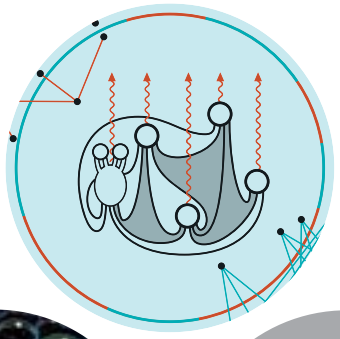
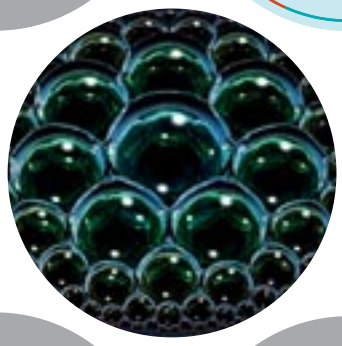
Isaac Newton Institute for Mathematical Sciences

25TH ANNIVERSARY | 1992–2017





Annual Report 2016-17

Mission Statements

Isaac Newton Institute for Mathematical Sciences

The Isaac Newton Institute is an international hub for supporting mathematical sciences research of the highest quality and impact. It aims to attract the world's leading researchers, in all areas of mathematics and its applications, who interact through a variety of long and short thematic programmes as well as associated workshops. Based in Cambridge, and benefiting from a bespoke building and other world leading facilities of this great University, INI is nevertheless an independent forum serving the whole of UK mathematical sciences. INI's environment, and supporting mechanisms, enable its Programmes to have a translational effect on their respective research areas.

All INI scientific programmes are carefully designed to allow for novel ideas to be created, nurtured and exchanged. Programme topics cover all areas of mathematics, with increasing focus on emerging intra and interdisciplinary fields, where engagement is with other scientists, social scientists, economists, policy makers etc. The Institute also helps to develop the next generation of mathematical scientists by encouraging participation of young researchers, by widening access, and by addressing the gender gap in mathematics.

The INI has broadened its role in the community in recent years, and informs policy makers and funders about the relevance, value and timeliness of emerging mathematics. Through the Turing Gateway to Mathematics it carries out stand-alone knowledge exchange events, and activities within Programmes, aimed at end users of mathematical ideas in commerce, industry, government, and other sciences. Further, it assists universities in achieving their own goals; showcases UK research in the mathematical sciences; and engages with non-mathematicians through public lectures, exhibitions, and other activities for schools and the general public.

Turing Gateway to Mathematics

The Turing Gateway to Mathematics (TGM) acts as a vehicle for knowledge exchange between the mathematical sciences and potential users of mathematics, including industry, government, business and other academic disciplines, both in the UK and internationally. It does this by facilitating interactions and activities such as programmes of work, research and training events, as well as bespoke projects. The TGM aims at widening access to mathematics generally, to shorten pathways to impacts for academic research, and to support education and training in areas where mathematical skills are needed.

Director's Foreword

My first year as Director of the Isaac Newton Institute (INI) has been both exhilarating and a little daunting. INI is unique and its model is one that has proved itself time and again. It is an enormous privilege to see first-hand that the Institute routinely changes the lives of its visitors and moves disciplines! However, its novelty lies in the originality, variety and timeliness of the programmes that it runs and so, as a new Director, I have the difficult job of helping maintain the quality and vitality of all that we do.

My first task is to acknowledge the dedication of all past Directors and Deputy Directors who have helped position INI as one of the principal international mathematical sciences research institutes. Particular thanks must go to my immediate predecessor, John Toland, whose attention to detail and work rate I cannot hope to emulate. Over his period of tenure he has transformed the administration, continued to broaden INI's focus, and created the Turing Gateway to Mathematics (TGM), which is the successful knowledge exchange arm of the Institute. He has made these changes without compromising the role INI makes to the core areas of mathematics; the result has meant that the demand for programmes across the mathematical sciences and into interdisciplinary fields has been unprecedented. As a result, the Institute has been trialling the running of three programmes in parallel over an 18-month period. So far the results have been very positive, but the demands on INI staff, and the increased activity within the building, mean that this can only be continued if we have sufficient financial resources.

July 2017 marked the 25th anniversary of the opening of the Institute. It is true to say that INI started with a bang - Andrew Wiles announcing his proof of Fermat's last theorem in 1993. Perhaps this was down to exceptional good fortune and timing, but I believe that what is exceptional elsewhere is commonplace at the Institute. Take, for example, a snapshot of the last 4 months of the 2016-17 academic year

The Institute routinely changes the lives of its visitors and moves disciplines

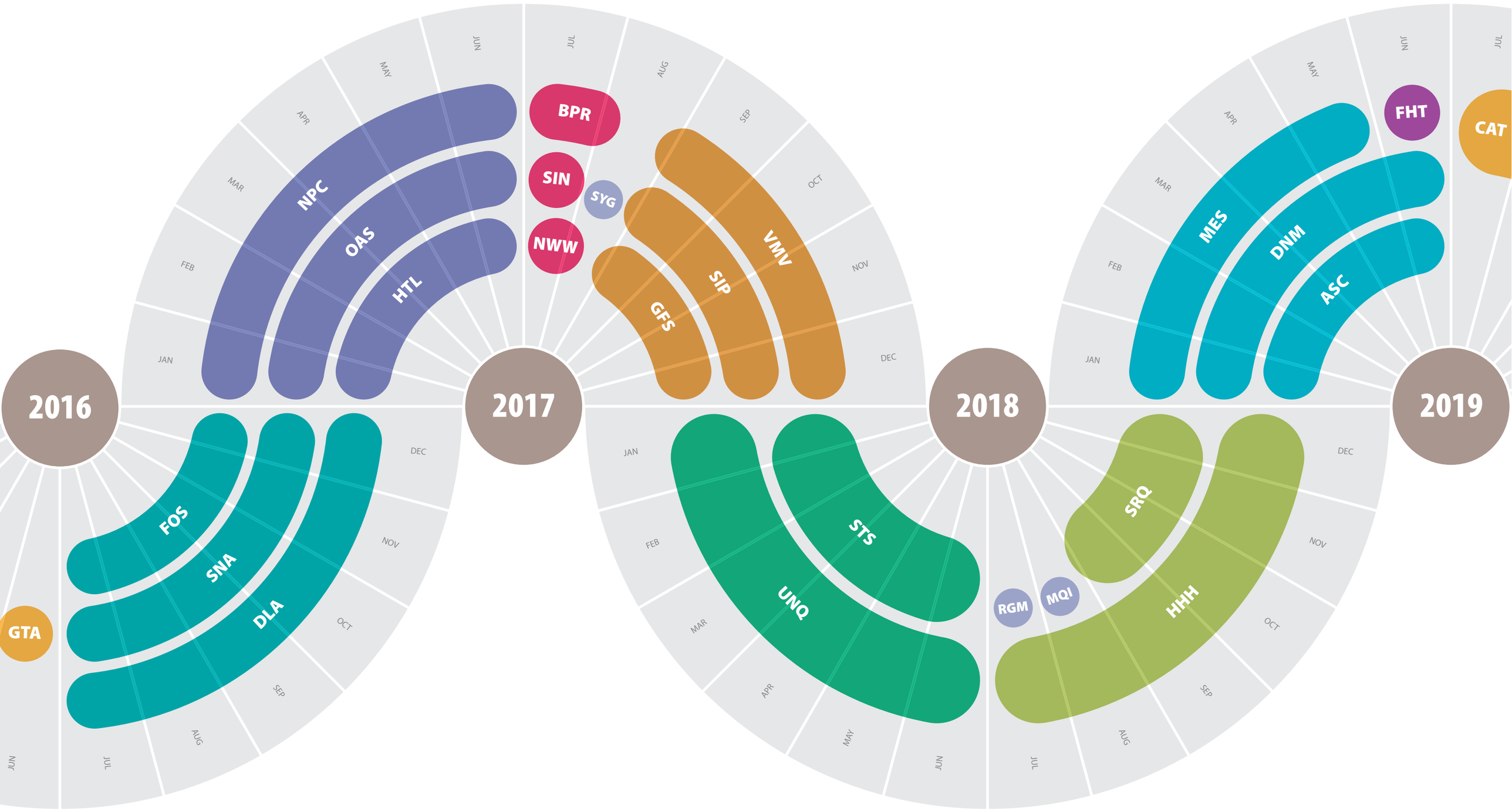
– there were talks by Fields medallists Martin Hairer, Vaughan Jones and the late Vladimir Voevodsky, Abel and Wolf Prize winner Mikhail Gromov, Richard Schwartz who solved the 100 year old Thomson problem, and by Thomas Hales, who announced at INI the publication of the formal proof of the 300 year old Kepler conjecture using a combination of the HOL Light and Isabelle proof assistants.

