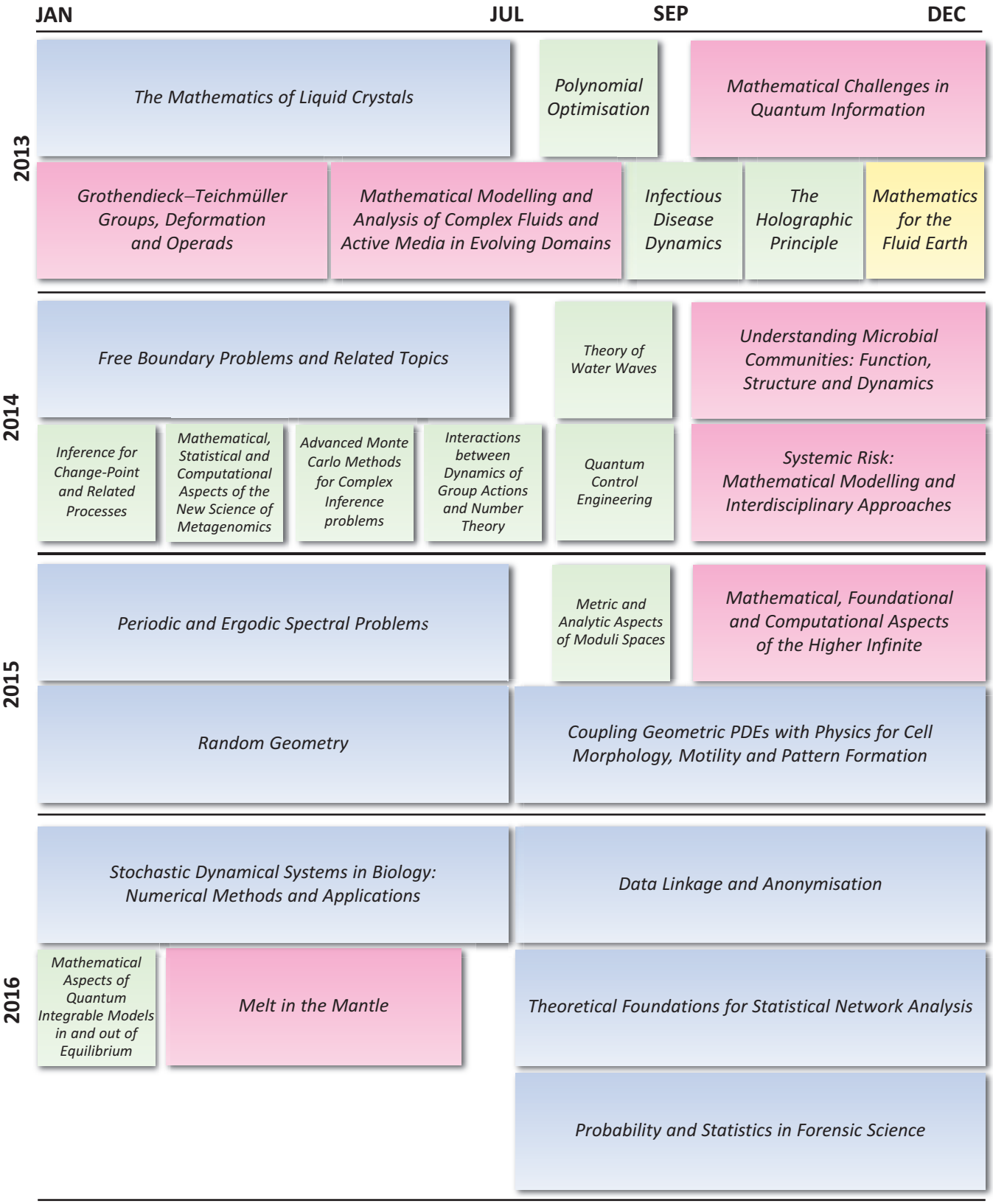
Isaac Newton Institute
for Mathematical Sciences

Annual Report 2013–14

UNIVERSITY OF
CAMBRIDGE

Current and Future Programmes

The schematic below shows recent and forthcoming programmes selected by the Scientific Steering Committee. Further details of each of these programmes, including the names and contact details of the organisers, can be found on the INI website at **www.newton.ac.uk/science/programmes/**.



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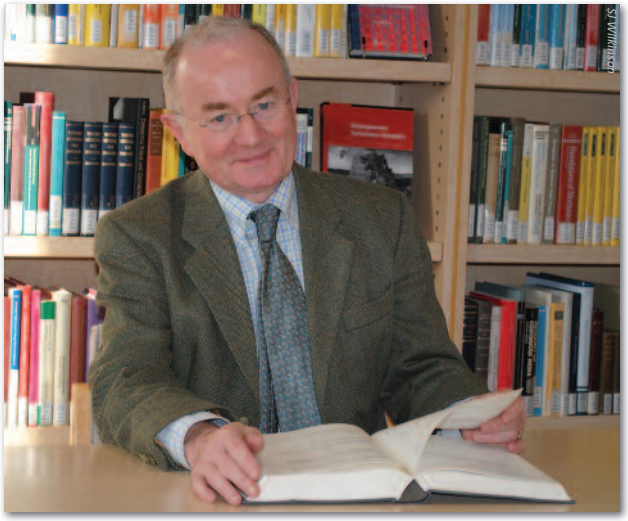
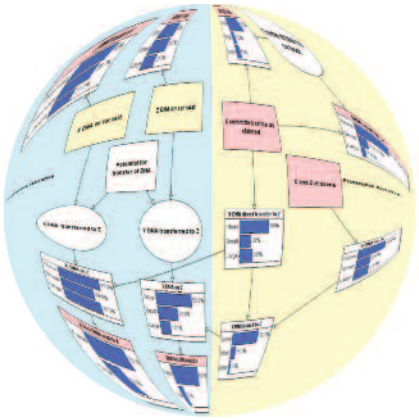
Further statistics are available from **www.newton.ac.uk/science/publications/annual-reports/**

Director's Foreword



John Toland
Director

The Isaac Newton Institute (INI) is a famous place for research in the mathematical sciences with a reputation for efficient organisation and a warm welcome for visitors. I was reminded of this recently when INI received two high level delegations from Tokyo and Singapore. They wanted to study the architecture of the INI building and asked how INI activities are managed. It was explained that peer review by an independent Scientific Steering Committee, high quality organisers and key participants, the time committed to programme planning and the professionalism of INI staff when dealing with about 1,700 visitors per year, are all key to maintaining INI's high standards. Beyond these, vigilance in looking out for research opportunities, and awareness of changes in the research environment are important when nurturing creativity and encouraging collaboration in an institute such as this. INI has recently been informed that the EPSRC's Strategic Advisory Team has been asked to conduct a review of the research infrastructure that supports the Mathematic Sciences in the UK. INI looks forward to engaging with this process and through it with all stakeholders.

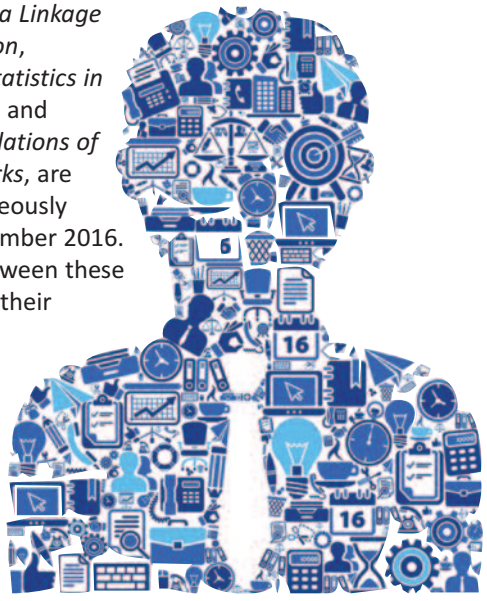


Probability and Statistics in Forensic Science

There has been a striking increase in the number of proposals received in the last few years, not only in classical fields of pure and applied mathematics and statistics but also from research in the earth, life, social, physical and biological sciences, and from technology and big data analytics when advanced mathematics is involved. The remit of INI is to identify and support only the best of these, and its reputation rests on the quality of the programmes that emerge.

From this year on INI's core activity will be supported by five Research Councils[1] (two-thirds by EPSRC and the rest from BBSRC, ESRC, NERC and STFC) in recognition of its successful programmes in these areas in the past. However, the nett outcome is a reduction in Research Council support, the impact of which is magnified by the rising number of proposals from a widening spectrum of disciplines. This means that firm action is required to avoid a threat to important research areas and new initiatives. I am pleased to report that INI is so far coping with the emerging situation.

To deal with the growing number of strong proposals INI has decided to organise additional programmes in parallel. For example, three programmes: *Data Linkage and Anonymisation*, *Probability and Statistics in Forensic Sciences*, and *Theoretical Foundations of Statistical Networks*, are planned simultaneously from July to December 2016. The synergies between these programmes and their relevance to the currently highly topical theme of Big Data, mean that the benefits are not only practical, but significant both scientifically and to society more broadly.



Data Linkage and Anonymisation

INI has also embarked on a thorough automation of its administrative processes using a new customised database called ISAAC, the development of a new web

site, the introduction of a web-based process for the submission and peer review of proposals, and the automated capture of personal data from applicants and participants. When these are in place staff resources will become available to give additional support to existing activities, such as the *Turing Gateway to Mathematics*, and to develop new initiatives.

All this goes hand in hand with continued fundraising efforts, through the sustained activity of our volunteer Development Board[2] and by working with the University's professional fundraisers. The success of INI would not be possible without support from Cambridge University, educational foundations and trusts, and specific support from particular programmes. It is gratifying to report, for the first time, support from the Simons Foundation[3] for four years from 2015 for thirty long-stay fellows per annum on INI programmes.

How do mathematicians collaborate?
Ursula Martin (above right) intends to find out in a new study

This year INI was central to a new anthropological study that examined how mathematicians collaborate with each other. The project, led by Professor Ursula Martin from the University of Oxford, aims to understand how scientists work with each other and what communication technology (blackboards, smartboards etc.), if any, they use. Many of the INI participants that were interviewed by the project team commented that the process of being observed had a positive impact on their science. The project is part of a broader research programme supported by an EPSRC Fellowship.

In March, Professor Ian Stewart from the University of Warwick gave a public lecture[4] at INI as part of the Cambridge Science Festival. He spoke about the mathematical patterns in animal markings and the work done by Alan Turing to describe the chemical process that makes these patterns.

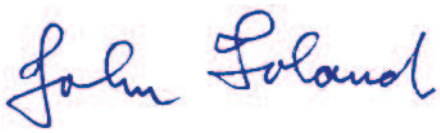
A spectacle in the seminar room?

In June, Professor Ray Goldstein from the University of Cambridge gave a plenary lecture[5] in which he explained the way that a Volvox embryo (a multicellular alga) can turn itself inside out. During the talk he invited the audience to wear 3D glassed to view the time-lapse movie of inversion. This is a first for INI!

INI is indebted to the personal generosity of many individuals who make donations to its endowment, or who selflessly give of their time and effort, expertise and advice, because they value what INI stands for. I include here members of the Management Committee, the Development Board and the Scientific Steering Committee.

It is a particular pleasure this year to welcome Professor Valerie Isham, Professor of Probability and Statistics at UCL and recently President of the Royal Statistical Society, as the first female chair of the Scientific Steering Committee. Professor Isham is no stranger to INI, having been an organiser of programmes, but this is her first involvement on the other side of the fence.

I hope you enjoy reading the rest of the 2013–14 Annual Report.



