputy Director of the Isaac Newton Institute. We also were

Members of the Mirzakhani Society with the President of the Emmy Noether Society

able to explore Cambridge. The LMS funding was used to cater this event for our members.

We'd like to take this opportunity to thank the LMS for the funding; it was much appreciated.

Helen Ryan (President)
Rebecca Lowiss (Treasurer)
Emma Beer (Secretary)

WHY BE NONCOMMUTATIVE?
Report

The conference *Why be noncommutative?* was held on 8 February 2016, at Imperial College London, funded by an LMS Conference grant celebrating new appointments, as well as by Imperial College London. The conference was attended by over 50 participants, including at least 30 PhD students, some travelling from as far as Edinburgh (and receiving travel support from the conference). It was geared towards PhD students and postdocs, introducing aspects of noncommutative geometry from the point of view of algebra and representation theory. Many participants

gave positive feedback.

The first talk was by the organizer, Dr Travis Schedler (Imperial College London), entitled *Poisson and noncommutative geometry*, explaining the idea of studying noncommutative algebras as functions on a noncommutative space, the Kontsevich-Rosenberg approach via representation varieties, and how Poisson geometry and Hamiltonian flow enter via deformation theory, ending with a discussion of deformation quantization and Kontsevich's formality theorem. The second talk was by Professor Iain Gordon (University of

Edinburgh), entitled *Why be noncommutative with algebraic combinatorics?*, which began with the classic theorem of Shepherd-Todd and Chevalley that quotients of linear spaces by groups are smooth if and only if the group is generated by complex reflections (and their classification), and then proceeded to explain the intricate combinatorics arising when taking a quotient of two copies of the reflection representation, involving conjectures and theorems of Haiman, Gordon, and others. The third and final talk was by Toby Stafford (University of Manchester), entitled *Noncommutative projective algebraic geometry,* and focussed on the problems of classification of noncommutative projective spaces of low dimension, beginning with classic results of Artin, Tate, and Van den

Bergh for curves and surfaces, leading up to birational classification of noncommutative surfaces, including Artin's conjecture and results of Rogalski, Sierra, and Stafford on subalgebras of the Skylanin algebra. All talks presented open questions in the field and led to lively discussions with the audience that continued into two breaks for tea and coffee as well as lunch.

The conference dinner, attended by 30 participants (and subsidized for PhD students), was held at Olives Restaurant in Kensington, a short walk from the conference, and was full of interesting discussions which continued afterwards until late at a nearby bar.

Travis Schedler
Imperial College London

INTEGRABLE SYSTEMS IN NEWCASTLE
Report

The third occurrence of the workshop *Integrable Systems in Newcastle* took place from 5 to 6 February 2016 at the University of Northumbria at Newcastle. The meeting was hosted by

Attendees at the *Integrable Systems in Newcastle* workshop

the Nonlinear Waves and Integrable Systems group and focused on investigating new connections between integrability and physics.

The success of the event is due in great part to the excellent contributions of the speakers Martina Balagović (Newcastle), Pierre-Philippe Dechant (York), Gennady El (Loughborough), Katrin Leschke (Leicester), Davide Proment (East Anglia), Noel Smyth (Edinburgh), and Iain Stewart (Strathclyde). The topics ranged from liquid crystals and rogue waves to new constructions in Lie algebras and surface theory. A workshop dinner was held on the Friday evening and was well attended. We would like to thank all participants, with a special mention to the research students for further stimulating the discussions during the coffee breaks with very interesting posters.

It is a great pleasure to acknowledge the generous support from the London Mathematical Society and the Department of Mathematics and Information Sciences which makes this series possible.

Benoit Huard
Northumbria University

VISIT OF DR JYUN-AO LIN

Dr Jyun-Ao Lin (Institute of Mathematics, Academia Sinica) is visiting Vanessa Miemietz at the University of East Anglia from 2 to 30 April 2016. Dr Lin works on geometric representation theory, especially on the Hall algebras of curves. His visit will be devoted to the study of the categorification of the spherical Hall algebra of a projective line defined over a finite field. The structure of the associated KLR algebra relies on the computation of extensions between the Eisenstein sheaves and will provide another approach to the representation theory of quantum affine algebras as well as the geometric Langlands program.

He will give a talk at the pure mathematics seminar at UEA on 25 April at 3 pm on *The spherical Hall algebra of a weighted projective curve*, in which he will also present some recent applications of this work.

For further information contact Vanessa Miemietz (byr09xgu@uea.ac.uk). This visit is supported by an LMS scheme 5 grant.

VISIT OF YONG HOU

Dr Yong Hou (Institute for Advanced Study, Princeton) will be visiting the UK between 25 May and 10 June 2016. Dr Hou works on hyperbolic 3-manifolds and his recent work has focused on properties of the Hausdorff dimension of the limit set of Schottky groups acting on hyperbolic 3-space. Details of Dr Hou's talks during his visit are:

- Friday 27 May, University of Southampton
  Measure decompositions on Cayley graph of free group
  (contact Jim Anderson:
  j.w.anderson@soton.ac.uk)
- Thursday 2 June, University of Warwick
  Rigidity of Kleinian groups
  (contact Saul Schleimer:
  s.schleimer@warwick.ac.uk)
- Monday 6 June, Oxford University
  Hausdorff dimension and complexity of Kleinian groups
  (contact Marc Lackenby:
  lackenby@maths.ox.ac.uk)

Further details may be obtained from Jim Anderson (j.w.anderson@soton.ac.uk). The visit is supported by an LMS Scheme 2 grant.

VISIT OF CHRISTIAN LOMP

Professor Christian Lomp (University of Porto) will be visiting the UK between 4 May and 11 June 2016. Professor Lomp works on Hopf algebras, quantum groups and ring theory. Details of Professor Lomp's talks during his visit are:

- Tuesday 17 May, Swansea University
  Actions of semisimple Hopf algebras on semiprime rings
  (contact Tomasz Brzezinski:
  t.brzezinski@swansea.ac.uk)

- Wednesday 1 June, Queen Mary University of London
  Integral Calculus on Quantum Exterior Algebras
  (contact Shahn Majid: s.majid@qmul.ac.uk)
- Wednesday 8 June, University of Glasgow
  Actions of semisimple Hopf algebras on iterated Ore extensions
  (contact Gwyn Bellamy: gwyn.bellamy@glasgow.ac.uk)

Further details of these arrangements may be obtained from Tomasz Brzezinski (t.brzezinski@swansea.ac.uk). The visit is supported by an LMS Scheme 2 grant.