INI has also been in the vanguard of developments in interdisciplinary and impactful research. A quick look at our calendar of future programmes reveals topics such as *"Statistical scalability"*, *"Uncertainty quantification for complex systems"* and *"Mathematics of sea-ice phenomena"*. Perhaps the biggest development in recent years has been in the field of data science, where it is interesting to note that as much, if not more, fundamental research is now being carried out outside academe (in places such as Microsoft and Google) than inside. These researchers are and will be engaging in INI activities, for example in the 2017 programme on *"Variational methods and effective algorithms for imaging and vision"*.

In conclusion, I wish to thank all those who have supported me through my first year in office including: Valerie Isham, Chair of the Scientific Steering Committee; Christie Marr, Deputy Director; Samantha Skehel, Adminstrator; and Jane Leeks, TGM Manager. I also wish to offer sincere thanks to the outgoing Chair of the Management Committee, Howard Covington, for his tireless work on behalf of the Institute over some eight years, and welcome the new Chair, Ewan Kirk, who I look forward to working with over the next four years. It is incumbent on me, as we enter this anniversary year, to also thank the INI founders and many benefactors for their vision and support; the INI staff both past and present for their dedication and diligence; and the thousands of world-leading researchers who have refereed, served on, organised and participated in INI proposals, committees, programmes and other events. I hope that we can call on your support for the next quarter of a century!

Professor I David Abrahams

Programme Schematic



GTA Gravity, twistors and amplitudes
DLA Data linkage and anonymisation
SNA Theoretical foundations for statistical network analysis
FOS Probability and statistics in forensic science

NPC Non-positive curvature group actions and cohomology
OAS Operator algebras: subfactors and their applications
HTL Homology theories in low dimensional topology

BPR Big proof
SIN Scalable inference; statistical, algorithmic, computational aspects
NWW Nonlinear water waves
SYG Symplectic geometry: celebrating the work of Simon Donaldson

SIP Mathematics of sea ice phenomena
GFS Growth, form and self organisation
VMV Variational methods and effective algorithms for imaging and vision
UNQ Uncertainty quantification for complex systems: theory and methodologies
STS Statistical scalability

RGM Random geometry: follow-up workshop
MQI Mathematical challenges in quantum information: Beyond I.I.D. in information theory
HHH Homotopy harnessing higher structures
SRQ Scaling limits, rough paths, quantum field theory

DNM The mathematical design of new materials
ASC Approximation, sampling and compression in data science
MES The mathematics of energy systems
FHT The fickle heart
CAT Complex analysis: techniques, applications and computations

Theoretical foundations for statistical network analysis

Kirill Photography

ORGANISERS
Sofia Olhede *(UCL)*,
Patrick Wolfe *(UCL)*,
Bela Bollobas *(Cambridge)*,
Stephen Fienberg *(CMU)*,
Bin Yu *(Berkeley)*

This very timely six-month programme brought together branches of pure mathematics (specifically probability and combinatorics), applied mathematics and statistics. It opened with a bang with the announcement during the first workshop of three programme participants having been awarded the 2016 George Pólya Prize in Combinatorics. The excitement continued with the announcement of the establishment of the European Cooperation for Statistics of Network Data Science (COSTNET), a major European initiative to promote cross-disciplinary collaboration in this important area.

Fueled by this momentum in the field, the workshops associated with this programme proved very popular. The opening workshop, attended by over 120 researchers, showcased recent developments connecting the concept of graph limits with nonparametric network models, particularly focusing on the current problem of networks with strong heterogeneity. Subsequent workshops focused on: problems in computation; network data analysis; and networks in time and in situations where multiple interactions exist between vertices. Presented work included new theory to define such processes, and applied contributions pertaining to neuroscience and international relations.

The programme opened with a bang with the announcement during the first workshop of three programme participants having been awarded the 2016 George Pólya Prize in Combinatorics

In his lecture, *'From Small Data to Big Data and Back: Statistics and Data Science'*, Rothschild Visiting Professor Peter Bickel (University of California, Berkeley), highlighted the connections between statistical network analysis and high dimensional data analysis. He placed the programme within the broader context of progress being made in modern statistical theory and methods and shared his personal view of some of the key results from the programme to date, stressing the fundamental role of sparsity in both assisting and hindering the analysis of real networks and their mathematical structure.

Outreach and engagement were important components of this programme and a satellite workshop was held at the Royal Society in London in late November. With over 60 attendees including many from industry, this event highlighted cross-disciplinary influences on network mathematics, ranging from control theory, to topology and graph limits. Also in November, an Open for Business Day co-organised with the Turing Gateway to Mathematics (TGM) demonstrated the power of mathematics to address problems in energy networks, financial systems, urban systems and social networks. This event attracted more than 30 participants from industry, 35 from universities, and 10 from other public sector or charitable bodies.

The main outputs from the programme included new models and several different techniques for studying: networks that have degrees with an unbounded variance; networks which comprise only one portion of the collected data; networks in which there is more than one type of edge; and networks which are dynamic in terms of temporal and process-related evolution over time. The final workshop showcased significant innovations in the field, and closed the programme with a future-oriented perspective, identifying several important research questions that remain for statistical analysis of dynamic networks.

All at INI were deeply saddened to hear of the death of Professor Stephen Fienberg in December 2016. An acclaimed statistician, he was an organiser of both the SNA and DLA programmes and would also have acted as a Simons Fellow for FOS. His presence at the Institute would have been of huge value to all three programmes and our sincerest condolences are extended to his family, colleagues and loved ones.

ROTHSCHILD FELLOWSHIP
Professor P Bickel

SIMONS FELLOWSHIPS
Professor F G Ball,
Professor S Janson,
Professor E Levina,
Professor S Olhede,
Professor P Wolfe

GENDER BALANCE
(F : M, %)

24	76

GEOGRAPHIC DISTRIBUTION
(UK : NON-UK, %)

30	70

AGE DISTRIBUTION
(≤29 : 30-49 : ≥50, %)

10	62	28

Data Linkage and Anonymisation

ORGANISERS
Chris Skinner *(LSE)*,
Peter Christen *(ANU)*,
Stephen Fienberg *(CMU)*,
David Hand *(Imperial)*,
Robin Mitra *(Southampton)*,
Natalie Shlomo *(Manchester)*

Data about people plays an essential role in research in the social and health sciences, as well as in government and commerce. Linkage of databases enriches data whilst anonymization helps protect confidentiality and privacy, critical to data access. Both linkage and anonymization raise urgent methodological challenges and the potential for connections between the two themes was a distinctive aim of this INI programme.