[1] BBSRC (Biotechnology and Biological Sciences); EPSRC (Engineering and Physical Sciences); ESRC (Economics and Social); NERC (Natural Environment); STFC (Science and Technology Facilities Council)
[2] www.newton.ac.uk/devboard/
[3] www.simonsfoundation.org/
[4] Available at sms.cam.ac.uk/media/1685333
[5] Available at www.newton.ac.uk/seminar/20140623100010451

Science at the Institute

Valerie Isham
Chair of the Scientific Steering Committee

This is my first year as a member and chair of the Scientific Steering Committee (SSC) and I am already greatly impressed by the range, depth, diversity and high quality of the proposals that are submitted to INI. At the May meeting twelve proposals were reviewed and three accepted. By the July deadline seven had been resubmitted following revision in the light of referees' comments and guidance from this committee, and five new proposals had been received. The proposals are usually highly interdisciplinary (both between mathematical disciplines and between mathematics and other disciplines) so that it is often difficult to characterise them. Nevertheless there were roughly equal numbers in pure mathematics, applied mathematics (across many disciplines) and statistics (pure and applied), with several others involving mathematics, statistics and computing in equal measure. A schematic showing the upcoming programmes can be found on the inside back cover.

Comparing such a wide range of proposals is a huge challenge for this committee and it relies heavily on advice from international experts (usually five for each proposal). We are very grateful to them for the time and care they take in preparing authoritative reports. There is no doubt that resubmission refines and sharpens the objectives of a proposal but the danger of accumulating large collections of highly refined, excellent proposals which cannot be run for lack of time or money needs to be avoided. For this reason the policy of increasing from two to three the number of proposals that can be run in parallel is a very sensible one. The SSC will monitor carefully how it works out.

Finally, on behalf of INI, I want to thank Muffy Calder (Scotland's Chief Scientist), Wilf Kendall (Warwick) and Endre Süli (Oxford) whose terms on the committee are coming to an end for their extremely valuable contributions to the SSC. The INI is greatly in their debt.

Scientific Steering Committee

Membership of the Scientific Steering Committee at 31 July 2014 was as follows:

Name	Institution	End of Service
Professor Helen Byrne	University of Oxford	31 Dec 2017
Professor Muffy Calder	University of Glasgow	31 Dec 2014
Professor Steve Cowley	Atomic Energy Authority	31 Dec 2016
Professor Michael Harris	Institut de Mathématiques de Jussieu	31 Dec 2016
Professor Valerie Isham (Chair)	University College London	31 Dec 2017
Professor Wilfred Kendall	University of Warwick	31 Dec 2014
Professor John Lygeros	ETH Zürich	31 Dec 2015
Professor Sylvia Richardson	University of Cambridge	31 Dec 2015
Dr Emily Shuckburgh	British Antarctic Survey	31 Dec 2016
Professor Endre Süli	University of Oxford	31 Dec 2014
Professor Richard Thomas	Imperial College, London	31 Dec 2015
Professor John Toland	Director, Newton Institute	30 Sep 2016
Professor Cédric Villani	Institut Henri Poincaré	31 Dec 2015
Professor Keith Ball (*ex-officio*)	ICMS	–

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**.

Polynomial Optimisation

15 July to 9 August 2013

www.newton.ac.uk/event/POP/

Report from the Organisers:
Jörg Fliege *(Southampton)*, Jean-Bernard Lasserre *(Toulouse)*, Adam Letchford *(Lancaster)* and Markus Schweighofer *(Konstanz).*

Optimisation problems in which the objective and constraint functions are polynomials have recently attracted considerable attention for the following reasons. First, this class of problems is extremely general and includes not only linear and convex quadratic programming but also a range of continuous and discrete NP-hard problems. Second, there are many important practical applications in operational research, statistics, computer science, engineering and the physical sciences. Third, it is inherently inter-disciplinary. Particular care was taken to ensure that the programme participants came from a wide variety of academic backgrounds.

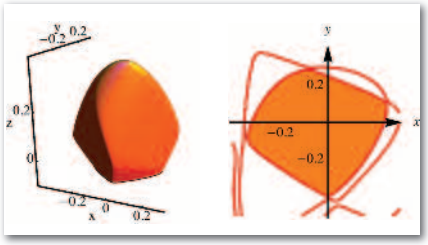
participants came from a wide variety of academic backgrounds

During the programme it was abundantly clear that polynomial optimisation continues to motivate several highly interesting problems in mathematics (e.g., representations of convex semi-algebraic sets as spectahedra, representations of polynomials as sums of squares, bounds on the algebraic degree of optimal solutions etc.). Semi-definite programming (and closely-related techniques such as co-positive programming and eigenvalue optimisation) was highlighted several times as a key tool in obtaining non-trivial relaxations and approximations of NP-hard polynomial optimisation problems. Additional techniques, such as algorithmic versions of Hilbert's Nullstellensatz, and methods for computing Gröbner bases, also played a role.

The programme began with several distinguished introductory lecture series chosen to reflect the breadth of mathematics (pure, applied, computational, optimisation and operational research) that would be involved.

- *Some Recent Uses of Convex Programming in Data Science* by Emmanuel Candès (Stanford)
- *Nonlinear Semidefinite Optimization* by Michal Kocvara (Birmingham)
- *Algebraic and Geometric Ideas in the Theory of Discrete Optimisation* by Jesús De Loera (California, Davis)
- *Semidefinite Programming and its Feasible Sets* by Tim Netzer (Leipzig)
- *Convex Algebraic Geometry* by Bernd Sturmfels (California, Berkeley)

The remaining programme involved three specific topics: (i) Algebraic Approaches; (ii) Convex Relaxations and Approximations; and (iii) Algorithms and Software.



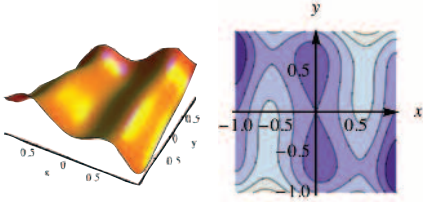
An example of a spectrahedron

An *Open for Business* event was held, to facilitate interactions between academia and industry. Among the attendees were representatives from IBM, MOSEK, Radio Design, the Numerical Algorithms Group (NAG), the European Space Agency (ESA), and the Industrial Mathematics KTN, along with independent consultants. The representatives from MOSEK and NAG explained the current features of their optimisation software. The delegate from IBM discussed some optimisation problems arising in the production and transmission of electricity. The delegate from ESA explained a multitude of very complex optimisation problems arising in space engineering, in particular spacecraft trajectory optimisation. A particular highlight of the event was the talk by the speaker from Radio Design, and the following discussion. It turned out that his problem,that of designing and tuning radio frequency filters, was essentially a problem of optimising the degree and coefficients of a rational function. The academics present were able to offer immediate helpful advice, which has led to a joint project between Radio Design and Professor Kocvara (Birmingham).

FACT FILE

Total participants on programme and workshops: 95

Gender Balance:
Male: 73 Female: 22



Graph of the polynomial
$15x^2 - 30x^4 + 15x^6 + 2xy - 3y^2 + 4y^4$

Infectious Disease Dynamics

19 August to 13 September 2013

www.newton.ac.uk/event/IDD/

Report from the Organisers:
Chris Dye (WHO), John Edmunds (London School of Hygiene and Tropical Medicine), Julia Gog (Cambridge), Bryan Grenfell (Princeton), Hans Heesterbeek (Utrecht), Valerie Isham (University College London) and Denis Mollison (Heriot-Watt).

Since the Epidemic Models (1993) programme during the Institute's first year, the field of Infectious Disease Dynamics has become rich and highly multi-disciplinary, aimed at understanding the dynamics, control and intervention effects of human and animal infections, both fundamentally and as applied to relevant public health concerns. Not only have the number and diversity of researchers grown tremendously, but also the tools used, data available, and questions studied, have changed. For example, there is now much better understanding of the way in which various characteristics of individuals, populations and infectious agents - such as genetic composition, age, social interaction, life history and location - influence, and are influenced by, the dynamics of infectious diseases. Data, mathematical and statistical methods, and computational tools, have evolved accordingly. For example, genetic, immunological, social, contact, spatial, ecological and movement data are increasingly collected because analysis of models has shown the importance of the corresponding of these factors. This evolution has brought an increased understanding of key processes and mechanisms, and stronger ties to veterinary and human public health decision making. The goal of the programme was to:

- take stock and set an agenda for future research;
- determine the main challenges, both in understanding and public health needs, and in methodology;
- take a systematic look at the use of models to inform public health decisions, and to analyse where and why models fail in their predictions (learning from past performance);
- foster collaboration and nurture a new generation of talented researchers by working on concrete research activities.

FACT FILE

Total participants on programme and workshops: 102

Gender Balance:
Male: 73 Female: 29

Outcomes and Achievements

- Sessions on the vision for the future were held on: design of experiments and statistical inference, stochastic methods, deterministic methods, social and spatial contact structure, evolution of virulence and resistance, phylodynamics, multi-host and multi-agent systems, immuno-epidemiology, decision-making in public health, priorities for HIV, for malaria and for neglected tropical diseases. A short hands-on course on phylodynamic methods was conducted.
- The programme resulted in a special issue of the journal *Epidemics* dedicated to *Challenges in Modelling Infectious Disease Dynamics* which will appear in December 2014. The intention is that the present generation of young scientists will have a well-argued set of excellent challenges to address. Collaborative work on key themes identified during the programme was started.
- There was a keynote address by Sir Roy Anderson (Imperial College) who provided his vision on the use of models for public health and the future needs for, and potential contributions of, the field to public health policy.
- A lively pair of lectures and a public debate on the role of badger culling in bovine tuberculosis control strategy culminated in an article in The Sunday Times.

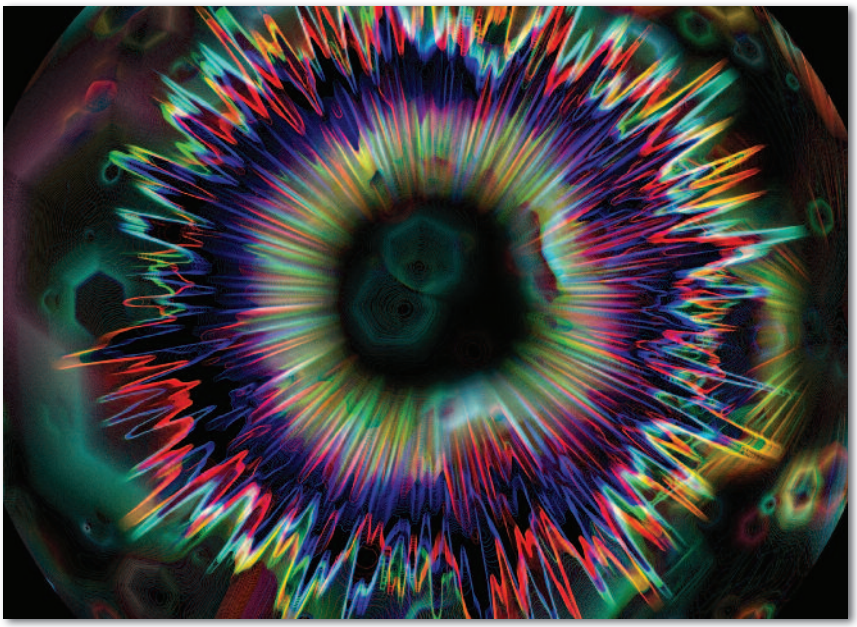
- There was a particular emphasis on links to public health decision-making, and the programme held a successful *Open for Business* event on *Mathematical Modelling for Public Health*.
- A review paper, summarising the field and its future directions, for the benefit of public health officials and a general scientific audience is being prepared for a prominent general science journal.

Mathematical Challenges in Quantum Information

27 August to 20 December 2013

www.newton.ac.uk/event/MQI/

Report from the Organisers:
Organisers: Richard Jozsa (Cambridge), Noah Linden (Bristol), Peter Shor (MIT) and Andreas Winter (Bristol/Barcelona).



The crucial role of information processing and communication in modern society makes the transformative potential of quantum information science for 21st century technology immense. The subject of quantum information ranges from the foundations of quantum mechanics and the physical limitations of information processing to technological issues such as the exploitation of quantum physics, to obtain exponentially enhanced computing power and novel possibilities for communication and information security. It is a highly cross-disciplinary field with essential inputs from computer science, information theory, quantum physics, engineering and mathematics, include the use of random states and operations, methods from operator theory, functional analysis and convex geometry. Although the range of techniques already used is wide, expertise is dispersed and it is clear that other areas of mathematics have much to contribute.