VISIT OF DANA SCOTT

Professor Scott's visit to the UK, from 7 to 28 May 2016, was announced in the March issue of the *LMS Newsletter*. Below are provisional titles of lectures/seminars he will give, together with email addresses of local contacts who will supply further information on request, closer to the date.

Oxford: 7-11 May
Philosophy of Mathematics Seminar, 9 May at 16.30
Does Mathematics Need a Foundation?
Computer Science Seminar, 10 May at 14.00
Stochastic Lambda Calculus
Logic Seminar, 11 May at 11.00
Can Modalities Save Naive Set Theory?
Contact: Dan Isaacson
(daniel.isaacson@philosophy.ox.ac.uk)

Birmingham: 11-15 May
Seminar title and date to be announced.
Contact: Martin Escardo
(m.escardo@cs.bham.ac.uk)

Leeds: 15-19 May
Math Logic Seminar, 17 May at 16.00
Lambda Calculus and Type Theory
The Löb Lecture, 18 May at 16.30
Does Mathematics Need a Foundation?
Contact: Stan Wainer
(s.s.wainer@leeds.ac.uk)

Cambridge: 19-24 May
The Mordell Lecture, 20 May at 17.00
Does Mathematics Need a Foundation?
PSSL Workshop 21-22 May
Stochastic Lambda Calculus
Contact: Peter Johnstone
(ptj@dpmms.cam.ac.uk)

London: 24-29 May
UCL, 25 or 27 May
Lambda Calculus and Type Theory
Imperial, 26 May
Stochastic Lambda Calculus
BCS lecture 26 May evening
Lambda Calculus: Then and Now
Queen Mary, 25 or 27 May
Title: To be announced
Contacts: Alexandra Silva
(alexandra.silva@gmail.com)
Ivan Tomasic (i.tomasic@qmul.ac.uk)

VISIT OF TOBIAS KUNA

25

Dr Tobias Kuna (University of Reading) will be visiting Dr Dimitrios Tsagkarogiannis at the University of Sussex during the week 16 to 20 May 2016. This visit, together with a previous one (14 to 18 March) will be devoted to the study of the convergence properties and remainder estimation of perturbative expansions for interacting particle systems. The convergence analysis requires the identification of massive cancelations based on a deep understanding of the underlying combinatorial and graph theoretical structure. These singular perturbation expansions allow a fine control of the influence of smaller on larger scales.

During his visit, on Tuesday 17 May, Dr Tobias Kuna will also give a talk on *Controlled cluster expansion, graphical representation and convergence* in which he will also present the recent developments in this work.

For further information contact Dr Dimitrios Tsagkarogiannis (D.Tsagkarogiannis@sussex.ac.uk). The visit is supported by an LMS Scheme 4 Research in Pairs grant.

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LMS Women in Maths Days 2016
Cambridge and Edinburgh

Friday 15 April
Microsoft Research, 21 Station Road, Cambridge CB1 2FB

Register by contacting womeninmaths@lms.ac.uk (free for students, £5 for others)

This event will focus on mathematics in industry and will include:
- Talks from mathematicians working in and with industry
- Opportunities for early career researchers to give talks
- Poster competition
- Panel discussions on careers in mathematics
- Networking opportunities

For full details of the day please visit lms.ac.uk/womeninmaths

Any postgraduates, postdocs or research assistants interested in giving a talk or presenting a poster should contact Eugenie Hunsicker (E.Hunsicker@lboro.ac.uk).

Friday 22 April
International Centre for Mathematical Sciences, 15 South College Street, Edinburgh EH8 9AA

Register by visiting icms.org.uk (free for students, £5 for others)

This event will focus on mathematics in both academia and industry and will include:
- Talks from mathematicians working in academia and industry
- Opportunities for early career researchers to give talks
- Poster competition
- Panel discussions on careers in mathematics
- Networking opportunities

For full details of the day please visit lms.ac.uk/womeninmaths

Any postgraduates, postdocs or research assistants interested in giving a talk or presenting a poster should contact Tara Brendle (tara.brendle@glasgow.ac.uk).

Limited funds are available for both days to help students with travel costs. Please email womeninmaths@ ac.uk for further details.

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LMS HARDY LECTURE TOUR 2016

G.H. Hardy, LMS President 1926–1928 and 1939–1941
Photo Courtesy of Master and Fellows of Trinity College
Cambridge

Jacob Lurie (Harvard) Hardy Lecturer 2016

The 2016 LMS Hardy Fellow is *Professor Jacob Lurie* (Harvard).

The Hardy Lectureship was founded in 1967 in memory of G.H. Hardy in recognition of outstanding contribution to both mathematics and to the Society. The Hardy Lectureship is a lecture tour of the UK by a mathematician with a high reputation in research.

Jacob Lurie will visit the UK in June and July 2016 and he will give talks at:

Oxford
20 June
Organiser: Ulrike Tillmann

Southampton
21/22 June
Organiser: Jelena Grbic

Glasgow
27 June
Organiser: Andy Baker

Aberdeen
28 June
Organiser: Assaf Libman

Leicester
30 June/1 July
Organiser: Frank Neumann

Sheffield
4/5 July
Organiser: John Greenlees

Cambridge
6/7 July
Organiser: Julius Ross

Hardy Lecture, London

Weil's Conjecture for Function Fields
8 July at 3.30 pm, London
Organiser: London Mathematical Society

For further information on attending each lecture, please contact the local organisers.
For general enquiries about the Hardy Lectures, please contact Elizabeth Fisher (lmsmeetings@lms.ac.uk).

LONDON MATHEMATICAL SOCIETY
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GRESHAM COLLEGE
Founded 1597

THE LONDON MATHEMATICAL SOCIETY
JOINTLY WITH GRESHAM COLLEGE

Tuesday, 24 May 2016

6:00pm at The Museum of London

Mathematics, Measurement and Money

Professor Norman Biggs

London School of Economics

Throughout its brief history, mathematics has been closely linked with measurement and money. In the ancient settlements the rules of arithmetic and geometry were used to solve problems about the allocation of food and resources. When life became more complex, the use of coined money led to computational problems that required good algorithms for their solution.

Nowadays we rely on mathematics for security, and the links between information and money have become blurred. Can mathematics keep us safe?