The programme kicked off with an opening workshop that bridged these two themes of data linkage and anonymization, bringing together leading researchers in both fields to identify the frontiers of research. With two further workshops focused separately on linkage and anonymization/privacy areas, cross-disciplinary discussions were promoted by including speakers from both statistics and computer science and, for example, through 'speed-networking' sessions, welcomed particularly by junior participants, which stimulated conversations between disciplines. A fourth workshop addressed the interface between economics and computer science regarding privacy.

> *"This has been the most stimulating environment I have ever been in. The ideas will keep my group busy for one or two years. I consider this programme one of the best academic projects I have seen so far."*
> SENIOR DLA PARTICIPANT

In both thematic areas, the practitioner community involved in the application of techniques is larger than the community of researchers undertaking mathematical sciences research. Three very well-received Open for Business days were organised, supported by the Turing Gateway to Mathematics (TGM), to promote interchange between these two communities. These benefitted from collaboration with the UK Anonymisation Network, which represents the practitioner community.

The programme nurtured both theoretical and applied developments. Examples of theoretical developments were in:

- privacy-preserving record linkage, developing new kinds of cryptanalysis attacks on Bloom filter encoding; and
- re-identification risk assessment, applying developments in record linkage theory.

The programme was planned with the needs of major UK scientific research groups in mind and with significant participation from such groups. Many applied outcomes were orientated to the needs of such constituencies. Examples of applied developments included:

- a dataset repository, to be used as a 'testbed' for evaluating data linkage techniques;
- applications of differential privacy in government statistics (the National Statistician was open to a suggestion that some of these methods provide the basis for a joint discussion/ workshop with the Office for National Statistics later in 2017);
- synthetic data methods, (a challenge-based collaboration was piloted during the programme and it is hoped that a formal open challenge will be issued later in 2017); and
- a decision-making framework for implementing anonymization techniques in practice (ways of expanding an existing framework were discussed and ideas for cooperation with other organisations internationally developed).

The programme themes both fall within the field of 'data science' and as part of one of its workshops, the programme hosted a well-attended and thought-provoking Women in Data Science event.

ROTHSCHILD FELLOWSHIP
Professor C Dwork

SIMONS FELLOWSHIPS
Professor P Christen
Dr R Mitra
Dr C O'Keefe
Professor Y Rinott
Professor N Shlomo
Professor C Skinner

GENDER BALANCE
(F : M, %)

32	68

GEOGRAPHIC DISTRIBUTION
(UK : NON-UK, %)

43	57

AGE DISTRIBUTION
(≤29 : 30-49 : ≥50, %)

15	57	28

Probability and Statistics in Forensic Methods

ORGANISERS
Leila Schneps *(IMJ-PRG)*, David Balding *(Melbourne, UCL)*, Norman Fenton *(Queen Mary)*, Richard Gill *(Leiden)*, David Lagnado *(UCL)*

Not only mathematicians attended this Isaac Newton Institute (INI) programme devoted to applying cutting-edge mathematical methods to the study of crime evidence. The statisticians worked together with forensic scientists specialising in DNA, fungi and soil analysis, and with psychologists studying such phenomena as jury behaviour, paradoxes and risk. Moreover, judges, lawyers and members of the police force came to hear the newest results, to present their views, and to join in panel discussions at one of the associated workshops and at the two Turing Gateway to Mathematics (TGM) events.

Distinguished Rothschild Professor Gerd Gigerenzer, renowned for decades of research into public understanding of statistics, gave lectures that caused both dismay and laughter, as he analysed for example thousands of lay interpretations of common statistical statements of the type that we hear on a daily basis made by medical professionals or weather forecasters.

In between workshops, the longer time programme participants, mathematicians and other researchers, held frequent seminars and meetings, some devoted to an exposition of techniques and others to the detailed analysis of specific criminal cases, with the purposes of testing the robustness of the newest methods. Examples include recent software packages created by members of the programme for the purpose of 'deconvoluting' mixed DNA samples, in other words separating out the different contributors in all possible ways and then calculating the probabilities of each possible combination, or of a particular combination of known individuals.

It is thought that no other programme in the history of INI has given rise to as many heated arguments and emotional fireworks.

Another particularly active focus of the programme was the global analysis of crime evidence using Bayes nets, a graphical method for assessing the weight of a collection of pieces of evidence which are not independent from each other, avoiding the pitfalls of double counting (like counting the arrest of a suspect as evidence of guilt along with the evidence that caused the arrest) or multiplying probabilities of dependent events causing the probability of guilt to soar sky-high (as happened in the famous case of Sally Clark whose two infants died of SIDS). Specific working groups used Bayes nets, in an innovative software package developed by programme members, to analyse complex well-known cases such as the Amanda Knox murder as well as a selection of lesser-known cases (e.g. the Los Angeles Samoan) chosen for bearing features typically known to be confusing and difficult for juries to assess. It is thought that no other programme in the history of INI has given rise to as many heated arguments and emotional fireworks!

As the programme drew to its conclusion, many of the participants worked together to draft a set of guiding principles intended to help open all phases of criminal investigation to the confident use of scientific methods that will be robust, unchallengeable on appeal, and accepted by all sides.

ROTHSCHILD FELLOWSHIP
Professor G Gigerenzer

SIMONS FELLOWSHIPS
Professor G D'Agostini, Professor N Fenton, Professor D Lagnado, Dr G S Morrison, Professor J Mortera, Professor W Thompson, Dr P Wiltshire

GENDER BALANCE (F : M, %)

35	65

GEOGRAPHIC DISTRIBUTION (UK : NON-UK, %)

42	58

AGE DISTRIBUTION (≤29 : 30-49 : ≥50, %)

15	41	44

Non-positive curvature group actions and cohomology

ORGANISERS
Goulnara Arzhantseva *(Vienna)*,
Cornelia Drutu Badea *(Oxford)*,
Alessandra Iozzi *(Zürich)*,
Nicolas Monod *(Lausanne)*

The goal of this programme was the study of non-positive curvature under its various aspects. The main themes were: bounded cohomology; stability of homomorphisms; fixed point properties and proper actions; CAT(0) groups and coarse embeddings. These lie at the nexus of a number of interacting areas in algebra, geometry and analysis, situated at the forefront of mathematical research in recent years.

The response of the community was impressive, with a large number of positive answers, and commitments to long visits. Throughout its duration, without exception, the programme was attended to the maximal capacity of the working and accommodation space offered (and occasionally beyond), with an incessant stream of interactive activities, punctuated by four workshops (with 60 to 80 registered participants each), and a satellite workshop in Oxford aimed at young researchers (with a record number of participants: over 170 registered, and many more actually following our mini-courses). The main programme too was particularly well attended by young researchers. Several strong results have co-authors among them and at our suggestion, an Isaac Newton Prize for Young Researchers was instituted, to be awarded to the most significant preprint (co)authored by a young participant.

The programme led to many new collaborations, complemented by several joint research grant applications.

The weekly schedule had several components. During the non-workshop periods, and in addition to the weekly research seminars (one to two talks per week) and to the Rothschild Lecture and the four Leverhulme Lectures, five mini-courses (9-12 hours each) were given by long term programme participants, including the Rothschild Professor. One mini-course was held in conjunction with the University of Cambridge, since the lecturer was also a Leverhulme Visiting Professor at the University. The content of at least one of the minicourses will be published as a book and is already published on arXiv and the INI preprint server.