> **A scientific highlight of the programme was the resolution of the "Gaussian optimizer conjecture",**

Indeed the need to improve the subject's mathematical connectivity was a key motivation for the programme which was built around the participation of international experts in quantum information theory. With large numbers of visiting fellows, it is impossible to record all the discussions that took place and their impact. However the hoped for increase in mathematical sophistication was quickly realised. Indeed many of the key break-throughs were made by early-career researchers who were new to the field and brought perspectives from different backgrounds. To illustrate the general picture here are two examples: one concerns an important scientific breakthrough and the other recalls a chance encounter between different communities who interacted at the Institute.

A scientific highlight of the programme was the resolution of the "Gaussian optimizer conjecture", whose proof by visiting fellows Raul Garcia-Patron, Vittorio Giovannetti and Alexander Holevo concluded a more than 40-year quest for the capacity of bosonic quantum channels. The breakthrough followed their unsuccessful attempt during the programme to find a counter-example! The new technique which emerged is elegant and yields a refined understanding of bosonic channel capacity beyond its numerical determination. However it does not settle a stronger conjecture, the so-called Entropy Photon Number Inequality, thus fuelling renewed interest in this deep question which has broad ramifications in quantum information theory. An INI Case Study on the programme is available online at **www.newton.ac.uk/files/reports/casestudies/quantum.pdf**.

FACT FILE

Total participants on programme and workshops: **224**

Gender Balance:
Male: 196 Female: 28

Rothschild Distinguished Visiting Fellow:
Alexander Holevo

Microsoft Visiting Fellow:
Dong Yang

This field is now the subject of major investment by the UK government, news of which was announced during the programme and is now embodied in an EPSRC call for a National Network of Technology Hubs.

During September/October there was a parallel programme in the Institute on the *Mathematics and Physics of the Holographic Principle*. This led to a series of very fruitful joint discussions on the black hole firewall question – whether an observer, upon falling into a black hole old enough to be maximally entangled with its environment, would be burned up immediately at the hole's event horizon, rather than surviving to be destroyed later, as previously thought.

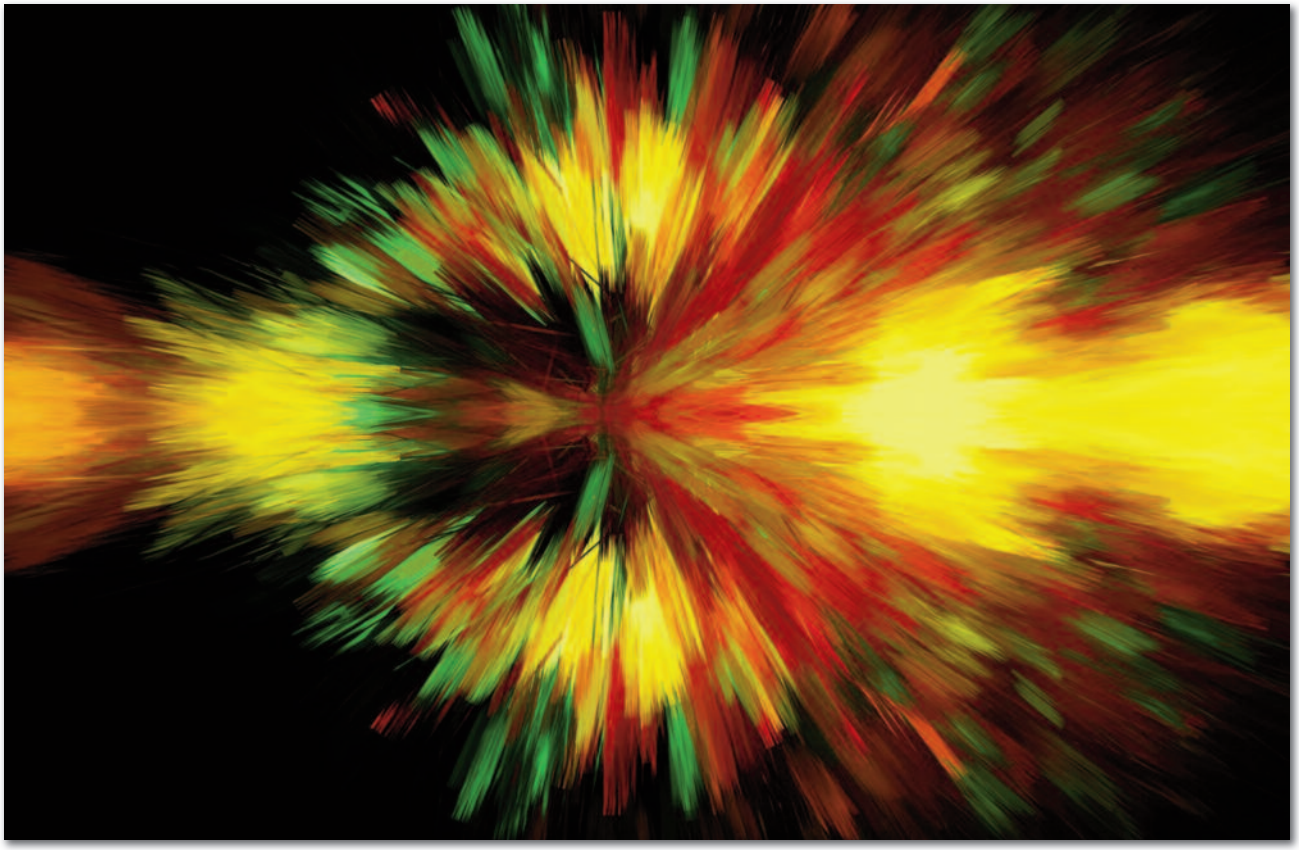
There were three workshops during the programme. The first made a conscious effort to include speakers from outside quantum information; it did an excellent job in setting the tone of the whole programme.

The second was on quantum marginals, an area where long-standing difficult problems are yielding to new techniques from convex analysis and random matrix theory and there are emerging links to algebraic and symplectic geometry, and asymptotic representation theory. The final meeting was supported by the Heilbronn Institute, and it was focussed on issues of quantum computational complexity and algorithms.

A remote lecture was delivered from Stanford University in the USA by Patrick Hayden on *The computational complexity of entanglement detection* and the programme held a Q+ google hangout, delivered by Renato Renner from ETH Zurich on the topic *Does freedom of choice imply that the wave function is real?* In addition, a number of programme participants were invited speakers to the *UCL-Paris Quantum Connection*, a 2-day meeting at University College, London in November.

Follow up meetings are planned: for example, Andreas Winter (Barcelona), Nilanjana Datta (Cambridge), Renato Renner (ETH Zurich) and Mark Wilde (LSU Baton Rouge) made a successful bid for a week-long workshop *Beyond IID in Information Theory*, to be held in July 2015 at the Banff International Research Station (BIRS).

This field is now the subject of major investment by the UK government, news of which was announced during the programme and is now embodied in an EPSRC call for a *National Network of Technology Hubs*. The Institute Director and programme participants took part in a consultation exercise with GCHQ to advise on a forthcoming funding call.



Mathematics and Physics of the Holographic Principle

16 September to 11 October 2013

www.newton.ac.uk/event/HOL/

Report from the Organisers:
Antonio García-García (Cambridge/Lisbon), Hong Liu (MIT) and Jan Zaanen (Leiden)

Holographic duality (also called gauge/gravity duality or the AdS/CFT correspondence) relates a string theory — i.e. a quantum theory of gravity — to a strongly interacting quantum field theory without gravity. The versatility and generality of the holographic principle has many applications beyond string theory, first in the context of the quark-gluon plasma physics and more recently in condensed matter and statistical physics, and it is rapidly coming to the forefront in theories of subjects as diverse as superconductivity and exotic phases of strongly coupled quantum matter in- and out-of-equilibrium, numerical relativity and partial differential equations. This programme was a recognition that holographic duality is now a powerful mainstream tool for tackling problems where traditional methods had proven inadequate.

There was a strong emphasis on cross-fertilization between experts in the far-from-equilibrium dynamics, quantum information, string theory and numerical relativity communities. An important theme throughout was the far-from-equilibrium evolution of strongly interacting systems. This is a booming research theme in condensed matter and cold atom physics because of the recent experimental identification of novel transient states of quantum matter and the conditions for reaching thermal equilibrium. Holography is one of the very few tools, especially in more than one spatial dimension, that yield quantitative results in this problem. An important goal of the programme was to turn predictions by the holographic principle into quantitative descriptions of the out-of-equilibrium dynamics of realistic, strongly interacting systems in condensed matter and related disciplines.

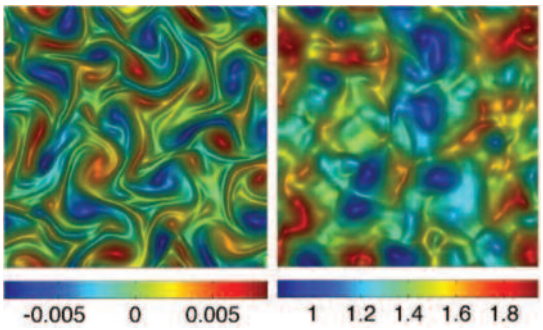


Fig. 1: The boundary vorticity (left) and the horizon area element (right) for a time for which turbulence is fully developed. These results were first presented in the workshop and are now published in Phys. Rev. Lett. 112, 151602 (2014)

The workshop *Holography: From Gravity to Quantum Matter*, was an extraordinary meeting of the most distinguished AdS/CFT practitioners, leading researchers in condensed matter theory, and numerical relativists. Experimentalists in condensed matter, cold atom, and quantum information theory further stimulated the research agenda. Some cross-fertilizations were:

- The discovery by a leading expert in numerical relativity that a perturbation in an AdS background leads to the formation of a black hole which, in the field theory dual, implies that a quantum quench always leads to full thermalization for sufficiently long times;
- Holographic duality was applied to high dimensional field theories by a systematic expansion in the inverse of the spatial dimensionality. In condensed matter it is well known that this approximation is usually a fair description of the 3+1 dimension case with the advantage that analytical results are available;
- A holographic description of fully developed turbulence, including Kolmogorov 5/3 law. Remarkably the calculation in the gravity dual is more stable and requires much less computing effort. Moreover the fractal turbulence of the boundary fluid is dual to a black hole event horizon turning it into a fractal manifold (Fig. 1);
- Substantial progress in tailoring holographic strange metals to be more realistic by including the background ionic lattice encountered by the electrons when they move through the solid. Such a lattice influences strongly the transport properties of strange metals and the first results are very promising.

Although there have recently been many international meetings on this theme, there was a consensus among participants that this programme was an important one of the very highest quality by any standards.

FACT FILE

Total participants on programme and workshops: **113**

Gender Balance:
Male: 104 Female: 9

Mathematics for the Fluid Earth

21 October to 20 December 2013

www.newton.ac.uk/event/MFE/

Report from the Organisers:
Mike Cullen (Met Office), Klaus Fraedrich (Hamburg), Valerio Lucarini (Hamburg/Reading), Beatrice Pelloni (Reading) and Sandro Vaienti (Marseilles).

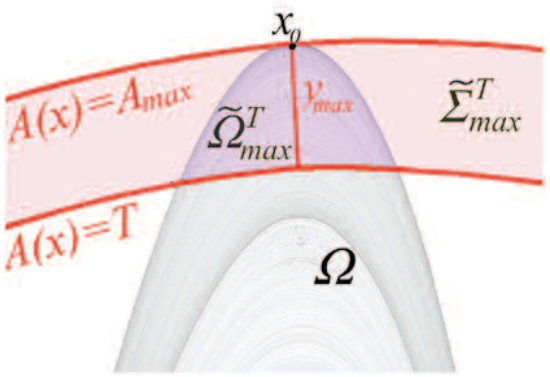


Figure 1: The extremes of the observable A(x) for a dynamical system possessing attractor Ω can be studied by looking at the geometry of the intersection between the attractor and the level sets of A(x)

Background

Atmospheres and oceans, with their variability on a vast range of spatial and temporal scales and sensitivity to initial conditions, can be considered as complex dynamical systems and it often suffices to model their behaviour using simplified versions of the partial differential equations that govern their motion. However to model the occurrence of extreme events the statistical properties of solutions of more realistic nonlinear models must be considered. Progress in our understanding of such systems necessitates a collaboration between mathematicians working on dynamical systems and in ergodic theory and more applied researchers working in nonlinear physics and climatology. The purpose of this programme was to nurture that collaboration: the study of the statistical properties of dynamical systems, in particular the study of extreme value distributions and perturbations, being a bridge between the two communities.