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020 7831 0575 enquiries@gresham.ac.uk www.gresham.ac.uk

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Combinatorics and Operators in Quantum Information Theory

LMS Research School
Queen's University, Belfast
5-9 September 2016
Organisers: I. G. Todorov (QUB) and S. Severini (UCL)

Course outline
In the past decade, progress on zero-error quantum information has not only strengthened the existing links with graph theory, but has also uncovered new and unexpected connections with operator algebras and optimisation. This has led to the formation of a new area on the crossroad of quantum computing, combinatorics, operator theory and mathematical programming. The purpose of the School is to introduce PhD students and young researchers to both its methods and problems, discussing topics such as zero-error capacities, graph entropy, quantum graph parameters, games for quantum players, quantum correlations, conic optimisation and communication complexity.

The three main lecture courses are:

- *Graphs and information theory* (**Andreas Winter**, Barcelona/Bristol)
- *Non-commutative order in quantum games* (**Vern Paulsen,** Waterloo)
- *Optimisation methods in quantum information theory* (**Monique Laurent**, Amsterdam/Tilburg and **Jop Briët**, Amsterdam)

These lecture courses will be supplemented by tutorial sessions.
For further information please visit: http://www.qciao.org

Apply by Friday 27 May 2016 using the registration form available at:
https://www.surveymonkey.co.uk/r/RS-23ApplicationForm

Research students, post-docs and those working in industry are invited to apply.
Numbers will be limited and those interested are advised to make an early application.

Registration Fees: Graduate Students(£150); Early Career Researchers (£250)

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SCOTTISH PARTIAL DIFFERENTIAL EQUATIONS COLLOQUIUM

The fourth *Scottish Partial Differential Equations Colloquium* (4th SPDEC 2016) will be held at the University of Dundee from 9 to 10 June 2016. The aim of this meeting is to bring together researchers whose work features PDE's and their analysis, to provide a platform for early career researchers to exhibit their recent work and research interests, as well as to create an opportunity to discuss in an informal setting with internationally leading researchers. Plenary speakers are:

* John Ball (Oxford)
* Willi Jäger (Heidelberg)
* Charalambos Makridakis (Sussex)
* Barbara Niethammer (Bonn)

The organisers of 4th SPDEC are Irene Kyza and Mariya Ptashnyk. For more information visit the website at www.maths.dundee.ac.uk/spdec2016/.

The Colloquium is supported by an LMS Conference grant, the Edinburgh Mathematical Society Research Support Fund, the Glasgow Mathematical Journal Learning and Research Support Fund, and the University of Dundee.

COMBINATORICS AT OXFORD

A one-day meeting in Combinatorics will be held in Oxford on Wednesday 1 June 2016. The meeting will take place at the Mathematical Institute, with talks starting at 11.00 am and coffee available beforehand from 10.30 am.

This year's speakers are Leslie Goldberg (Oxford), Penny Haxell (Waterloo), Mihyung Kang (Graz), János Pach (Lausanne) and Gábor Tardos (Budapest).

Anyone interested is welcome to attend. Some funds may be available to contribute to the expenses of research students who wish to attend the meeting. Further details can be obtained from the web page, which can be found at http://people.maths.ox.ac.uk/scott/Pages/one-day_meeting.htm.

The meeting is supported by an LMS Conference grant and the British Combinatorial Committee.

COMPUTATIONAL AND ANALYTIC PROBLEMS IN SPECTRAL THEORY

A conference on *Computational and Analytic Problems in Spectral Theory* will take place at Cardiff University from 6 to 9 June 2016. The topics include spectral theory of differential operators, inverse problems, block operator matrices, periodic and quasiperiodic differential operators, quantum graphs and networks, modern sampling methods and computations, and numerical analysis.

The organisers are B.M. Brown (Cardiff) and I. Wood (Kent). Further information, including registration and contact details, can be found on the website at www.cs.cf.ac.uk/spectral.

There is some financial support available for UK based research students. The meeting is supported by an LMS Conference grant and the Cardiff School of Computer Science and Informatics.

QUANTUM PHYSICS AND LOGIC

The 13th international conference on *Quantum Physics and Logic* (QPL) will be hosted by the University of Strathclyde in Glasgow between Monday 6 and Friday 10 June 2016. QPL is a conference that brings together researchers working on mathematical foundations of quantum physics, quantum computing, and related areas, with a focus on structural perspectives and the use of logical tools, ordered algebraic and category-theoretic structures, formal languages, semantical methods, and other computer science techniques applied to the study of physical behaviour in general.

Invited lectures will be given by:
- Elham Kashefi (University of Edinburgh)
- Tom Leinster (University of Edinburgh)
- Krysta M. Svore (Microsoft Research)
- Stephanie Wehner (TU Delft)

Additionally, tutorial lectures will be given by:
- Kohei Kishida (University of Oxford)
  Sheaves and contextuality
- Aleks Kissinger
  (Radboud University Nijmegen)
  Process theories and graphical languages
- Conor McBride (University of Strathclyde)
  Logic and functional programming
- Daniel Oi (University of Strathclyde)
  Quantum foundations and Bell experiments
- Ognyan Oreshkov (University Libre de Bruxelles)
  Causality in quantum theory
- Peter Selinger (Dalhousie University)
  Quantum programming languages

On Saturday 11 June, there will be a co-located workshop on *Semantic Spaces* at the Intersection of NLP, Physics, and Cognitive Science. Invited speakers are Hans Briegel (University of Innsbruck), Peter Gardenfors (University of Lund) and Dominic Widdows (Microsoft Research).

For registration and more information, see http://qpl2016.cis.strath.ac.uk. The conference is partially funded by an LMS Conference grant to support attendance by research students. See the website about how to apply for support.