The informal components of the schedule included as a starting point the *"Monday@4"* teas, an occasion for the participants to decide on informal reading seminars or working groups tackling a particular problem. Additionally we fostered interaction between the three concurrent INI programmes and organised a common talk by Fields Medalist Sir Vaughan Jones.

The programme led to many new collaborations, complemented by several joint research grant applications. Following his time at INI, our Clay Senior Scholar accepted the Sadleirian Chair of Pure Mathematics at the University of Cambridge. Scientific outcomes include progress in several important problems: the description of the Carathéodory metric on the Teichmüller space; higher Teichmüller theory; the existence of a renormalization scheme for a certain family of dynamical systems coming from a group action by planar piecewise rotations; the *"L-space conjecture"* on 3-manifolds; a unified way of studying growth of groups acting on hyperbolic spaces; a structure theory for compactly generated soluble locally compact groups; computations of action dimension for a wide family of groups; construction of examples relevant to the problem as to whether all automatic groups are biautomatic.

ROTHSCHILD FELLOWSHIP
Professor R E Schwartz

SIMONS FELLOWSHIPS
Professor G Arzhantseva
Professor P-E Caprace
Professor M Davis
Professor T Delzant
Professor C D Badea
Professor E Guentner
Professor V Markovic
Professor P Pansu
Professor E Swenson
Professor K Vogtmann

GENDER BALANCE (F : M, %)

16	84

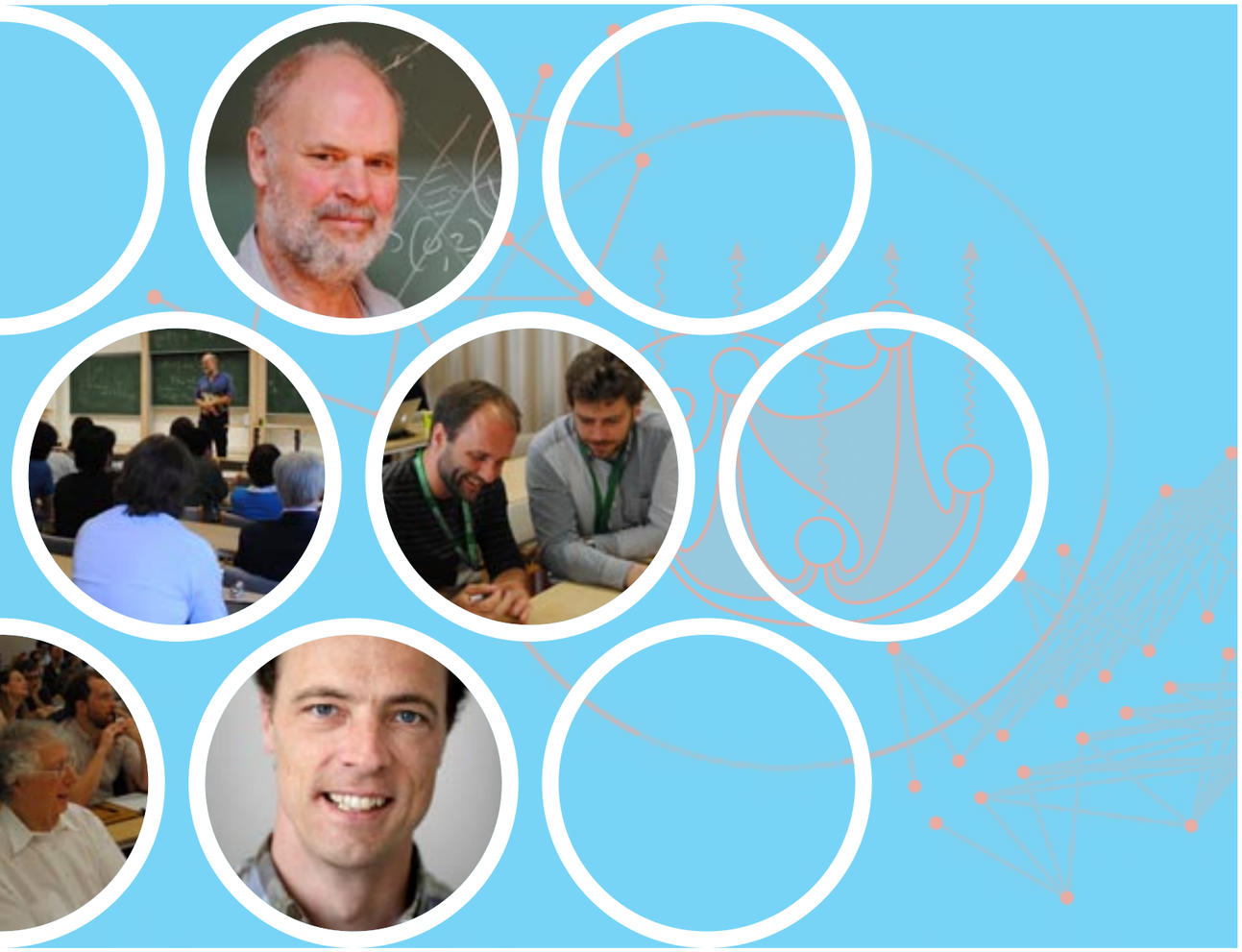
GEOGRAPHIC DISTRIBUTION (UK : NON-UK, %)

31	69

AGE DISTRIBUTION (≤29 : 30-49 : ≥50, %)

24	43	33

Operator algebras: subfactors and their applications



ORGANISERS
David Evans *(Cardiff)*
Masaki Izumi *(Kyoto)*
Vaughan Jones
(Vanderbilt, Berkeley, Auckland)

Fields Medalist and programme organiser Vaughan Jones initiated the study of subfactors in the early 1980s, in the theory of von Neumann algebras of operators on Hilbert spaces. Subfactor theory rapidly led to connections with link and 3-manifold invariants, quantum groups and exactly solvable models in statistical mechanics. Subsequently deep applications and connections have been uncovered with algebraic, topological and conformal quantum field theory (CFT).

This INI programme was driven by recent breakthroughs on two fronts: the classification of subfactors up to a little beyond index five, involving the newer planar algebra tools; and the growing evidence that subfactors, such as the Haagerup subfactor, previously thought to be exotic, yield natural conformal field theories.

Highlights of the programme included:

- The adaption of a homotopy fixed point notion from homotopy theory to the programme of classifying group actions on C*-algebras in terms of certain principal bundles.
- The construction by Jones of a "semicontinuous limit" by reversing the idea of block spin renormalisation in an attempt to construct a CFT directly from a subfactor. This involved a general procedure for constructing actions of groups of fractions of certain categories. Although this method failed to produce CFT, it took on a life of its own and may have applications to real life quantum spin chains. The first spinoff was a way of producing all knots and links in 3-dimensional space from elements of the Thompson groups. Invariants of knots and links arise as coefficients of these unitary representations. Transfer matrices (generators of dynamics) are constructed on the semicontinuous limit.

This INI programme was driven by recent breakthroughs on two fronts

This involves the study of a classical dynamical system and its behaviour under iteration. In the simplest case of the Temperley-Lieb algebra this dynamical system is a rational function on the complex numbers which has Julia and Fatou sets and a Mandelbrot set in the parameter space defined by the spin-blocking operator. Quantum phase transitions arise when the varying physical parameter is the spectral parameter of the transfer matrix. The average of the log of the vacuum expectation value of the transfer matrix is smooth on the connected components of the Fatou set but is discontinuous on the Julia set.