To prepare, *Satellite Meetings* on *Non-equilibrium Statistical Mechanics and the Theory of Extreme Events in Earth Science* and on *Mathematics for the Fluid Earth*, which covered a wider range of topics, were held in Reading and London before the programme began.

Scientific outcomes

There were highly successful workshops on extreme events and geophysical fluid dynamics, with experts in partial differential equations, meteorology, oceanography and geophysical fluid dynamicists taking part. Considerable progress was made on time averaging and the convergence to asymptotic-limit solutions of multi-scale systems. The advantages and disadvantages of the semi-geostrophic equations and slow dynamics in the semi-geostrophic limit were widely discussed because they explain certain observed coherent structures but do not explain stratified turbulence and other motions that occur on smaller scales. Moreover, more realistic extensions of the semi-geostrophic system to the variable rotation case, and results on the uniqueness of solutions required if semi-geostrophic solutions are to be regarded as limiting solutions of the Euler equations, were obtained by optimal transport methods.

The purpose of this programme was to nurture that collaboration: the study of the statistical properties of dynamical systems, in particular the study of extreme value distributions and perturbations, being a bridge between the two communities.

FACT FILE

Total participants on programme and workshops: 119

Gender Balance:
Male: 105 Female: 14

Rothschild Distinguished Visiting Fellow:
David Ruelle

Microsoft Visiting Fellow:
Isabelle Gallagher

There is a rapidly expanding body of knowledge connecting extremes in dynamical systems with the basic properties of such systems. The programme focused on a theory of extremal index and a geometric approach to extreme values which are particular useful when constructing robust algorithms for studying the spatial structure of extremes starting from time series.

Another qualitative description of the atmospheric system regards it as a thermodynamical system and is based on an extension of Ruelle's theory of linear response. (David Ruelle, who participated throughout, learned of the award of the 2014 Max Planck Medal by the Deutsche Physikalische Gesellschaft during the programme.) This point of view, which provides a very general framework for understanding the behaviour of systems, was much debated at the meeting.

About the impact of low-dimensional dynamical-systems theory on our understanding of more complex systems such as those arising in atmosphere and ocean science David Ruelle wrote:

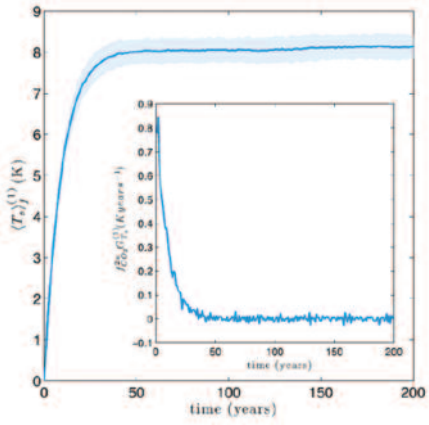


Figure 2: Using the Ruelle Response theory, it is possible to construct the Green function describing the response of the globally averaged surface temperature to increasing CO2 concentrations

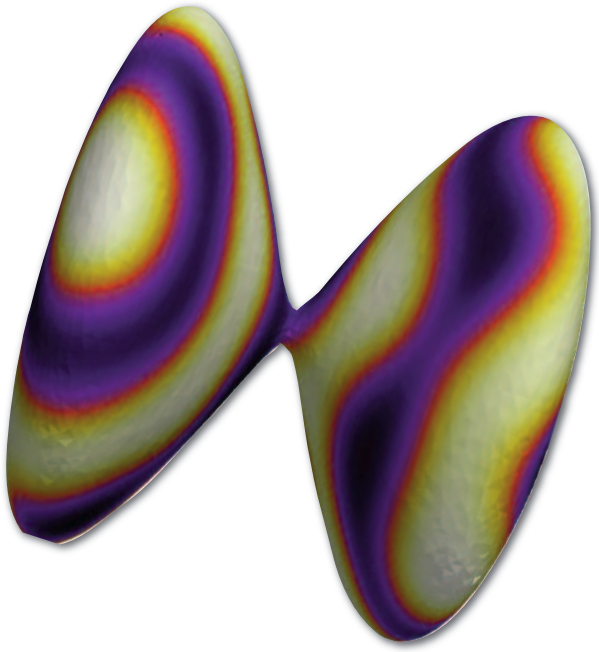
"the present programme has put together two somewhat distant scientific areas, in a way that makes perfect sense, but need not be easy to realize. This challenge has been met in a very satisfactory way by the MFE programme".

Free Boundary Problems and Related Topics

6 January to 4 July 2014

www.newton.ac.uk/event/FRB/

Report from the Organisers:
Gui-Qiang Chen (Oxford), Henrik Shahgholian (Stockholm) and Juan Luis Vázquez (Madrid)



Free boundary problems (FBPs) concern partial differential equations (PDEs) on domain for which part of the boundary (called the free boundary) is not specified but is part of the solution. Typically they arise in phase separation problems where the boundary, the location of which is part of the problem, may be either stationary or moving. The challenge is to determine both the free boundary and the solution of the PDE. For example, when a block of ice floating on water melts, the interface between ice and water is a moving free boundary. It must be found, after which the solution of the PDE gives the temperature distribution in the ice and water phases. Because FBPs are hugely important in PDE theory and ubiquitous in applications, new methods are constantly needed to address challenges arising from diverse areas in science, technology and beyond. This has led to independent developments being made even when the underlying ideas have common mathematical themes.

Therefore an important aim of this programme was to unify FBP techniques, mainly in the areas of Analysis of PDEs; the Calculus of Variations, Conservation Laws, Differential Geometry, and Numerical Analysis (numerical methods to capture the evolution of interfaces is a major challenge in computational mathematics), with a view to encompassing many applications. It also aimed to enhance the interaction between UK mathematicians and leading international researchers. The first event with an introductory school, FBPs and Related Topics, to provide background material on current research and to set the scene for much of what was to come. Five leading experts offered short courses, open to all but targeted at young researchers, on the regularity of free boundaries in obstacle-type problems, models for tumor growth, numerical methods, geometric approaches to water-wave and free-surface flows, and problems involving long-distance interactions modelled by fractional Laplacians.

A satellite workshop in Oxford on Free Boundaries and Moving Interfaces was to promote interaction between the FBP community and researchers working on fluid-flow equations such as the Euler, Stokes, quasi-geostrophic and Navier-Stokes equations, Hele-Shaw flows and Muskat problems. A second satellite workshop at Warwick on Recent Developments and Challenges in Interface and Free Boundary Problems focused on problems arising in physics, engineering, industry, finance, biology.

FACT FILE

Total participants on programme and workshops: **176**

Gender Balance:
Male: 141 Female: 35

Rothschild Distinguished Visiting Fellow:
Luis Caffarelli

Turner-Kirk Fellows:
- **Gui-Qiang Chen**
- **Charles Elliott**
- **John King**
- **Juan Luis Vázquez Suárez**

An International Conference on FBPs, Theory and Applications was structured to identify the common challenges that have the greatest potential for research, knowledge transfer, public policy and commercial impact. In addition an event involving leading experts in biology and medicine who require mathematical modelling and computation of free boundaries in their research was held under the auspices of the *Turing Gateway to Mathematics*

www.turing-gateway.cam.ac.uk/frb_jun2014.shtml

> **The purpose of this programme was to nurture that collaboration: the study of the statistical properties of dynamical systems, in particular the study of extreme value distributions and perturbations, being a bridge between the two communities.**

The Rothschild Distinguished Visiting Fellow, Luis Caffarelli (University of Texas-Austin) who is a major figure in the field of FBPs and in the geometric analysis of PDEs more generally, was very influentially involved in the programme and gave a beautiful Rothschild lecture. The long list of active participants included many distinguished figures in pure and applied mathematics related to FBPs.
A regular weekly seminar was complemented by informal lunchtime sessions for the free discussion of ongoing research or recent work, and by introductory talks on central topics, open problems and emerging directions in the field.

As a consequence, new collaborations and new research projects that will shape the field in the near and far future have emerged. Together with SkYpE conversations, streamed lectures (viewed either in real time or later) these activities have meant that colleagues in the UK around the world who were unable to attend in person have had an opportunity to contribute to the scope of the programme and to benefit from it. Informal discussions, seminars and individual interactions of all sorts, were essential to the success of the programme.

The permanent archive of videoed lectures from the programme will form an important source of material for researchers worldwide, extending the impact of the programme far into the future. Moreover a planned special issue of Philosophical Transactions of the Royal Society will consist of survey articles that include discussions of open problems and recent developments in free-boundary theory that were identified during the programme. Also a special issue of the European Mathematical Society journal Interfaces and Free Boundaries will comprise papers by participants on their research findings during the programme.

Inference for Change-Point and Related Processes

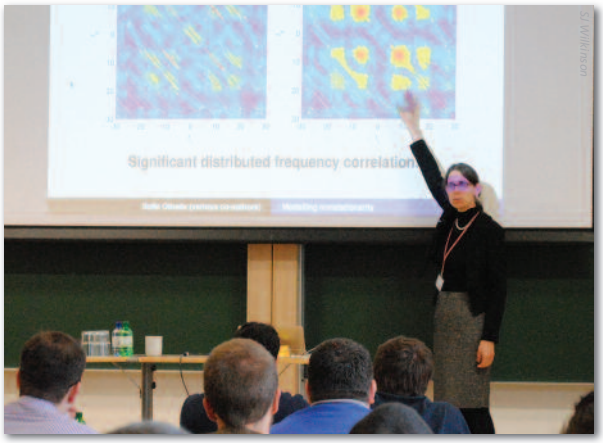
13 January to 7 February 2014

www.newton.ac.uk/event/ICP/

Report from the Organisers:
John Aston (Cambridge), Idris Eckley (Lancaster), Paul Fearnhead (Lancaster) and Georgy Sofronov (Macquarie).

In the age of "Big Data", it is unreasonable to assume that long time series of complex data are stationary, and change points are to be expected. Often these change points are of primary interest, as in high-profile applications to climate change or the recent financial crisis. Issues of detecting such changes, or allowing for uncertainty about future changes, are important practical problems that require novel statistical methods. At the same time there have been significant advances in the statistical theory of change points, from the theoretical underpinnings for high dimensional data to the algorithmic implementations of change-point routines, that can be used on massive data sets.

The focus of this programme was to bring together researchers from the methodological areas of change-point analysis and locally-stationary time series analysis, and to highlight a wide variety of applications in which they can interact. Many researchers in these methodological areas work independently on similar problems, and an aim of the programme was to build links between them. With this in mind, the programme was organised into four distinct themes. The first was dealt with in a workshop that focused on methodological issues. The other three concentrated on broad areas of application: Economics and Social Science, Energy and Environment, and Biomedicine.



Visiting Fellow Sofia Olhede gives a lecture at the workshop

The workshop began with keynote lectures by Rainer Dalhaus (Heidelberg) on *Locally Stationary Processes*, David Siegmund (Stanford) on *Change-Point Analysis*, and Guy Nason (Bristol) on *Wavelet Analysis for Non-stationary Time Series*. Together they gave an overview of the state of the art in locally-stationary time series and change-point analysis. In all there were 34 presentations. With a roughly even split between the two areas they covered a huge range of theoretical, methodological and applied statistics.

Theme 2, which considered applications to finance, demography, and social network analysis, produced one of the highlights of the programme: namely an insight into the relevance of change-point analysis and local stationarity in the study of social network graphs .

The third theme focused on applications that include wind energy, climate change and emissions monitoring, where diverse change-point and time-series questions present statisticians with challenging methodological and theoretical questions, the answers to which would have significant impact.

The final theme considered biomedical applications such as the detection of changes in DNA copy number variation and structural analysis of EEG signals which participants considered particularly important.