RANDOM INTERACTING SYSTEMS

The school and workshop on *Random Interacting Systems* will take place from 19 to 24 June 2016 in Bath, with focus on recent developments on random interacting systems, including (but not restricted to) interacting and self-interacting particle systems, random growth processes, percolation, spin systems, random walks and other stochastic processes in random environments, random and evolving graphs, random interlacements,

and random polymers. The meeting will comprise the following two mini-courses:
- Michael Damron (Georgia Institute of Technology)
  Geodesics in first-passage percolation
- Ron Peled (Tel Aviv University)
  The spin and loop O(n) models

and invited talks by the following speakers (*to be confirmed):
- Krzysztof Burdzy (University of Washington)
- Manuel Cabezas (PUC Chile)
- Elisabetta Candellero (University of Warwick)
- Pietro Caputo (Universitŕ Roma Tre)
- Shirshendu Ganguly* (University of Washington)
- Jack Hanson (City College of New York)
- Dmitry Ioffe (Technion)
- Elena Kosygina (Baruch College, CUNY)
- Fabio Martinelli (Universitŕ Roma Tre)
- Allan Sly* (UC Berkeley)
- Yinon Spinka (Tel Aviv University)
- Alain-Sol Sznitman (ETH Zürich)
- Vincent Tassion (Université Genčve)
- Bálint Tóth (Bristol & TU Budapest)
- Daniel Ueltschi (University of Warwick)

There is a £70 registration fee, and some funding is available to contribute to local expenses of some participants, with preference given to PhD students, post-docs and young researchers. There will be slots for a small number of contributed talks. For more information, including how to register, visit http://people.bath.ac.uk/ ados20/ris2016/.

The meeting is supported by an LMS Conference grant, the Marie Curie Actions, Prob-L@B and University of Bath.

BSDES, SPDES AND THEIR APPLICATIONS

The University of Edinburgh will host from 3 to 7 July 2017 the international workshop on Backward Stochastic Differential Equations (BSDE), Stochastic Partial Differential Equations (SPDE) and their applications. The meeting provides a platform for researchers to showcase state-of-the-art

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developments and to identify and explore converging research directions within Stochastic Analysis, Numerical Approximations and applications in Finance and Physics. The confirmed speakers include:

- Emmanuel Gobet, École Polytechnique)
- István Gyöngy (University of Edinburgh)
- Peter Imkeller (Humboldt University)
- Monique Jeanblanc (University of Evry)
- Nicolai V. Krylov (University of Minnesota)
- Jin Ma (University of Southern California)
- Annie Millet (University of Jussieu)
- Etienne Pardoux (University of Marseille)
- Michael Röckner (Bielefeld University)
- Marta Sanz-Sole (University of Barcelona)
- Nizar Touzi (École Polytechnique)
- Shige Peng (Shandong University)

The meeting offers an ample opportunity for participants to interact with world leaders in these fields and to generate new ideas and reinforce existing collaborations.

The meeting is being organized by Gonçalo dos Reis (Edinburgh), Lukasz Szpruch (Edinburgh), Samuel Cohen (Oxford), Dan Crisan (Imperial College), Michela Ottobre (Heriot-Watt) and Anke Wiese (Heriot-Watt).

There is a grant to support young researchers, more information on the website. Participants should register at this website or, in case of difficulty, email the organisers at BSDE.SPDE.2017@gmail.com. Find out more at www.ed.ac.uk/maths/bsde-spde-2017.

The meeting is supported by the International Centre for Mathematical Sciences (ICMS), the University of Edinburgh, the Heriot-Watt University and the London Mathematical Society (LMS Conference grant).

GROUPS ST ANDREWS 2017

Groups St Andrews 2017 will be held in Birmingham from Saturday 5 to Sunday 13 August 2017. The talks will take place from 6 to 12 August inclusive.

Main Speakers:
- Michael Aschbacher (California Institute

of Technology)
- Radha Kessar (City University, London)
- Pierre-Emmanuel Caprace (Universite Catholique de Louvain)
- Gunter Malle (TU Kaiserslautern)

Plenary Speakers:
- Tim Burness (University of Bristol)
- Vincent Guirardel (Universite de Rennes 1)
- Harald Helfgott (University of Gottingen)
- Andrei Jaikin-Zapirain (Universidad Autonoma de Madrid)
- Donna Testerman (École Polytechnique Federale de Lausanne)

The conference website is available at: www.groupsstandrews.org/2017/index. shtml. The organisers encourage those interested in attending the conference to register on the website to receive further updates on the conference. Conference organisers are Colin Campbell, Chris Parker, Martyn Quick, Edmund Robertson and Colva Roney-Dougal.

REPRESENTATION THEORY OF ALGEBRAIC GROUPS
In Honour of Stephen Donkin

A conference on *Representation Theory of Algebraic Groups* in honour of Stephen Donkin will be held at King's Manor at the University of York from 13 to 15 July 2016. Professor Donkin has been a leading light in the world of algebra for many years; his huge contribution to representation theory in particular is evidenced by the distinguished list of speakers at the conference. The meeting will offer participants a fantastic opportunity to reflect on the development of the subject and to look ahead to new problems and new ideas.

A list of speakers and further information is available at www.math.unipd.it/~taylor/RAGS/. Here participants can also find a link to the registration form. There is a £30 registration fee.

The meeting is supported by an LMS Conference grant, the Heilbronn Institute and

the Royal Commission for the Exhibition 1851. The LMS funding also provides limited support for UK PhD students. Contact the organisers at haralampos.geranios@york.ac.uk for more information.

ECSTATIC 2

Following the great success of last year, there will be a second edition of ECSTATIC (Early Career Stage Topologists at Imperial College). This is a two-day workshop aimed at young researchers (ie PhD students and postdocs) interested in topology. As the name suggests, the workshop will be at Imperial College London, from Monday 13 to Tuesday 14 June 2016. The two invited speakers are:

• András Juhász (Oxford)
• Sarah Whitehouse (Sheffield)

The main aim of the workshop is to encourage young researchers to give talks themselves on their area of research. Some funding is available for travel and accommodation. For further details visit the website at http://wwwf.imperial.ac.uk/~th2109/ecstatic/.

The conference is supported by an LMS Scheme 8 Postgraduate Research Conference grant, an IMA small grant, TCC Oxford, and Imperial College London.

POSTGRADUATE GROUP THEORY CONFERENCE 2016

The *18th Postgraduate Group Theory Conference* (PGTC) will be held at Imperial College London from Tuesday 28 June to Friday 1 July 2016. The PGTC is an annual student-organised conference which aims to bring together postgraduates working in mathematics and who have an interest in group theory or related areas. The plenary talks in the opening and closing of the conference will be given by:

• Tim Burness (University of Bristol)

• Rowena Paget (University of Kent)

The conference will consist mainly of talks by participants, where the environment is intended to be relaxed and stimulating. It will be a great opportunity to meet and exchange ideas with other students from around the UK and abroad.