- CFT via twisted equivariant K-theory. This resulted in not only understanding module categories and modular invariants for the twisted doubles of finite groups through correspondences as KK elements, but also in realising for the first time the twisted doubles of finite groups and doubles of Tambara-Yamagami systems as a CFT. The latter also resulted in a better understanding of the double of the Haagerup subfactor.
- Connections between subfactor planar algebras and quantum information.

ROTHSCHILD FELLOWSHIP
Professor S Vaes

SIMONS FELLOWSHIPS
Dr Y Arano
Professor A Jaffe
Professor Y Kawahigashi
Professor R Longo
Dr Y Tanimoto

GENDER BALANCE
(F : M, %)

13	87

GEOGRAPHIC DISTRIBUTION
(UK : NON-UK, %)

38	62

AGE DISTRIBUTION
(≤29 : 30-49 : ≥50, %)

20	50	30

Homology theories in low dimensional topology

ORGANISERS
Andrew Lobb *(Durham)*
Dorothy Buck *(Imperial)*
Jacob Rasmussen *(Cambridge)*
Liam Watson *(Glasgow)*

From its beginnings in the work of Floer and Khovanov, the theory of homological invariants of knots and three-manifolds has grown to touch on many areas of mathematics, including low-dimensional topology, algebraic geometry, representation theory, and string theory. A key goal of this programme was to bring together experts from all of these areas and to promote fruitful collaboration and discussion between them.

The three major areas of research addressed by the programme were: low dimensional topology and Floer homology for 3-manifolds; quantum invariants and interactions with string theory; and Khovanov homology and categorification. In addition to the cross-disciplinary winter school held at the start of the program and a very successful satellite workshop on Low-Dimensional Topology held on the Isle of Skye, a workshop was devoted to each of these themes.

The timeliness of this programme was reflected by the many announcements by participants during the programme and workshops of important developments in each of the following areas including, for instance:

- In low-dimensional topology, many of the program attendees were drawn into thinking about the L-space conjecture which relates Floer homology, algebra, and geometry. Progress was made towards understanding this conjecture.
- Highlights in physics included 2016 Breakthrough Prize winner Cumrun Vafa (Harvard) lecturing on the structure of the Witten-Reshetikhin-Turaer invariants, as well as exciting new developments in coloured knot homologies, quiver algebras, and the Labastida-Marino-Ooguri-Vafa conjecture.
- In the final workshop, we witnessed the unveiling of the proof of some long-conjectured properties of the HOMFLYPT homology of torus knots, as well as Mikhail Khovanov (Columbia), the originator of the field, explaining his categorification of the Jones polynomial.

The final lecture of the program was given by Rothschild Professor Cameron Gordon (Texas), who summed up the state of affairs for the L-space conjecture as *"one of the most exciting new developments in Floer homology for 3-manifolds"*.

The interaction between mathematics and physics in this programme was found to be so valuable... that it has spawned two follow-up events to be held in 2018

Follow up events

The interaction between mathematics and physics in this programme was found to be so valuable by the attending mathematical physicists, that it has spawned two follow-up events to be held in 2018, a six-week long program at the Kavli Institute in San Diego and a week-long conference at the Aspen Center.

ROTHSCHILD FELLOWSHIP
Professor C Gordon

SIMONS FELLOWSHIPS
Professor D Buck
Professor E Grigsby
Professor A Licata
Dr J Licata
Dr V Vertesi
Dr L Watson

GENDER BALANCE
(F : M, %)

19	81

GEOGRAPHIC DISTRIBUTION
(UK : NON-UK, %)

24	76

AGE DISTRIBUTION
(≤29 : 30-49 : ≥50, %)

13	71	16

Big Proof

ORGANISERS
Jeremy Avigad *(CMU)*
Natarajan Shankar *(SRI)*
Leonardo de Moura *(Microsoft)*
Georges Gonthier *(INRIA)*
Ursula Martin *(Oxford)*
J Strother Moore *(Austin, Edinburgh)*
Lawrence Paulson *(Cambridge)*
Andrew Pitts *(Cambridge)*

GENDER BALANCE (F : M, %)

12	88

GEOGRAPHIC DISTRIBUTION (UK : NON-UK, %)

34	66

AGE DISTRIBUTION (≤29 : 30-49 : ≥50, %)

16	46	38

In computer science, "formal methods" refers to the use of logic-based computational tools for proving correctness and precise reasoning about properties of hardware and software systems. The goal of this Big Proof programme was to bring together a diverse population of mathematicians and computer scientists to explore ways that such methods can be applied not only in computer science, but also in mathematics.

This is a fast-moving field. Interactive proof assistants have given rise to substantial libraries of formalized mathematics, and automated verifications of notable theorems, such as Feit-Thompson, by Big Proof organiser Georges Gonthier, and the Kepler conjecture, by programme participant Thomas Hales, have been accepted. Fast satisfiability solvers were recently used to solve the longstanding Pythagorean triples problem, and we are beginning to understand ways that search algorithms can be used to extend mathematical knowledge. Formal methods are also beginning to play a role in mathematics education and assessment, and in supporting social interaction and dissemination.

The technologies are still young, but they have the potential to extend and transform the way mathematics is carried out.

Informal seminars were held throughout the six-week programme with the main seminar room filled to capacity for the workshop which featured talks by luminaries in the field.

The technologies are still young, but they have the potential to extend and transform the way mathematics is carried out. Conversely, the rise of these technologies raises interesting questions and offers new research opportunities for mathematicians: firmly rooted in mathematical logic, formal methods draw on insights from across the spectrum of mathematics including computational, real and algebraic geometry, and numerical analysis and optimization.

Scalable Inference: statistical, algorithmic and computational aspects

ORGANISERS
Gareth Roberts *(Warwick)*
Christophe Andrieu *(Bristol)*
Paul Fearnhead *(Lancaster)*
David Firth *(Warwick, ATI)*
Chris Holmes *(Oxford)*

GENDER BALANCE (F : M, %)

14	86

GEOGRAPHIC DISTRIBUTION (UK : NON-UK, %)

59	41

AGE DISTRIBUTION (≤29 : 30-49 : ≥50, %)

15	58	27

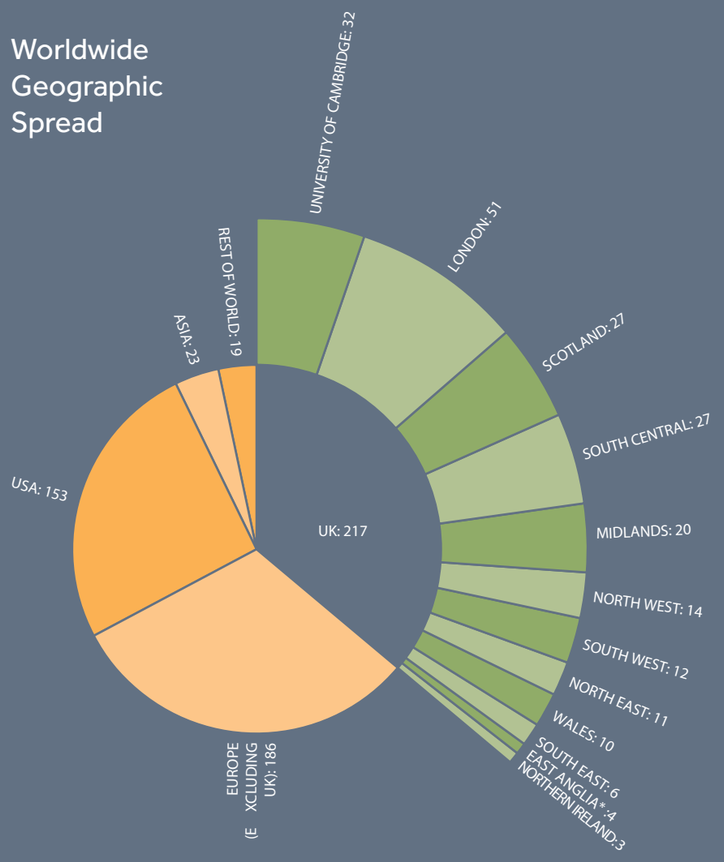
This INI programme focused on methods associated with likelihood, its variants and approximations, taking advantage of and creating new advances in statistical methodology. These advances have the potential to impact on all aspects of science and industry that rely on probabilistic models for learning from observational or experimental data.