The programme was successful because researchers from different areas, who had little or no previous interaction, established collaborations and shared ideas. This was facilitated by several interesting initiatives during the programme, including virtual seminars that allowed participants who were unable to travel to present their work at the programme, and "Ideas Lunches", where individuals who had connections in their work but did not know each other were identified and given the opportunity to dine together. A number of different collaborations were initiated during the programme.

Many participants indicated that this 1-month programme was ideal as a starting point for further developments of the area, but that a longer programme at INI in a few year's time would be a natural next step.

FACT FILE

Total participants on programme and workshops: 94

Gender Balance:
Male: 74 Female: 20

Microsoft Visiting Fellow:
David O Siegmund

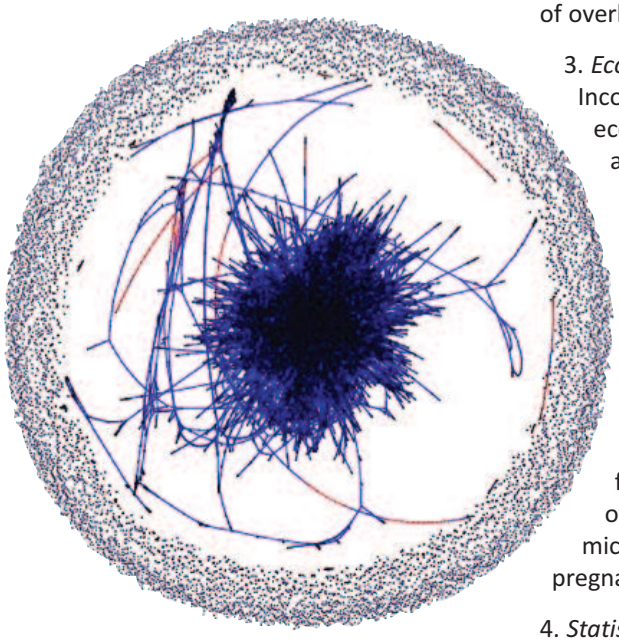
Mathematical, Statistical and Computational Aspects of the New Science of Metagenomics

24 March to 17 April 2014

www.newton.ac.uk/event/MTG/

Report from the Organisers:
Wally Gilks (Leeds), Daniel Huson (Tübingen), Elisa Loza (Rothamsted Research), Simon Tavaré (Cambridge), Gabriel Valiente (Technical University of Catalonia) and Tandy Warnow (Texas at Austin).

Metagenomics is a new discipline in which microbiomes are studied using DNA sequencing. Metagenomic experiments offer unprecedented opportunities for science and industry but generate huge amounts of data and present formidable analytical and computational challenges. To forge new multidisciplinary research teams around these problems and techniques, this programme brought together mathematicians, statisticians, computer scientists, bioinformaticians, biologists, biomedical scientists, ecologists and agronomists.



A De Bruijn graph of two metagenomes, coloured red and blue. Nodes represent distinct 20-mers, and edges are drawn connecting 20-mers that overlap by 19 basepairs. Image courtesy of D Koslicki.

Research strands

1. *Taxonomic profiling* aims to estimate the relative abundances of microbial taxa in a metagenomic sample. A new profiling method was shown to be capable of estimating relative abundances at finer taxonomic levels than previously possible.

2. *Reference-free methods*. Because only a small percentage of reads in a metagenomic sample map unambiguously to fully sequenced reference genomes, analyses that do not involve referencing can give a more complete picture than taxonomic profiling. Approaches based on k-mers (subsequences of length k) in the sample were studied and the complexity function (the number of unique k-mers as a function of k) was found to give insight into the diversity of a given set of reads, in particular when viewed through the De Bruijn graph of overlapping k-mers.

3. *Ecological modelling*. Incorporating ideas from ecological modelling, statistical approaches relating microbial community structure and phylogeny were developed, as were statistical mixture models for disaggregating microbial data. Models were applied to two specific metagenomic datasets: one showed the influence on microbial communities of fertilizer in agriculture and the other showed that the vaginal microbiome is more stable in pregnant women.

4. *Statistical design*. In addition to the usual experimental design techniques in biology, metagenomic experimental design should consider the pooling of samples and the trade-off between sample size and DNA sequencing depth. Paired and balanced block designs, which are easily implemented using DNA barcoding and multiplexing, and the use of prior information on the likely ranges of model parameters, were proposed.

FACT FILE

Total participants on programme and workshops: 67

Gender Balance:
Male: 50 Female: 17

5. *Seeking the fourth domain of life.* The three known domains of life are the Eukaryota (animals, plants and fungi), the Bacteria, and the Archaea (found in soils, oceans and the human gut). Programme Participant Eddy Rubin stimulated debate by asking "Is there a fourth domain?" Statistical bioinformatic approaches to this open problem were examined.

6. *Critical Assessment of Metagenome Interpretation (CAMI).* The interpretation of metagenomic data is sophisticated and computationally intensive. Despite tremendous methodological progress, existing approaches invariably rely on simplifying assumptions that can lead to inaccuracies. To address the hitherto *ad-hoc* assessment of these computational methods, a *Follow-up Meeting*[1] in the format of a one-week hackathon for developers of metagenomic software was held at INI in September 2014.

[1] http://blogs.nature.com/methagora/2014/06/the-critical-assessment-of-metagenome-interpretation-cami-competition.html

Advanced Monte Carlo Methods for Complex Inference Problems

22 April to 16 May 2014

www.newton.ac.uk/event/MCM/

Report from the Organisers:
Rong Chen (Rutgers), Dan Crisan (Imperial College London), Arnaud Doucet (Oxford), Simon Godsill (Cambridge), Ajay Jasra (Singapore) and Sumeetpal Singh (Cambridge).

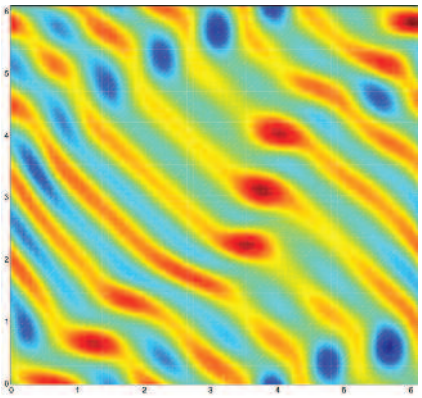
The availability of data sets which are analytically challenging is ever increasing in areas such as Ecology, Epidemiology and Genetics. The stochastic models that represent the data generating processes are high dimensional and the only computationally feasible and accurate way to perform statistical inference is with Monte Carlo. Over the past several years a few techniques have emerged as being effective and have genuinely enthused Statisticians: Approximate Bayesian Computation, Sequential Monte Carlo (SMC) and Markov Chain Monte Carlo (MCMC).

The challenges these complex models pose have led to the development of algorithms of increased technical sophistication. For example, recently MCMC and SMC have been combined to give rise to a class of algorithms that accurately approximate "idealised" algorithms that themselves cannot be implemented but are favoured due to the accurate results they would yield.

FACT FILE

Total participants on programme and workshops: 80

Gender Balance:
Male: 78 Female: 12



Estimated posterior mean of predicted vorticity for a 2D velocity field using Sequential Monte Carlo in the context of Eulerian Data Assimilation. The velocity field evolves on a torus according to the 2D Navier-Stokes equations and is initialised using an appropriate Gaussian Process (Image courtesy of Nikolas Kantas)

A major challenge is to articulate a general theory for such constructions. The aim of the programme was to assemble the leading experts, covering theory and practice, in order to bridge gaps in understanding of the mathematical properties of these methods and to address the fundamental challenge of designing effective Monte Carlo methods for complex statistical problems.

A workshop covering the major themes started the programme and was a catalyst for the remaining three research intensive weeks. The talks included introductory elements aimed at acquainting new researchers with the subject area. It was cross-disciplinary with contributions from Engineers, Mathematical Biologists and Statisticians, but they were coherent in their message: real problems involve complex models with many random variables, and these are costly to evaluate. Practical inference techniques must scale well with the data without compromising accuracy and efficiency.

The workshop was well attended, swelled by daily attendees, and seeded new ideas for the research intensive period that followed in which participants delivered seminars and engaged in roundtable discussions. Problems discussed included practical SMC for high-dimensional models, MCMC for large data sets, Information Geometry in MCMC and Stochastic Approximation in high dimensions.

The participants embraced opportunities for collaboration with enthusiasm: some involved their respective research teams overseas in collaborative discussions via video conferencing, some organised visits to the Institute for their Industrial collaborators, some travelled within the UK to give seminars and set up new links. There were surprises too: two groups working independently on SMC for Graphical Models came to know about each others work and combined forces. Grant proposals have arisen and a proposal to bring a large international Engineering conference to Cambridge has been submitted.

> **The participants embraced opportunities for collaboration with enthusiasm...**

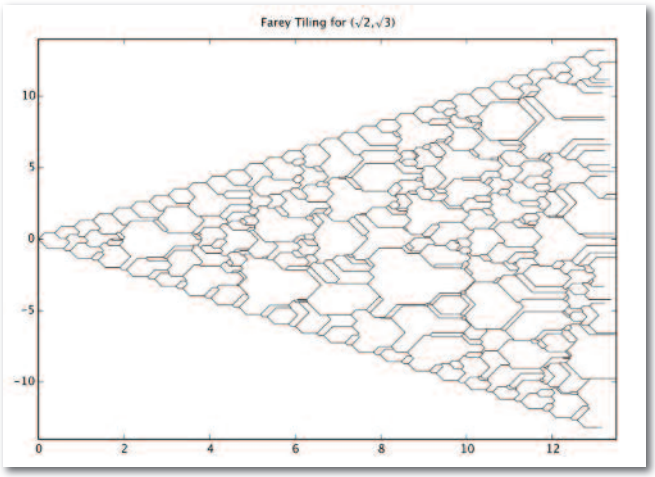
Other than new collaborations, an important measure of success is the new publications that are generated. It is early days but there were announcements of new results, e.g. Dr. Lee's new insights into exact Simulation using SMC, Dr. Heine's new parallelizable resampling strategies for SMC.

Interactions Between Dynamics of Group Actions and Number Theory

9 June to 4 July 2014

www.newton.ac.uk/event/GAN/

Report from the Organisers:
Anish Ghosh (Tata Institute), Alexander Gorodnik (Bristol) and Barak Weiss (Tel Aviv).



Dynamics of the Weyl chamber flow (Image courtesy of Y Cheung)

In the last decade there have been a number of important breakthroughs in number theory and Diophantine geometry, where progress on a longstanding problem has been achieved by utilising techniques originated from the theory of dynamical systems. The aim of this programme was to explore and expand this promising and far-reaching interplay.

The programme brought together close to fifty experts and young mathematicians working in ergodic theory, Diophantine approximation and analytic number theory. The programme was preceeded by an introductory school that was intended for postgraduate students, postdocs as well as more senior mathematicians who wanted to get a head start and learn more about related topics. The first three weeks comprised of a few talks every day with the majority of the day left free for participants to discuss mathematics with each other. The stimulating atmosphere of the programme and the lovely ambience of the Isaac Newton Institute were very popular with the participants and resulted in a very productive time. During the last week of the programme there was a workshop that covered the latest developments in the field.

The participants judged the programme to be an overwhelming success, and it is likely to have a substantial scientific impact in the years to come. Many new collaborations were started and significant progress was made on many others. Thomas Ward made progress on a book which he is writing jointly with M Einsiedler and E Lindenstrauss titled *Entropy in dynamics*. J An, V Beresnevich, and S Velani made progress on a joint paper on the topic of Schmidt Games and SG Dani and A Nogueira made progress on a joint research project exploring Diophantine approximation by primitive vectors. A Ghosh, A Gorodnik and A Nevo finished their paper titled *Best possible rates of distribution of dense lattice orbits in homogeneous spaces*. J Athreya and J Chaika worked on a project on the Hausdorff dimension of non ergodic interval exchange maps, and B Kra and B Host made progress on their joint project exploring return times in dynamical systems. T Wooley obtained close to best possible estimates for Weyl sums equipped with lower order coefficients restricted to sets of measure one, motivated in part by results of Flaminio and Forni.