Registration and more information is available at www.imperial.ac.uk/pgtc-2016/. For any queries contact the organizers at pgtc2016@imperial.ac.uk. The conference is supported by an LMS Scheme 8 Postgraduate Research Conference grant, the Heilbronn Institute for Mathematical Research, the TCC and Department of Mathematics, Imperial College London.

MODELLING, ANALYSIS AND SIMULATION

A European Summer School on *Modelling, Analysis and Simulation: Crime and Image Processing* will be held at the Mathematical Institute, Oxford, from 4 to 8 July 2016. The focus is on the mathematical topics of crime modelling and image processing, which currently attract a lot of attention but are rarely taught together. It combines a traditional research school that introduces the participants to mathematical topics, theory and techniques of current interest with a typical modelling week, where the participants apply these techniques to specific real-world problems during several days of hands-on group work. Two types of techniques will be taught for each topic, one based on partial differential equations (PDEs) and the other on a discrete approach such as networks. The lecturers are:

• Andrea Bertozzi (UCLA)
• Mason Porter (Oxford)
• Gabriel Peyré (Paris)
• Carola Schönlieb (Cambridge)

The organisers are Andreas Münch, Jared Tanner, Gitta Kutyniok and Barbara Wagner. For more information visit the website at http://tinyurl.com/zrge5vu. The event is supported by the EMS and the Mathematical Institute.

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IINII Isaac Newton Institute
for Mathematical Sciences

BAYESIAN METHODS FOR NETWORKS
25 - 27 July 2016
in association with the Isaac Newton Institute programme
Theoretical Foundations for Statistical Network Analysis
(11 July – 21 December 2016)

Bayesian models of networks and of relational data have a long history in statistics and machine learning. The Bayesian approach provides a natural framework to construct statistical network models from structured parametric or nonparametric probabilistic models, and infer its parameters.

The purpose of this workshop is to bring together experts on topics such as Bayesian inference of network parameters, exchangeable models of networks and relational data, latent variable models of user preferences, and other aspects of this diverse field.

Further information available from the website
www.newton.ac.uk/event/snaw05.

Closing date for receipt of applications 2 May 2016

GRAPH LIMITS AND STATISTICS
11 – 15 July 2016
in association with the Isaac Newton Institute programme
Theoretical Foundations for Statistical Network Analysis
(11 July – 21 December 2016)

The opening workshop will be focused on merging ideas from combinatorics, probability and statistical theory with methodology, starting from the notion of graph limits and nonparametric statistical models. This will be the means to:

i. identify the methodological and theoretical challenges in establishing the foundations of networks;
ii. highlight the state of the art in relevant branches of mathematics, including in-depth talks and overview presentations in the topics.

Further information available from the website
www.newton.ac.uk/event/snaw01.

Closing date for receipt of applications 11 April 2016

Isaac Newton Institute
for Mathematical Sciences

DATA LINKAGE AND ANONYMISATION: SETTING THE AGENDA

5 – 8 July 2016

in association with the Isaac Newton Institute programme
Data Linkage and Anonymisation
(4 July – 21 December 2016)

The opening workshop sets the agenda for the *Data Linkage and Anonymisation* programme. It will bring together a diverse range of participants, including mathematical scientists from statistics and computer science as well as researchers and data users from other disciplines and domains of application. Viewing data linkage and anonymisation as fields of methodological research in the mathematical sciences, the objectives of the workshop are:

i. to introduce the programme topics to participants with varied degrees of familiarity with these fields, including induction of junior researchers, and promotion of communication between participants working in different methodological/ disciplinary traditions;

ii. to identify key challenges which these research fields address; to map out and discuss recent developments and research frontiers; to clarify connections between different areas of research;

iii. to activate participants to identify common interests with a view to initiating further discussion and to potential collaboration and to develop a future timetable of events to facilitate collaboration.

At the end of the workshop, participants will be able to identify other participants with common interests, organise themselves into informal working groups and collaborate on research activities, seminars, etc. as the programme continues.

Further information available from the website
www.newton.ac.uk/event/dlaw01

Closing date for receipt of applications 14 April 2016

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LONDON MATHEMATICAL SOCIETY EST. 1865

Northern Regional Meeting

The University of Manchester
23 June 2016

12.50 pm - Opening

1.00 pm - Plenary speaker 1: Professor Sanju Velani (The University of York)

2.00 pm - coffee break

2.30 pm - Plenary speaker 2: Professor Julien Barral (Paris 13)

3.30 pm - minibreak

3.45 pm - Public lecture: Henna Koivusalo (The University of York)

4.45 pm - Wine reception (Alan Turing Building)

7.00 pm - Dinner at EastZeast

These lectures are aimed at a general mathematical audience. All interested, whether LMS members or not, are most welcome to attend this event.

For further details and to register and to reserve a place at the dinner, please visit http://personalpages.manchester.ac.uk/staff/jonathan.fraser/LMSregionalmeeting16.html

The meeting forms part of a workshop on *Dynamical systems, ergodic theory and applications* from 23-24 June 2016. There will talks on Thursday morning and all day Friday with plenary lectures from Ian Melbourne and Dejun Feng.

For further details visit:
http://personalpages.manchester.ac.uk/staff/jonathan.fraser/LMSregionalmeeting16.html
or contact the organisers. (Jonathan Fraser; jon.fraser32@gmail.com)

There are funds available to contribute in part to the expenses of members of the Society or research students to attend the meeting and workshop. Requests for support, including an estimate of expenses, may be addressed to the organisers.

1865 - 2015

MANCHESTER 1824
The University of Manchester

LONDON
MATHEMATICAL
SOCIETY
EST. 1865

Society Meeting & Reception

At the 7ECM, Berlin, Germany
Thursday 21 July 2016

Lecture Theatre, Main Building, TU Berlin

4.30 Opening of the meeting, **Terry Lyons (Oxford)**
From Hopf Algebras to Machine learning via Rough Paths

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Rough path theory aims to build an effective calculus that can model the interactions between complex oscillatory (rough) evolving systems. At its mathematical foundations, it is a combination of analysis blended with algebra that goes back to LC Young, and to KT Chen. Key to the theory is the essential need to incorporate additional non-commutative structure into areas of mathematics we thought were stable. At its high points, there are the regularity structures of Martin Hairer that allow robust meaning to be given to numerous core nonlinear stochastic pdes describing evolving interfaces in physics.