The programme considered intractable likelihood problems, where the repeated evaluation of a likelihood function is impossible or too computationally expensive to carry out. It sought to identify methodologies for statistical inference where computational cost and statistical validity scale well with both model complexity and data size. Understanding and developing scalable methods for intractable likelihood problems requires expertise across statistics, computer science, probability and numerical analysis. Thus it was imperative that the programme was broad, covering statistical, algorithmic and computational aspects of inference, cutting across traditional boundaries e.g .between frequentist and Bayesian inference, and incorporating both statistics and machine learning approaches to inference. Motivated strongly by big data, big models, and specific major scientific challenges, the programme tackled some of the most demanding problems facing modern statistics. It created an ideal environment for cross-fertilisation to occur and yielded a unified effort to identify solutions, requiring expertise across fields. Highlights of the programme included the presentation of novel discrete time non-reversible Markov chain Monte Carlo methods (Bouchard-Cote, Sherlock and Michel), and the description of a connection between accelerated optimization techniques and various cutting edge sampling techniques. There is a very strong UK community working in this area. Indeed the five organisers, all UK-based, are co-investigators on an EPSRC Programme Grant, ilike (Intractable Likelihood). They are grateful to INI for allowing this project to hold its annual Advisory Board meeting during the first workshop to discuss, prepare, and subsequently submit a follow-up proposal to EPSRC to ensure that momentum in this field continues.

There is a very strong UK community working in this area.

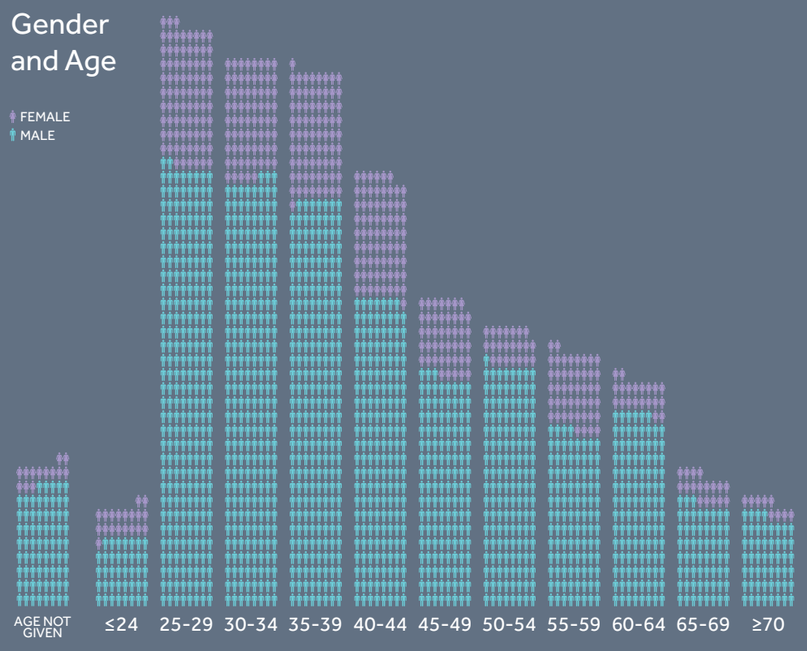
Statistics

Worldwide Geographic Spread

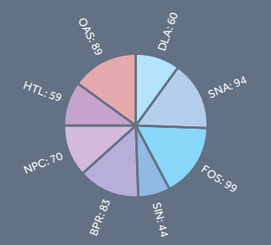


*Excluding University of Cambridge

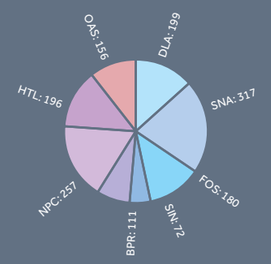
Gender and Age



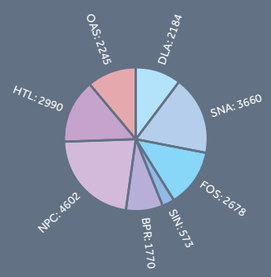
598
PROGRAMME PARTICIPANTS



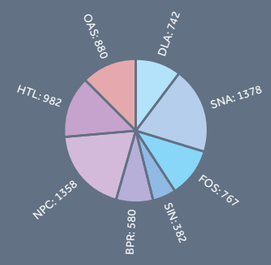
1488
WORKSHOP PARTICIPANTS



20702
PROGRAMME PARTICIPANT DAYS



7069
WORKSHOP PARTICIPANT DAYS



CORRECTION
In the 2015-16 Annual Report, that period's "Workshop Participant Days" figure was erroneously given as 25,256. The correct figure is 5,218.

Celebrating 25 years of INI: 1992-2017

This year marks the 25th anniversary of INI's official opening in 1992. To celebrate this important milestone a range of outreach activities were organised in and around the Institute. Their aim was to showcase INI's continuing devotion to the mathematical sciences and the successes that have been reached here in such a relatively short length of time.

The first of these events - an audience with artist Nigel Hall RA - took place at INI on the evening of 19 July 2017. Welcoming a crowd of more than 60 mathematicians and art lovers, it consisted of an open audience and drinks reception with the artist. Nigel, whose works are exhibited across the globe from New York's Museum of Modern Art (MOMA) to the Tokyo Metropolitan Art Museum, was joined by Dorothy Buck (Professor of Mathematical Biology, University of Bath; co-organiser of INI's HTL programme) and Barry Phipps (Fellow and Curator of Works of Art, Churchill College). The ensuing conversation examined the complex and inspiring relationship between art and mathematics, told via the medium of Nigel Hall's compelling geometric sculptures, sketches and painting. Many of these artworks – which were located in and around the Institute – had been on long-term loan for visitors and participants to enjoy throughout the summer.

This was followed on 20 July 2017 by a day of talks and interactions attended by a guest list of over 100 esteemed mathematicians and affiliates of the Institute. Amongst those presenting were founding INI director Sir Michael Atiyah OM FRS FRSE FMedSci FREng, Fields Medallist Martin Hairer KBE FRS, broadcasters Dr Hannah Fry and Dr Simon Singh, and - to mark a landmark in INI's 25 year history, the announcement of his original proof of Fermat's Last Theorem - Sir Andrew Wiles. The series of talks, which ranged from the academic to the more public-facing in nature, took place in the very same room in which Sir Andrew first presented his proof of the 17th century conjecture.

To see more images, and also video content of events from 20 July, please visit the following link: bit.ly/ini25th

Institute Activities: Serving the UK Community

The passing of the 25th Anniversary milestone is an ideal opportunity for INI to reflect upon its engagement with the UK mathematics community, its contribution to the healthiness of the discipline, and the processes that it has in place to sustain these.