During this period, there were many talks by young mathematicians discussing their research, many of whom were junior members of the institute. A major highlight during the programme was a series of lectures by Y Benoist, Clay Senior Scholar in residence, on his groundbreaking work jointly with J Quint on stationary measures. Benoist's lucid and detailed lectures were very beneficial to the participants. Most participants went away with new projects and new ideas and several grant proposals are being planned as a result of consultations during the programme. As part of the INI outreach programme, Athreya, Ghosh and Gorodnik gave talks at the University of York, and Athreya, Eskin, and Chaika gave talks at Warwick University.

The programme ended with the participants keen to return for a *Follow-up Meeting*.

FACT FILE

Total participants on programme and workshops: 66

Gender Balance:
Male: 59 Female: 7

Follow-up Meetings

The Institute is constantly seeking ways to extend and add value to its programmes. To this end, *Follow-up Meetings* are short events which compliment full programmes that were held some years earlier. These are proving increasingly popular with programme organisers because they provide an effective way to strengthen collaborations started during the original programmes and are particularly beneficial because the true implications of results may emerge from developments only years after a programme has finished. *Follow-up Meetings* take place either at the Institute or at suitable venues anywhere in the UK. Short reports from the organisers on the *Follow-up Meetings* that have taken place this year are shown below.

Stochastic Processes in Communication Sciences

12–16 August 2013

Organisers: Venkat Anantharam (Berkeley), Francois Baccelli (INRIA/ENS/Texas at Austin), Sergey Foss (Heriot-Watt/Institute of Mathematics, Novosibirsk), Peter Glynn (Stanford).

The original 6-month *Stochastic Processes in Communication Sciences* programme took place in 2010 and aimed at the exposition of the latest developments in mathematical sciences lying on the boundary between the disciplines of stochastics and communications.

Probability theory and communications have developed hand in hand for about a century. The research challenges in the latter field (from telephone networks to wireless communications and the Internet) have spurred the development of the mathematical theory of stochastic processes, particularly in the theory of Markov processes, point processes, stochastic networks, stochastic geometry, stochastic calculus, information theory, and ergodic theory to name but a few. Conversely, a large number of applications in communications would not have been possible without the development of stochastics.

Building on the success of the 2010 programme, the *Follow-up Meeting* concentrated upon a number of areas that are currently attracting significant interest within the scientific community. It was organised around the three major mathematical themes of: Stochastic Networks; Random Graphs and Spatial Networks; Network Statistics and Simulations. There was a special emphasis to applications in Grid Networks; Wireless Networks; Communication Networks; and Social Networks.

The conference made an important and timely contribution to the development of modern mathematical theory, and added a valuable impulse to recent activities in the modelling and analysing of complex applied stochastic systems and networks, such as energy grid networks.

Inverse Problems

10–14 February 2014

Organisers: Malcolm Brown (Cardiff), Thanasis Fokas (Cambridge), Yaroslav Kurylev (UCL), Bill Lionheart (Manchester), William Symes (Rice) and Adrian Nachman (Toronto).

This *Follow-up Meeting* focussed on recent developments in the mathematical problems associated with and generated by two meetings held in 2011: *Analytic and Geometric Methods in Medical Imaging* and *Inverse Problems in Science and Engineering*. Since then, there has been much progress; representative examples include:

- breakthrough on the local X-ray transform by Uhlmann and Vasy;
- important work of Singer and Wu on 2-D tomography from noisy projections taken at unknown random directions;
- recovery of SPECT images from minimal data.

In the area of Industrial Seismology, the seismic inverse problem is now central to major commercial efforts, while remaining a source of very difficult computational and mathematical problems. There is ongoing work to quantify the need for very low frequency data acquisition, the possibility of effective quality control, and the very difficult problems associated with shallow geological waveguides which are prevalent in some parts of the world. Developments in this area include de Hoop's Banach space analysis of the basic inverse problem, and Plessix's techniques for estimating more than one mechanical parameter as function of position along with reliability measures. These topics will continue to grow in sophistication and economic importance in the next few years.

Another area of remote geophysical sensing in which progress has been made is landmine detection and security screening. Especially noteworthy are recent work by Ammari, Volkov, and Kang, and the initiative by the Bobby Charlton Charity to develop new landmine detection equipment.

An unexploded landmine

The National Aquatics Centre, Beijing

Foams and Minimal Surfaces: 12 Years On

24–28 February 2014

Organisers: Simon Cox (Aberystwyth) and Denis Weaire (Trinity College Dublin).

The *Follow-up Meeting* began with a broad survey of applications – some of the fundamental reasons why one would want to study foams and in particular their geometric structure – and of the contributions that Surface Evolver (a computer programme for the study of surfaces shaped by surface tension and other energies) continues to make to many branches of science, indicating the many instances of minimal and constant mean curvature surfaces in real applications. The speakers made clear that the engineering models that serve industrial needs need the input of careful modelling and simulation by the foam and minimal surface community in order to be properly grounded. Areas of current research included: fluids in microgravity; ore separation in the mining industry; improved oil recovery; and soil remediation. Further uses of Survace Evolver re-surfaced during the week, for example in soap film instabilities (Cox & Whittaker) and modelling of biological tissues (Bi).

At the original meeting in 2002, there was much discussion about the Weaire–Phelan structure, conjectured to be the most efficient partition of space into regions of equal volume, and the seminal role that Brakke's Surface Evolver played in its discovery. Since then, this foam structure generated a surprisingly large amount of public interest due to its use in the "Water Cube", the National Aquatics Center for the Beijing Olympics. In addition to its visual appeal, the design allows daylight into the building, reducing the energy required for lighting, it uses solar energy for heating, and it is seismically-resistant.

Highlights of the meeting included:

- Further debate on the optimal division of space, and the different restrictions on the Kelvin problem (of filling space) that are now being explored;
- Goldstein's talk on soap film singularities;
- Blumenfeld, Durand, and Hilgenfeldt all presented statistical methods that aim to describe geometrical and topological correlations in foams and granular materials;
- There was "robust" discussion of the effectiveness of potentials to describe bubble interactions, initiated by Höhler, in response to the rather prevalent use of models from granular materials, with undeformable grains, in the field of foams (where the bubbles are of course deformable);
- Grassia's presentation on Improved Oil Recovery with foams developed a special case of a model familiar in the foam rheology community.

The meeting finished with a bang, with a presentation from Monloubou on the effectiveness of foams in blast suppression. Commercial tests suggest that foams can provide excellent protection from blast waves, but quantitative results appear scarce, at least in the published literature.

Infectious Disease Dynamics

19 May – 6 June 2014

Organisers: Chris Dye (WHO), John Edmunds (LSHTM), Julia Gog (Cambridge), Bryan Grenfell (Princeton), Hans Heesterbeek (Utrecht), Valerie Isham (UCL) and Denis Mollison (Heriot-Watt).

This original *Infectious Disease Dynamics* programme took place in 2013 (see report on page 8) and as the programme developed it became clear that there was a need to set the agenda for future research. This led to a successful application for a 3-week *Follow-up Meeting* nine months later, in which small working groups explored specific challenges, aiming to reach well defined, relevant and realistic research questions, with formulated approaches to address them. There was a particular emphasis on links to public health decision-making, and the programme concluded with a well-attended *Open for Business* event *Mathematical Modelling for Public Health*.

The aims of the meeting included:

- To finalise the systematic look at the use of models to inform public health decisions and to analyse where and why models fail in their predictions;
- To set the agenda for future research: to determine the main challenges, both in understanding and public health needs and in methodology;
- To foster collaboration and a new generation of young talented researchers with the aim of starting to address some of the challenges identified above, through a programme of concrete research activities.

Serving the UK Community

Michael Singer
Chair of Correspondents

As Chair of Correspondents I see it as my responsibility to remind the Newton Institute of the need to keep the UK mathematical sciences community fully engaged with its activities. This often leads me to play Devil's Advocate and to challenge ideas and to question current practices. I think it important that the Institute takes advantage of modern technologies to connect with the UK community and am delighted to see INI's increased use of twitter and facebook. I welcomed the use of Google Hangout to enable Correspondents from further afield to participate in Correspondents' Day remotely. Along with the rest of the Management Committee I am pleased with the "fresh look" of the Institute's new website and on behalf of INI would like to thank Correspondents for their comments and feedback on stylistic, navigational and structural issues.

Strong views were expressed at the 2013 Correspondents' Day about the then newly launched Turing Gateway to Mathematics. I am pleased to note that since these discussions the TGM has formalized its Aims, developed a Mission Statement, and has appointed an Advisory Board and Programmes Committee. It is important that Correspondents continue to spread the word about the TGM to ensure that it becomes the national resource it aspires to be.

I have greatly enjoyed working with the Director (John Toland), Deputy Director (Christie Marr), Librarian and Information Officer (Sara Wilkinson) and the Knowledge Transfer Facilitator (Jane Leeks). As Chair of Correspondents I will continue to be an advocate for the UK Mathematics community and always welcome their input and views.

Annual Meeting of Correspondents

This year the Annual Meeting of Correspondents was held at INI on Tuesday 20 May with the theme *The Ubiquity of Mathematics*. The day was attended by 48 Correspondents.

The afternoon began with a welcome from the Institute Director, John Toland, who gave an update of the developments at INI. This was followed by the Correspondent's Day lecture that was given this year by Professor John Barrow (Cambridge) and was entitled *Mathematics is Everywhere*. Representatives from four of the UK Research Councils then took to the stage for a panel session to outline their current priorities and how these link with the Mathematical Sciences. The representatives were Peter Burlinson (BBSRC), Claire Tansley (EPSRC), Samantha McGregor (ESRC) and Avril Allman (NERC).

A number of Correspondents from further afield said that they were unable to attend the meeting due to the disproportionate amount of travelling time required. In order to involve these participants, INI decided to trial hosting a "Virtual Discussion Group". This Virtual Group discussion was held via Google+ Hangout and was chaired by Frank Neumann who was present at INI.

He was then able to provide feedback from the virtual group in the Feedback Session. The conclusion at the end of the discussion was that the technology was certainly not perfect but that it was good enough and preferable to being excluded from the meeting. The two remote participants said that they would like to take part virtually again next year.

The recordings of the talk by John Barrow, Research Councils Panel Session and feedback from discussion groups are available to view or download online at **www.sms.cam.ac.uk/collection/1723392**.

A list of INI Correspondents both in UK HEI's and in learned societies, commercial organisations and research institutes can be found on the web at **www.newton.ac.uk/community/correspondents/current**.

Institute Activities

Seminars on the Web

All INI seminars and lectures are, with the permission of speakers, advertised in advance, streamed live and made available on the web in perpetuity.

In addition to broadcasting its own lectures, the Institute uses its facilities to provide distinguished scientists who are unable to attend in person with the opportunity to lecture during programmes or workshops. These interactive sessions are held in the seminar room, with question and answer sessions between the audience and the speaker at a different location.

The library of online seminars is a significant scientific resource. During 2013/14 within the 10 programmes covered by this report and including other events, over 750 seminars were added to the collection taking the total number of recordings available in the archive over 5,000!

Field's Medallist Grigory Margulis giving a seminar on the 'Oppenheim conjecture and related problems' during the 'Interactions between Dynamics of Group Actions and Number Theory' programme.
The seminar is available to view or download at www.newton.ac.uk/seminar/20140702160016501.

Short Visits

Any researcher associated with a UK University, academic institution or R&D group in industry or commerce may visit the Newton Institute for up to two days without an invitation, in order to attend seminars or to work with colleagues. We ask that reception@newton.ac.uk is emailed in advance to assist us with planning. Further details are at **www.newton.ac.uk/participate**.

Follow-up Meetings

As discussed in pages 18–19 and as stated in the Institute's Scientific Policy Statement (www.newton.ac.uk/about/governance/policy-statement), it is intended that each INI scientific programme will have long-term impact well beyond the event itself in terms of breakthroughs, new research directions and collaborations. The Institute, therefore, arranges short *Follow-up Meetings* some years after programmes end, whenever the original organisers are enthusiastic.