Classic results, by Clark, Cameron and Dickinson, demonstrate that a nonlinear approach to the data is essential. Rough path theory lives up to this challenge and can be viewed as providing fundamentally more efficient ways of approximately describing complex data; approaches that, after penetrating the basic ideas, are computationally tractable and lead to new scalable ways to regress, classify, and learn functional relationships from data. One non-mathematical application that is already striking is the use of signatures on a daily basis in the online recognition of Chinese Handwriting on mobile phones.

6.00 Reception (Ticket required)

LMS members will have the opportunity to sign the Membership Book which dates back to 1865. For a ticket to the reception, please email Elizabeth Fisher (lmsmeetings@lms.ac.uk)

1865 - 2015

7ECM
BERLIN 2016

EXPERIMENTAL MATHEMATICS

by V.I. Arnold, translated by Dmitry Fuchs & Mark Saul, 2015, MSRI Mathematical Circles Library, Vol. 16, 158 pp, £25.50, US$29.90, ISBN 978-0821894163.

This short book is the write-up of four lectures delivered by V.I. Arnold to participants of the 2005 Dubna Summer School "Contemporary Mathematics." The style is very direct and informal with appeals to the listeners/reader to get involved in the subject matter.

V.I. Arnold was very well known for his engaging style of lecturing and writing and his general enthusiasm for conveying how mathematics should be done. His main point is that one's own engagement with examples leads to insights and intuition — often geometrical in nature — via the search for underlying structures and patterns. This then allows for the formulation of a hypothesis or conjecture that may be proved or, if that appears to be very difficult, explored further by more experimentation. In the context of the book, mathematical experimentation refers to working out an increasing number of examples of the concept under consideration. Arnold's approach is literally hands-on, and he presents results of quite extensive calculations — mostly of combinatorial objects — that were performed by pencil and paper. Arnold mentions on several occasions that such calculations can and should be performed for larger examples with the help of computers and directly appeals to his audience for help in doing this.

I found it refreshing to read a book on mathematics that not only contains some well-defined open problems, but states several times that the correct questions have not even been formulated yet. Hence, the reader gets a glimpse of the coal-face of mathematics where problems are actively explored, defined and put into a wider context. Each chapter (or lecture) starts with examples that can be followed and reproduced quite readily, but Arnold then quickly develops more fundamental points of view, invoking different kinds of advanced mathematics as he goes along. In this way, he provides numerous examples of unexpected connections and insights. It will be helpful to have a brief look at the topics covered in the four lectures.

The first lecture, entitled *The Statistics of Topology and Algebra,* concerns quite classical material associated with Hilbert's 16th problem: the number and possible arrangements of ovals of an algebraic curve of a given degree and the enumeration of different types of Morse functions (over the sphere). Starting from the basic configurations with one saddle and three maxima/minima — referred to by Arnold as Mount Elbrus and Mount Vesuvius — the Morse functions are represented by properly ordered trees, which naturally leads to a combinatorial counting problem for which upper and lower bounds are derived. Also discussed are Morse functions over the torus, which give rise to graphs with a single cycle. Finally, a four-parameter family of periodic functions is presented, which is shown to give rise to at most 12 of the 550 possible graphs with four triple branch points and four end points. An open problem is to show that all 12 cases are actually realised by this function.

Lecture 2, *The Combinatorial Complexity of Randomness,* considers the operation of taking differences between successive digits to map the set of binary sequences of length n into itself. This operation results in a single cycle with trees attached to each vertex of the cycle (of preperiodic points). These graphs are determined for n up to 12, which is already a considerable task when performed without a computer. Interesting properties of the structure of the graphs emerge, for example regarding the length of
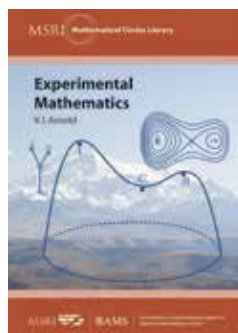
the largest cycle as a function of n and the fact that their sum is always a power of 2. The remainder of the chapter discusses the complexity of the discrete number theoretic logarithm and the complexity and randomness of p × p tables of Galois fields (where p is a prime). The reader is invited to explore in the same way sequences of three or more symbols, rather than binary sequences.

Lecture 3, *Random Permutation and Young Diagrams of their Cycles,* considers the representation of a permutation of the numbers 1 to n by its cycles, which can be presented conveniently as the Young diagram associated with the partition of n. Arnold considers the length (of the longest cycle), the height (number of cycles) and the number of representatives of a given Young diagram. The experimental part of this chapter consists of providing tables of these numbers up to and including n=7. This allows Arnold to consider the average length and height, as well as the average covered area of the minimal rectangle containing the Young diagram. Given the fact that the number of permutations is n!, such tables quickly become impractical for increasing n, even when using a computer. So to gain insight in the above averages Arnold devises a method to generate random permutations; his examples are for n = 100 and for n = 169. The lecture ends with a consideration of Fibonacci automorphisms of the two-torus, the most famous example of which is Arnold's cat map. These maps permute a set of n^2 points and the associated Young diagrams for n up to 20 are tabled and several observations are made.

The fourth and final lecture, *The Geometry of Frobenius Numbers for Additive Semi-groups,* is effectively a discussion of what values one can represent with a system of n given coins (positive base integers with greatest common divisor 1); the motivating example is coins of 3 cents and of 5 cents. The Frobenius number is the integer from where all integers can be represented. The case of two coins is covered by a classical result of Sylvester, and the lecture considers Frobenius numbers of three base integers a, b and c. When s=a+b+c is fixed, these can be arranged in a triangle with obvious symmetries of exchanging the integers; the triangles for s=19 and s=41 are given and properties of Frobenius numbers, including bounds, their averages for fixed s and continued fractions, are discussed at considerable length.

As may be clear from the very short summary above, each lecture or chapter is very dense and quite a tour de force. It will definitely help the reader to know already quite a bit about different areas of mathematics, including topology, geometry, graph theory, combinatorics and group theory. Alternatively or additionally, the reader may use the opportunity to learn more about the concepts covered while working through the examples, arguments and proofs in the book.

This brings me to the question of who to recommend this book to. I believe that fellow professional mathematicians will enjoy reading it because of its numerous connections between different fields, and because it provides an insight into the way of thinking of one of the towering figures of modern mathematics. However, Arnold's target audience is young mathematical talent. Participants of the Dubna Summer School have been selected as the best students throughout Russia from the last two years of high school and the first two years at university. I can imagine very well that such an exceptional audience will have been inspired by Arnold's lectures, which according to the School's website (www.mccme.ru/dubna/eng/) are to last exactly 74 minutes each!