From inception to completion, programme organisers are prompted to be mindful of the contribution that their programme will make to mathematics in the UK, with all proposal referees being asked to comment on the impact that the proposed programme would have on researchers in the UK. This reporting year, 217 of the 598 programme participants (36%) were UK-based and 595 of the 1488 workshop participants (40%) were UK-based. Between them they came from 67 different universities, institutions, companies and government departments, with backgrounds spanning the broad spectrum of the mathematical sciences. The **Network of Correspondents** is being reinvigorated and the next Correspondents Day is due to be held in early 2018.

The **gender imbalance** in the mathematical sciences across the UK and worldwide is a significant concern to the Institute and it continues to work hard to support women in mathematics including hosting events such as the very successful Women in Data Science day that was part of the Data Linkage and Anonymisation programme. Furthermore INI has met or surpassed almost all of the targets set in its 2014 Gender Balance Action Plan (GBAP). In particular in the present reporting year:

- The target of an 18% female participation rate for programmes and workshops has been far exceeded with 21% of programme participants and 24% of workshop participants being female.
- 24% of all programme organisers were female and the INI aspires to have at least one female organiser on each programme.
- The target of 20% of its committees being female has also been far exceeded: 5 out of 13 (38%) of the Scientific Steering Committee including the Chair are female and 4 out of 13 (31%) of the Management Committee are female.

For further details of this and for the 2017 Gender Balance Action Plan see: www.newton.ac.uk/science/publications

Nurturing the **next generation of scientists** is very important to INI and 30% of its programme participants and 35% of its workshop participants are early career researchers. Moreover, 34% of these early career programme participants and 40% of these early career

workshop participants are UK-based. Organisers are encouraged to offer innovative mechanisms to support their early career researchers. A recent example was the "speed networking" sessions that were part of the Data Linkage and Anonymization programme. Further details of the Institute's Junior Membership Scheme are given here: www.newton.ac.uk/community/junior-members

Subject to speaker permission, all seminars given during programmes and workshops are streamed live and made available in perpetuity via the Institute's **online seminar archive**. A further 696 seminars were added to this collection during this reporting year, bringing the total number of seminars in the archive to a little under 7,000. These can be accessed at: www.newton.ac.uk/webseminars

Satellite Meetings across the UK were introduced in 2000 and since then there have been 68 such meetings including 18 in Scotland and 7 in Wales. In this reporting year Satellites were held at the Royal Society in London, in Oxford and Southampton, and on the Isle of Skye.

Programme participants from overseas are encouraged to give **"Talks Elsewhere"** in the UK during their stay, with INI paying their travel expenses and the host institution paying their local expenses. In this reporting year there were 73 talks across the UK given by 47 people across 30 institutions including 14 talks given in Scotland and 8 talks given in Wales. A list of overseas participants from current and forthcoming programmes who are willing to give talks, and possible talk titles, is given at: www.newton.ac.uk/science/outreach/talkselsewhere

The Isaac Newton Institute's contribution to the **Cambridge Science Festival** is always very popular and this year was no exception. Seminar Room 1 was full to capacity to hear Emmy-award winning computer scientist Dr Andrew Fitzgibbon, Microsoft, speaking about how his work has been used in films such as Harry Potter, in the Xbox, and in Microsoft's latest gadget, the HoloLens, the first fully self-contained holographic computer. His slide "All of Maths" which he covered in approximately 8 minutes caused particular amusement!

Following the recent appointment of Information and Development Co-ordinator, Dan Aspel, INI has been giving considerable thought to the reach and impact of its **social media**. It encourages all those interested in INI activities to follow us via the following streams:

newton.institute NewtonInstitute isaacnewtoninstitute

Finances

Accounts for August 2016 to July 2017

	Notes	**2016-2017**	2015-2016
Income			
		£000	£000
Research Grants and Contracts	*1*	**1,833**	1,904
Contribution from the University of Cambridge	*2*	**429**	417
Donations	*3*	**158**	146
Additional workshop income		**138**	167
Additional income	*4*	**67**	1
Endowment and investment income		**389**	248
Total income		**3,014**	2,883
Expenditure			
Staff costs		**701**	684
Travel and subsistence	*5*	**1,194**	1,184
Other operating expenses	*6*	**164**	229
Overheads paid to the University	*7*	**507**	306
Total expenditure		**2,566**	2,403
Surplus/(deficit)		**448**	480

Notes to the Accounts

Note 1 - Research Contracts and Grants (EPSRC & Simons Foundation)

Salaries	271
Travel and subsistence	1,166
Other costs	2
Estates and indirect income	394
Total	**1,833**

Note 2 - Contribution from the University of Cambridge

The University's contribution towards the Institute's running costs. The University also provides the main and Gatehouse building, and pays for all services and rates.

Note 3 - Donations

London Mathematical Society	35
Cambridge Philosphical Society	4
Garfield Weston Foundation	25
Clive Humby & Edwina Dunn	46
Henderson Group	20
PF Charitable Trust	4
Turner Kirk Charitable Trust*	24
Total	**158**

** A total sum of £100k was received from Turner-Kirk Charitable Trust, which was placed in investment income and is not included in this figure*

Note 4 - Additional income

Merchandise sales	8
Programme sponsorship	59
Total	**67**

Note 5 - Travel and subsistence

Programme & workshop	1,190
Staff travel	4
Total	**1,194**

Note 6 - Other operating expenses

Computing	7
Institute running costs	3
Catering	89
Net housing costs	19
Furniture	11
Professional & brought in services	35
Total	**164**

Note 7 - Overheads paid to the University

Includes Estates and indirect costs on grants and overheads on Trust Funds

Governance: Advisory Council

Dr Ewan Kirk,
Chair of the Management Committee

Management Committee

The Management Committee is responsible for overall control of the budget of the Institute and for its financial planning. The Director is responsible to the Management Committee, which provides essential advice and support in relation to fund-raising activities, employment of the staff of the Institute, appointment of the organisers of programmes and general oversight of Institute activities. Its aim is to facilitate to the fullest possible extent the smooth and effective running of the Institute's programmes and all related activities. Membership of the Management Committee at 31 July 2017 was as follows:

Name	Institution	End of Service
Dr Ewan Kirk (Chair)	General Board	31 Dec 2018
Professor I. David Abrahams	Director, Isaac Newton Institute	30 Sep 2021
Dr Gabor Csanyi	Council of the School of Technology	31 Dec 2018
Professor Mark Gross	Faculty of Mathematics	31 Dec 2018
Dr Philippa Hemmings	EPSRC	
Professor Valerie Isham	Chair of the Scientific Steering Committee	31 Dec 2017
Dr Eric Lauga	Trinity College	31 Dec 2018
Professor Nick Manton	St John's College	31 Dec 2018
Dr Christie Marr (Secretary)	Deputy Director, Isaac Newton Institute	
Professor Andy Parker	Council of the School of Physical Sciences	31 Dec 2018
Professor Gabriel Paternain	Head, DPMMS, University of Cambridge	
Professor Nigel Peake	Head, DAMTP, University of Cambridge	
Professor Ulrike Tillman	London Mathematical Society	31 Dec 2018

Professor Valerie Isham
Chair of the Scientific Steering Committee

Scientific Steering Committee

The Scientific Steering Committee (SSC) meets twice each year to consider proposals for programmes (of 4-week,4-month or 6-month duration) to run two or three years later. Successful proposals are usually developed in a discussion between the proposers and the SSC conducted through the Director, and may well be considered at more than one SSC meeting before selection is recommended. Complete details of the Institute's regular call for proposals, including guidelines for submission, can be found on the Institute's website at www.newton.ac.uk/science/proposals. Membership of the Scientific Steering Committee at 31 July 2016 was as follows:

Name	Institution	End of Service
Professor Valerie Isham (Chair)	University College London	31 Dec 17
Professor I. David Abrahams	Director, Isaac Newton Institute	30 Sep 21
Professor Helen Byrne	Oxford	31 Dec 17
Professor Wolfgang Dahmen	Aachen	31 Dec 18
Professor Paul Glendinning	Manchester	31 Dec 19
Professor Iain Gordon	Edinburgh	31 Dec 17
Professor Saul Jacka	Warwick	31 Dec 18
Professor Jon Keating	University of Bristol	31 Dec 20
Professor Dame Frances Kirwan	Oxford	31 Dec 19
Professor Marta Kwiatkowska	Oxford	31 Dec 18
Professor Simon Tavaré	Cambridge	31 Dec 19
Professor Richard Taylor	Institute for Advanced Studies	31 Dec 20
Professor Susanna Terracini	Università degli Studi di Torino	31 Dec 20

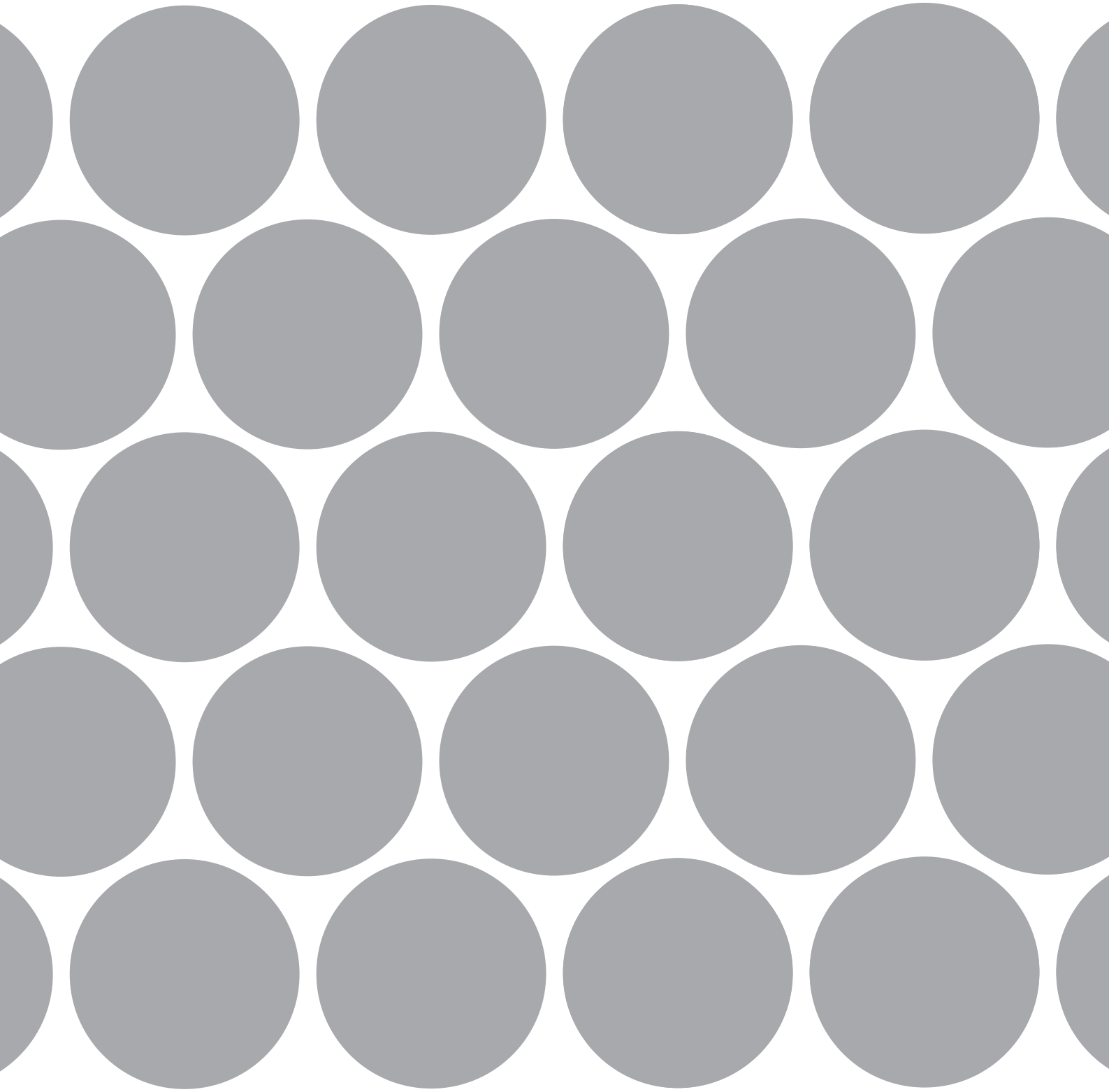
Cumulative Financial Grants and Donations above £10,000

Elena Ambrosiadou • Michael Astor • Apple Computers Ltd. • Applied Probability Trust • Autonomy Systems Ltd. • Iain Bratchie • Bank of England • Benfield Greig • BNP Paribas • British Aerospace • British Gas • Howard & Veronika Covington • William Craig • Cambridge Philosophical Society • Clay Mathematics Institute • CNRS • Credit Suisse • Daiwa Anglo–Japanese Foundation • DERA • Deutsche Forschungsgemeinschaft • Emmanuel College • European Molecular Biology Organisation • European Science Foundation • European Union • Dill Faulkes Foundation • Garfield Weston Foundation • GLC Charitable Trust (Lawrence Staden) • Gonville and Caius College • David Harding Foundation • Henderson Global Investors • Hewlett–Packard • Clive Humby & Edwina Dunn • Institute of Physics • Jesus College • John Templeton Foundation • Dr EM Kirk & Dr PJ Turner • Leverhulme Trust • London Mathematical Society • Hamish Maxwell • Steve Mobbs • Magnox Electric • Medical Research Council • Met Office • Microsoft Corporation/ Microsoft Research • National Science Foundation • NATO • Nomura Corporation • Nuffield Foundation • Office of Naval Research • Old Mutual plc • Paul Zucherman Trust • PF Charitable Trust • Prudential Corporation plc • NM Rothschild and Sons • Research Councils UK (SERC/ EPSRC/ PPARC/ STFC/ NERC/ BBSRC/ ERSC) • Rolls Royce • Rosenbaum Foundation • Royal Commission for the Exhibition of 1851 • Schlumberger • Simons Foundation • St John's College • Sun Microsystems inc. • Thriplow Trust • Trinity College • Trinity College (Isaac Newton Trust) • TSUNAMI • Unilever • University of Cambridge • David & Elizabeth Wallace • Wellcome Trust • Anonymous Donation

How to Donate

You may donate to the Isaac Newton Institute online by credit or debit card through the University of Cambridge's secure site. US tax payers may donate to Cambridge in America, a 501(c)(3) tax-exempt organisation and qualify for an income tax deduction. Please state when making your gift that you would like your donation to support the Isaac Newton Institute for Mathematical Sciences. The University has charitable status and so donations made to it or its constituent parts, including the Institute, may attract tax relief. For UK tax payers this is available under Gift Aid.

All donors will be acknowledged formally in the Institute's Annual Report (unless anonymity is preferred). The Institute offers recognition in various ways, including naming opportunities. If you would like to discuss these or other aspects of supporting our work, please do not hesitate to contact the Director (+44 (0)1223 335980 / director@newton.ac.uk) or Glen Whitehead at University Development and Alumni Relations (+44 (0)1223 330112 / gw366@cam.ac.uk).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