Participants in the Infectious Disease Dynamics Follow-up Meeting (see page 19 for short report)

Seminars in the UK

Participants on INI programmes are strongly encouraged to visit other institutions within the UK during their stay at the Institute, and 80 visitors did so during 2013/14 delivering a total of 137 seminars in 40 different institutions. To promote this activity, the Institute covers on request the travel costs within the UK for overseas participants.

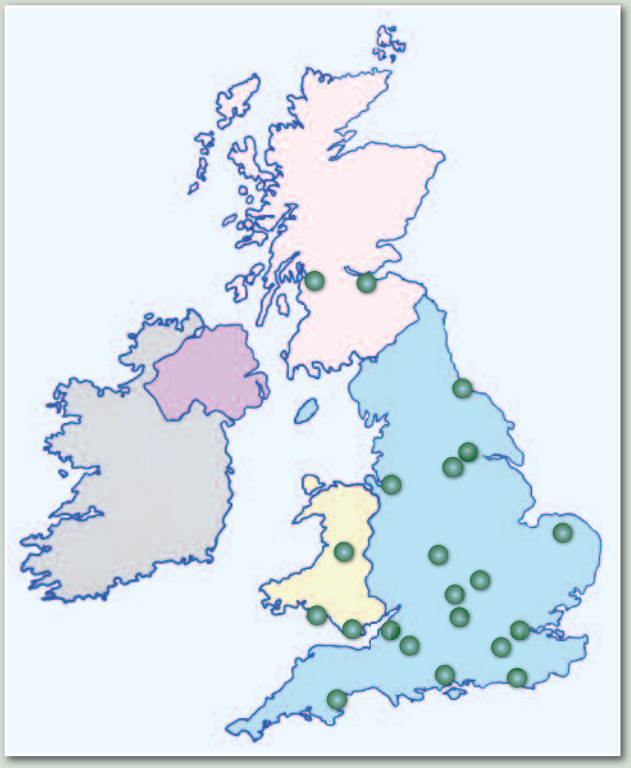
Lists of future participants, with dates of their visits, can be found on the individual programme web pages. In addition, the Institute has set up a register, with titles of topics, of those Fellows who are willing to travel to other UK institutions to give seminars. Correspondents are urged to ensure that organisers of local seminar series know about and consult this register when planning their schedule of speakers. Potential speakers may be contacted directly using the details listed in the online register at **www.newton.ac.uk/science/outreach/speakers**. Advice on suitable speakers may be obtained from the programme organisers of the relevant programme.

Satellite Meetings

The Institute encourages organisers of 4- or 6-month programmes to cooperate with local organisers in holding *Satellite Meetings* at UK Universities and institutions outside Cambridge. *Satellite Meetings* are organised on themes related to an Institute programme, and involve a significant number of the longer-stay overseas participants who are visiting the Institute at the time. They also, crucially, draw in and involve UK mathematicians and scientists who might not otherwise be able to participate substantially in the Institute programme; and they enable the expertise of the Institute's overseas participants to be shared more widely within the UK.

Costs for *Satellite Meetings* are shared between the Institute and the host institution and the Institute typically contributes £15,000 (excluding the overseas travel costs of Institute participants, which are covered separately).

The Institute is keen to continue to expand the geographical range of *Satellite Meeting* locations. Institutions interested in holding a meeting should contact either the organisers of the relevant programme or the Deputy Director, Christie Marr.



Distribution of Satellite Meetings

Since 2000 there have been 61 INI *Satellite Meetings* held in Institutions across the UK. Of these, 16 have been held in Scotland and 7 have been held in Wales.

Future *Satellite Meetings* are planned for 2015 at the University of East Anglia and the University of Sussex. Further details are available at **www.newton.ac.uk/events/calendar**.

Junior Membership

INI recognises that early career researchers have much to contribute to, and gain from it's programmes and events. In order to maximise the information available to them, and to facilitate their involvement in activities by offering additional funding opportunities, there is a special *Junior Membership* scheme. To be eligible you must be either a Research Student or within 5 years of having received your PhD (with appropriate allowance for career breaks), and you must work or study in a UK University or a related research institution. Those wishing to join the scheme should consult the INI web site at **www.newton.ac.uk/community/junior-members**.

Members will receive regular advance information regarding programmes, workshops, conferences and other Institute events. The Institute also makes available some of its general funds specifically to support early career researchers taking part in INI activities and Members may apply for grants from these funds. Types of involvement supported include attendance at workshops and conferences or longer visits (up to two weeks) to work with participants on research programmes. At the end of July 2014 there were over 500 registered Junior Members.

Management and Statistical Reports

Howard Covington
Chair of the Management Committee

The number and diversity of proposals continues to rise and the Institute's *Turing Gateway to Mathematics* initiative is gaining significant momentum. It is encouraging that this is being achieved while a smaller proportion than ever of the Institute's core activity is supported by the Research Councils. To repeat what I have said in previous *Annual Reports*, the Institute needs sustained support from beyond the public purse if timely proposals and new initiatives are not to be neglected and if it is to maintain its reputation for cutting edge pure research unrestricted by short-term constraints.

The Development Board and University's fundraisers are working hard to maintain awareness of the Institute's excellent work. I am personally always delighted to welcome luminary participants from the Institute's programmes to dinner at my home where they can explain their work to potential supporters.

As a result of the increase in research activity the Institute is considering how to modify its 20-year-old residential and academic accommodation so that it can cater for a larger numbers of participants at any one time. The Management Committee has recently approved a feasibility study of a proposal to deal with these issues.

I am delighted to report that the Management Committee awarded the Institute's Honorary Fellowship to Sir David Wallace, immediate former Director, at its Annual Dinner at the Royal Society in London in December 2013, and to Professor Peter Landshoff, a founder and essential supporter of the Institute from its earliest days, at a dinner hosted by Ewan Kirk in Cambridge in February 2014.

I would like to thank Bill Bruce who represented the London Mathematical Society, Martin Hyland, formerly Head of Pure Mathematics and Statistics at the University of Cambridge, and James Stirling, formerly head of the Cavendish Laboratory and now (the first) Provost of Imperial College London, who retire after considerable service to this Committee. I am also grateful to Michael Singer who has agreed to extend his chairmanship of INI Correspondents to a second two-year term.

Management Committee

Membership of the Management Committee at 31 July 2014 was as follows:

Name	Affiliation	End of Service
Professor Bill Bruce	London Mathematical Society	31 Dec 2014
Mr Howard Covington (Chair)	General Board	31 Dec 2018
Professor Peter Haynes	Head, DAMTP, University of Cambridge	–
Dr Phillippa Hemmings	EPSRC	–
Professor Valerie Isham	Chair of Scientific Steering Committee	31 Dec 2017
Professor Robin Langley	Council of the School of Technology	31 Dec 2014
Dr Joan Lasenby	Trinity College, Cambridge	31 Dec 2014
Professor Nick Manton	St John's College, Cambridge	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 Michael Singer	Chair of Correspondents	31 Dec 2015
Professor John Toland	Director, Isaac Newton Institute	31 Sep 2016

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.

Programme Participation

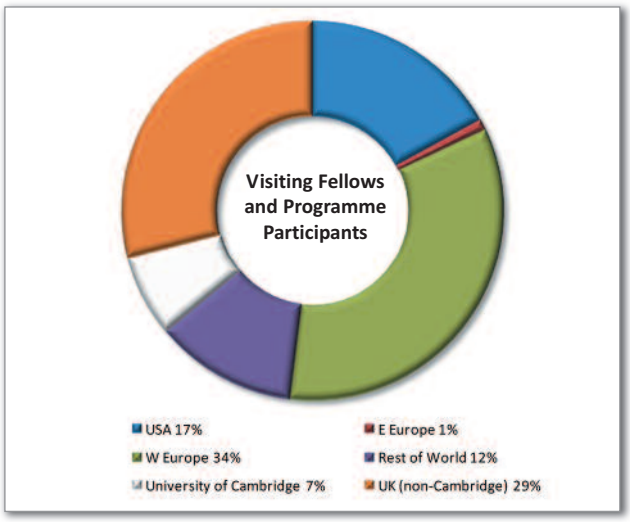
A total of 1688 visitors was recorded for 2013/14. This includes 438 Visiting Fellows and 197 Programme Participants. Within the 10 programmes during the year 21 workshops, which serve to widen UK participation in programmes attracted a further 511 visitors (i.e., those not already attending the programme).

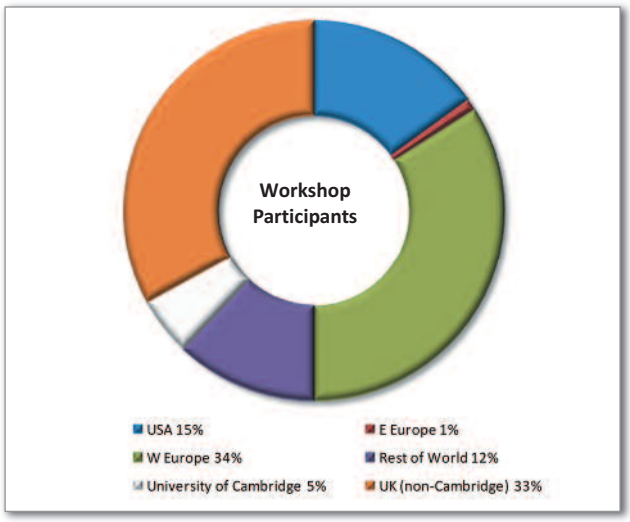
In addition to workshops, INI arranges less formal special academic meetings from time to time, as well as talks for the general public, so further opening up the activities of INI. More than 542 visitors attended such events and took part informally in INI activities or attended *Satellite Meetings* and *Follow-up Meetings*.

Over 900 seminars were given at INI during the year. The Institute also funds visits by overseas programme participants to other UK institutions to give seminars (see page 21), and 137 such seminars took place.

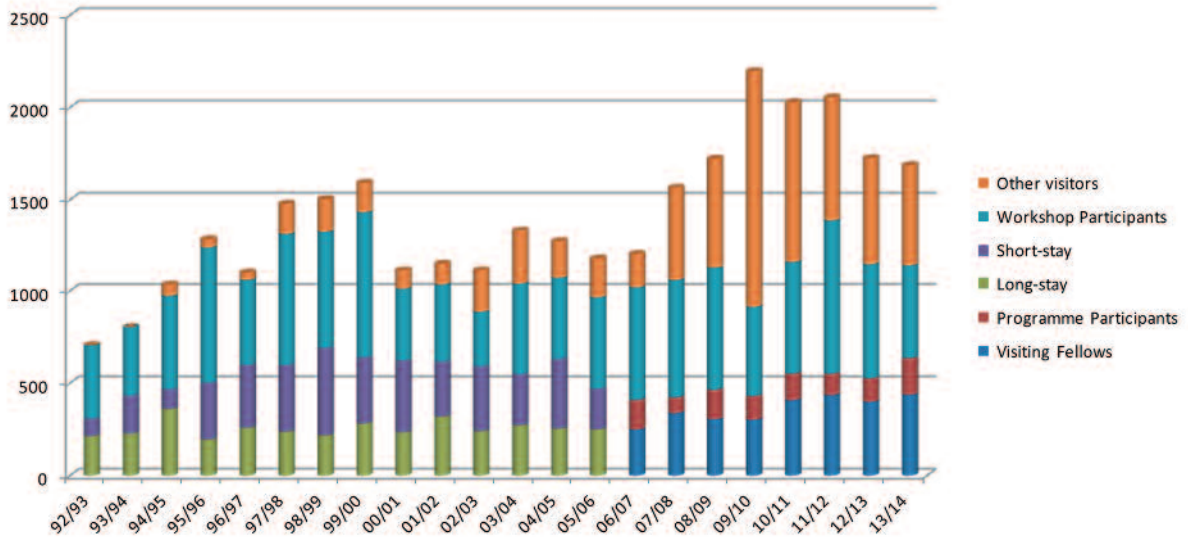
Programme	Visiting Fellows	Mean stay (days)	Programme Participants	Mean stay (days)	Workshop Participants
Polynomial Optimisation	21	19	28	11	46
Infectious Disease Dynamics	29	21	4	17	69
Mathematical Challenges in Quantum Information	56	43	59	43	109
Mathematics and Physics of the Holographic Principle	48	13	19	21	46
Mathematics for the Fluid Earth	61	24	12	14	46
Free Boundary Problems and Related Topics	84	45	31	20	61
Inference for Change-Point and Related Processes	44	14	11	13	39
Mathematical, Statistical and Computational Aspects of the New Science of Metagenomics	29	18	5	21	33
Advanced Monte Carlo Methods for Complex Inference Problems	34	16	14	12	42
Interactions Between Dynamics of Group Actions and Number Theory	32	17	14	12	20
	438	**26**	**197**	**24**	**511**