In fact, as the book and the very helpful further notes by translation editor Mark Saul show, several problems have subsequently been solved by participants. On the other hand, the book is clearly intended for a wider readership of young mathematical talent. Reading a chapter of a lecture is, of course, not the same as listening to it live: the covered material is extensive and there are jumps in mathematical depth.

The reader should be prepared to spend considerably more than 74 minutes per

chapter. Arguably the best way of approaching this book is indeed to perform one's own experiments and computations, and this requires time. In fact, each of the four chapters would provide ample material for several weeks of a graduate course.

Bernd Krauskopf
Auckland, New Zealand

THE GEOMETRY OF THE OCTONIONS
by Tevian Dray and Corinne A. Manogue, World Scientific, 2015, pp 228, £63.00, $95.00, ISBN 978-981401814..

It was on 16 October 1843 that Hamilton took his famous walk along the Royal Canal in Dublin and in a moment of inspiration discovered the algebra of quaternions which had a basis 1, i, j, k, where i, j, k were square roots of -1. The next day, Hamilton wrote to his good friend John T Graves about his discovery and this led Graves to think that it might be possible to invent more square roots of -1. On 26 December he wrote to Hamilton describing an 8-dimensional algebra with basis 1, e_1,…e_7 where e_i are square roots of -1. He called his new numbers octaves though today they are called octonions. Hamilton offered to publicize Graves' discovery but somehow never got round to it. Two years later, Cayley also discovered the octonions and published his result and octonions were called Cayley numbers. (While writing this review I wanted to find out more about John Graves. I looked at the Mactutor history of maths site and found that he was not even listed. Nor was he listed in AIMM, the annals of Irish Mathematics and Mathematicians. So not only did John Graves have his brilliant discovery named after somebody else, but he had been written out of history! I have written to both these organizations and I am pleased to report that this has now been corrected.) It turns out that octonions are not only an important topic in algebra, being one of four normed division algebras over the real numbers, but important in Physics too. As Ian Stewart wrote in his New Scientist article What seems like a pointless piece of Victorian whimsy turns out to be an essential part of the theory of everything [IS]; and it says says in the preface of this book that the authors believe that the octonions will ultimately be seen as the key to a unified field theory of Physics. Quite a claim for John Graves' discovery!

Thus this book on Octonions is very welcome. One other text in which octonions play the major part is On Quaternions and Octonions by Conway and Smith [CS]. However this concentrates on the arithmetic of octonions whereas the book under review tackles the geometry of octonions and goes on to discuss their applications to Physics. Also [CS] does not really present an elementary construction of the Octonions.

There are three parts. Part I is called Number Systems, Part II is called Symmetry Groups and part III is called Applications.

The octonions are actually constructed in chapter 4. The most straightforward way of constructing the octonions is by building an algebra with basis 1, e_1,…..e_7, where the ei are square roots of -1 and write out the
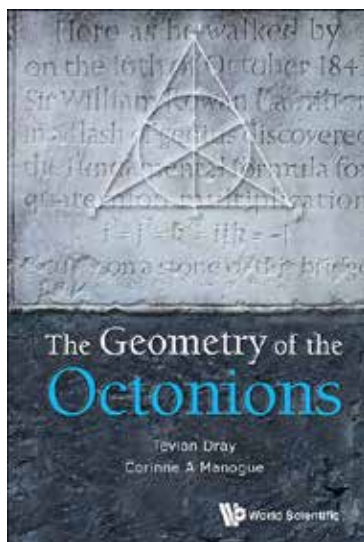
multiplication table. This is quite complicated but amazingly this can be done by drawing an oriented Fano plane where the seven vertices represent the e_i and the edges tell you how to multiply. To see this explicitly go to the excellent article on octonions by John Baez [JB]. In this book the authors take a different approach based on the Cayley-Dickson process which constructs a 2k-dimensional algebra from a k-dimensional one. They begin with the quaternions and then adjoin another square root of -1 which we call λ (in the book they use a handwritten "l"). They then write that it is easy to see that λi, λj, λk are square roots of -1 so we have our seven square roots of -l; i, j, k, λ, λi, λj, λk. Unfortunately, it is not easy to see that λi, λj, λk are square root of -1, but we could add axioms such as $(λi)^2$=-1, etc., and then everything is fine.

Because the octonions have a norm N which obeys N(ab)=N(a)N(b) we get the eight squares theorem which tells us that the product of two numbers each of which is the sum of eight squares is itself a sum of eight squares. This works if we replace eight by four or two, because of the quaternions and complex numbers but not if we replace eight by 16 or higher powers of two.

Part II is about matrix groups and octonions disappear for a short time. An elementary description is given of the matrix groups SO(n) for low values of n and also of some groups of the form SO(p,q). This enable the authors to describe some ideas that occur In physics such as Lorentz groups, Pauli matrices and Gell-Mann matrices. They then get on to unitary and symplectic groups and discuss matrix groups over the complex numbers.

Octonions reappear in chapter 9 where matrix groups over other division algebras are discussed, these other division algebras being the quaternions and octonions. First the well-known quaternionic description of SO(3) is given showing that rotations can be described by quaternion conjugation and then a quaternionic description is given of SO(4). They then go on to give octionic descriptions of SO(7) and SO(8). Chapter 10 is a very brief introduction to Lie groups and Lie algebras and then from chapter 11, the fun really starts!

The automorphism groups of the division algebras are described. The automorphism group of the octonion algebra is the smallest of the exceptional Lie groups G_2 which is shown to be 14 dimensional. In order to discuss the remaining four exceptional Lie groups the algebra of 3 × 3 octionic Hermitian matrices under the Jordan product A°B=1/2(AB+BA). (This is named after the German mathematical physicist Pascuel Jordan, who introduced them to study quantum mechanics.) This algebra is called the Albert algebra $H_3(0)$, 0 here being the algebra of octonions. They then go on to describe the exceptional Lie groups E_6 and E_7 using octonions.

Part III on applications is the most advanced part of the book. It has sections on octionic projective planes, octionic eigenvalue problems, arithmetic of octonions and physics, The section on arithmetic is of most interest to pure mathematicians where they describe how the E_8 lattice can be described using octionic integers. For more details about this see the book of Conway and Smith. The most intriguing part of this study is connections with physics. It is certainly true that some mathematical physicists use octonions in their work (e.g. see [GD]). Will they be used to describe "the theory of everything"? The jury is still out!

To sum up, this is a really interesting book. It does contain some errors and some of it could be more clearly explained but it has encouraged me to further explore this fascinating topic.

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David Singerman
University of Southampton

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References

[JB] John Baez, *The Octonions*, Bull. American Maths. Soc. Vol.39, no.2, 145-205, 2001.

[CS] John H. Conway and Derek Smith, *On quaternions and octonions*. A.K. Peters Ltd, 2003.

[GD] Geoffrey M. Dixon, *Division algebras, Lattices, Physics, Windmill Tilting*. Amazon.co.uk (2011).

[IS] Ian Stewart. *The missing link*, New Scientist, November 2002, 30-33.

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.

APRIL 2016

1-2 North British Functional Analysis Seminar, Lancaster University (456)

4-8 Advances in Numerical and Analytic Approaches for the Study of Non-Spatial Stochastic Dynamical Systems in Molecular Biology INI Workshop, Cambridge (456)

4-8 Explicit Methods in Number Theory in Honour of John Cremona's 60th, Warwick (455)

4-8 Easter Probability Meeting on Random Structures Arising in Physics and Analysis, Lancaster University (453)

5-8 BAMC 2016, Oxford (456)

6-8 Young Functional Analysts' Workshop, Queen's University Belfast (455)

9-10 Mathematics Emerging, The Queen's College, Oxford (456)

9-10 Probabilistic Combinatorics, Oxford (455)

11-15 From the Grain to the Continuum, INI Workshop, Cambridge (454)

13-15 British Algebraic Geometry Meeting, Edinburgh (456)

15 LMS Women in Maths Day, Cambridge (457)

20 LMS Inaugural Hirst Lecture, St Andrews (457)

22 LMS Women in Maths Day, Edinburgh (457)

26 Point Processes and Warping Functions with Statistical Applications, Nottingham (455)

MAY 2016

2-4 Hilbert's Sixth Problem Workshop, Leicester (455)

12 The David Crighton Lecture, Professor Frank Kelly, The Royal Society, London (457)

16-19 Operators, Operator Families and Asymptotics, Bath (455)

18-20 The Dymamics of Complex Systems, Warwick (454)

20-21 Groups in Galway, National University of Ireland, Galway (454)

21 The History of Number Theory, Birkbeck, University of London (455)

23-25 Wales Mathematics Colloquium, Gregynog Hall, Powys (455)

24 LMS and Gresham College Lecture, London (457)

26-27 Young Applied Analysts in the UK, Bath (456)

JUNE 2016

1 p-adic L-functions Day, Cambridge (457)

1 Combinatorics at Oxford (457)

6-9 Computational and Analytic Problems in Spectral Theory, Cardiff (457)

6-10 Quantum Physics and Logic, Strathclyde (457)

6-10 From the Continuum to the Tectonic INI Workshop, Cambridge (455)

9-10 Scottish Partial Differential Equations Colloquium, Dundee (457)

10 Interactions of Operator Theory with Quantum Processes, Newcastle

13-14 ECSTATIC 2, Imperial College London (457)

19-24 Random Interacting Systems, Bath (457)

20-24 Spatially Distributed Stochastic Dynamical Systems in Biology INI Workshop, Cambridge (456)

20-24 New Trends in Nonlinear PDEs, Cardiff (456)

23-24 LMS Northern Regional Meeting and Workshop, Manchester (457)

27-1 July General Relativity: From Geometry to Amplitudes INI Workshop, Cambridge (456)

28-1 Postgraduate Group Theory Conference, Imperial College London (457)

JULY 2016

4-8 Modern Topics in Nonlinear PDE and Geometric Analysis, Reading (457)

4-8 Modelling, Analysis and Simulation: Crime and Image Processing, Oxford (457)

5-8 Data Linkage and Anonymisation INI Workshop, Cambridge (457)

8 LMS Graduate Student Meeting, London

8 Hardy Lecture & LMS Meeting, London (457)

11-15 Graph Limits and Statistic INI Workshop, Cambridge (457)

11-25 Algebraic Combinatorics and Group Actions, Herstmonceux Castle, East Sussex (456)

13-15 Representation Theory of Algebraic Groups in honour of Stephen Donkin, York (457)

15 Mathematical Foundations in Bioinformatics, Kings College London

18-22 Representation Theory and Physics Workshop, Leeds

18-22 7ECM, TU Berlin (456)

21 LMS Meeting at the 7ECM, Berlin (457)

25-27 Bayesian Methods for Networks INI Workshop, Cambridge (457)

25-31 International Mathematics Competition for University Students, Blagoevgrad, Bulgaria (455)

AUGUST 2016

1-4 Young Researchers in Mathematics Conference, St Andrews

2-5 Topology and its Applications, Leicester

25-26 Caucasian Mathematics Conference, Turkey (453)

SEPTEMBER 2016

5-9 Combinatorics and Operators in Quantum Information Theory LMS Research School, Belfast (457)

13-16 LMS Midlands Regional Meeting and Workshop, Birmingham

18-23 Heidelberg Laureate Forum (454)

26-30 Clay Research Workshops, Oxford (456)

28 Clay Research Conference, Oxford (456)

NOVEMBER 2016

11 LMS Graduate Student Meeting, London

11 LMS Annual General Meeting, London

DECEMBER 2016

20 LMS South West & South Wales Regional Meeting, Bath

JULY 2017

3-7 BSDEs, SPDEs and their Applications, Edinburgh (457)

3-7 British Combinatorial Conference, Strathclyde

AUGUST 2017

5-13 Groups St Andrews 2017, Birmingham (457)

THE MAN WHO KNEW INFINITY

(review on front page)

Bertrand Russell (Jeremy Northam), Hardy (Jeremy Irons) and Littlewood (Toby Jones)

Hardy (Jeremy Irons) and Littlewood (Toby Jones)

Ramanujan (Dev Patel), Hardy (Jeremy Irons) and Littlewood (Toby Jones)

Ramanujan (Dev Patel)

Ramanujan (Dev Patel) and Sir Francis Spring (Stephen Fry)

Hardy (Jeremy Irons) addressing The Royal Society