The pie charts below show the percentages of Visiting Fellows, Programme Participants and Workshop Participants broken down by country of residence:

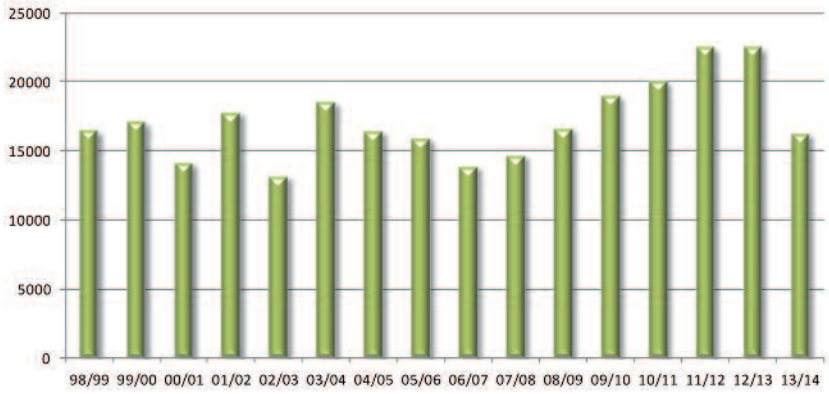




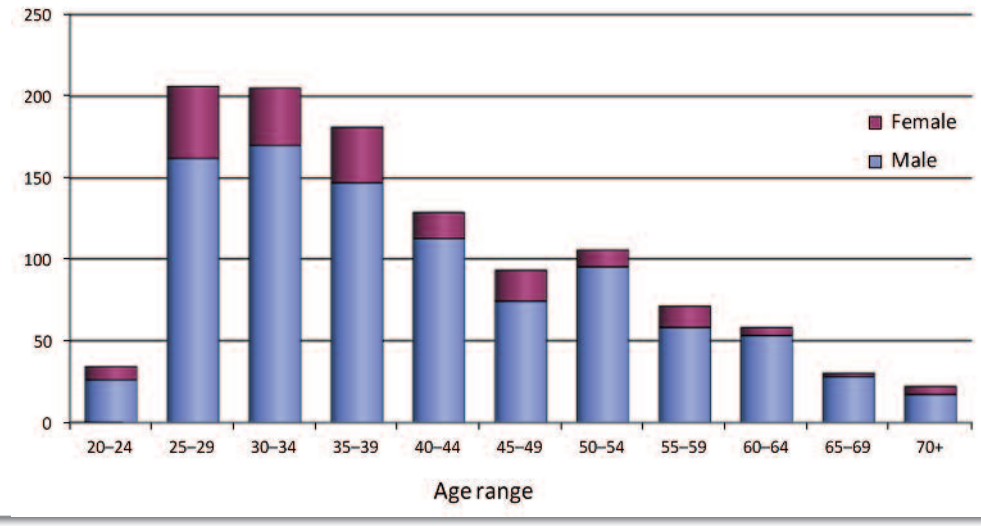
The following chart summarises the total participation figures since the Institute began:



The chart below summarises the total number of person-days for Visiting Fellows and Programme Participants combined, *excluding* Workshop Participants.

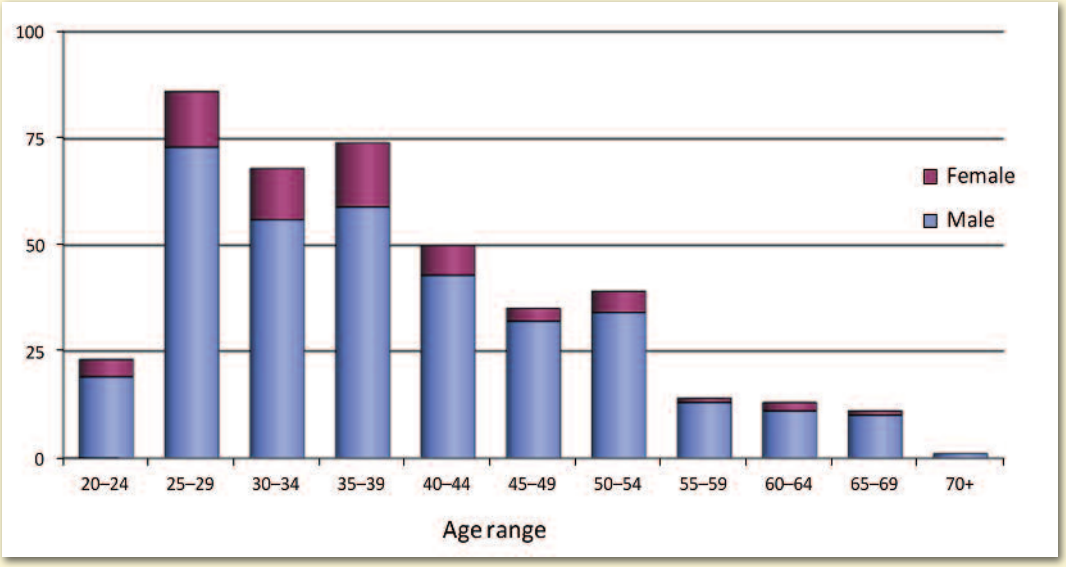


The numbers of all Visiting Fellows, Programme Participants *and* Workshop Participants combined in 2013/14 are shown below, by age and gender:

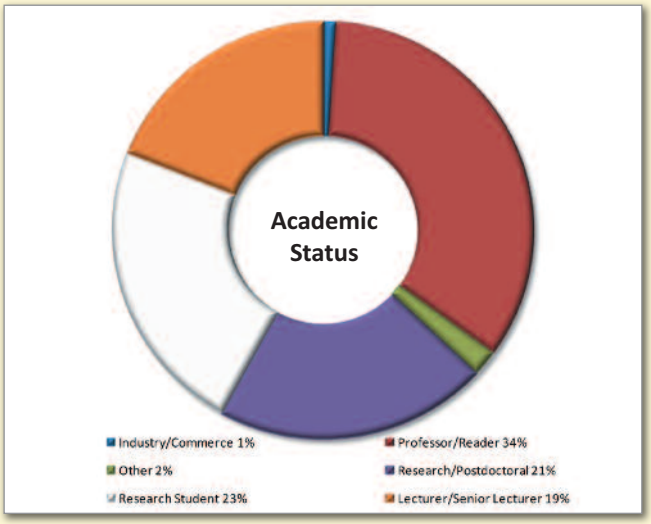


The statistics presented on this page relate only to visitors whose home institutions are in the UK: overseas visitors data are not included.

The age range and gender balance of all Visiting Fellows, Programme Participants and Workshop Participants from UK institutions in 2013/14 are illustrated below:



The following diagrams indicate the academic status and geographical distribution of all Visiting Fellows, Programme Participants and Workshop Participants from UK institutions during 2013/14:



More detailed statistics, including visit dates, home institutions, seminars given and papers written are shown in the Appendices, available at **www.newton.ac.uk/science/publications/annual-reports/**.

Finances

Accounts for August 2013 to July 2014 (Institute Year 22)

	2012/13 Year 21 £'000	2013/14 Year 22 £'000
Income		
Research Grants and Contracts[1]	2,130	1,800
Contribution from the University of Cambridge[2]	492	410
Donations[3]	72	173
Additional Workshop Income	180	78
Endowment and Investment Income[4]	181	205
Net Housing Surplus[5]	160	-18
Other Income	12	10
Total Income	**3,227**	**2,658**
Expenditure		
Staff Costs	670	715
Travel and Subsistence[6]	1,126	844
Workshop Expenditure	352	297
Other Institute Activities[7]	31	36
Other Operating Expenses[8]	119	250
Overheads paid to University[9]	427	265
Total Expenditure	**2,725**	**2,407**
Surplus / (Deficit)	**502**	**251**

Notes to the Accounts

1. Research Grants and Contracts. The income breaks down as follows:

EPSRC Salaries	323	306
EPSRC Travel and Subsistence	1,170	837
EPSRC Workshop Income	248	195
EPSRC Other Costs	32	208
EPSRC Estates and Indirect Income	273	172
Leverhulme Trust	84	82
Total	**2,130**	**1,800**

2. Contribution from the University of Cambridge. The amounts received break down as follows:

Rothschild Visiting Professorships (drawdown)	23	28
Rothschild Mathematical Sciences (income)	105	108
Contribution Towards Institute Operating Costs	358	274
SRIF, HEIF, CIF, HEFCE Funding	6	0
Total	**492**	**410**

The University also provides the main and Gatehouse buildings and pays for all gas, electricity and rates, which have not been included.

3. Donations. A total of £202k received via the Cambridge University Development Office was capitalised and is not included in this figure.

Cambridge Philosophical Society	3	2
Garfield Weston Foundation	7	32
London Mathematical Society	27	40
Microsoft	28	25
NERC	0	45
PF Charitable Trust	7	3
Turner-Kirk Charitable Trust	0	26
Total	**72**	**173**

4. Endowment and Investment Income. Income received from the Newton Trust fund, the Anonymous Donation Endowment, reserves and deposits.

5. Net Housing Costs.

Income	835	665
Expenditure	675	683
Total	**160**	**-18**

6. Travel and Subsistence. Expenditure incurred by Programme Visitors including Junior Members.

7. Other Institute Activities. These costs relate to *Open for Business* and fundraising activities as well as expenses from meetings of the Institute's committees, Institute Correspondents, programme organisers, and the travel expenses of overseas participants who visit other UK institutions to give seminars during their stay.

8. Other Operating Expenses.

Building maintenance	41	37
Catering	18	17
Consumables	16	12
Computing and Audio Visual	29	179
Equipment and Furniture	5	2
Library	6	2
Publicity	4	1
Total	**119**	**250**

9. Overheads Paid to University. Includes Estates and Indirect costs on grants and overheads on Trust Funds.

Grants and Donations August 2013 to date

In addition to substantial funding from the Engineering and Physical Sciences Research Council, the Institute is indebted for support from the Cambridge Philosophical Society, the Leverhulme Trust, the London Mathematical Society, PF Charitable Trust, NM Rothschild and Sons, and the University of Cambridge.

We are very grateful to the following organisations for their specific support during the year: the Biotechnology and Biological Sciences Research Council, Clay Mathematics Institute, Credit Suisse, the Economic and Social Research Council, European Research Council, the Garfield Weston Foundation, GLC Charitable Trust (with special thanks to Lawrence and Rosemary Staden), Henderson Global Investors, John Templeton Foundation, Microsoft Research Cambridge, NATIXIS Foundation, the National Environmental Research Council, the Office of Naval Research, Old Mutual plc, the Science and Technology Facilities Council, Simons Foundation, and the Turner-Kirk Charitable Trust.

Individuals gave generously in support of our activities: Howard & Veronika Covington, Thomas W Cusick, Mrs Ann and the late Professor Roy Garstang, Dr Jonathan Hodgson, Tracey Olsen, Simon Yun-Farmbrough, David & Elizabeth Wallace as well as donations from individuals who prefer to remain anonymous.

Cumulative Financial Grants and Donations above £10,000

(listed in order of cumulative value)

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

The Leverhulme Trust

LONDON MATHEMATICAL SOCIETY

CMI

ROTHSCHILD

Microsoft

Front cover: The image on the front cover is a numerical computation[1] of a model[2] for a vesicle formed by a two component lipid bilayers which is governed by a Helfrich bending energy with phase dependent material parameters together with a line energy associated with the phase interfaces. The components correspond to the blue and red regions. Image courtesy of CM Elliott and B Stinner from the INI programme *Free Boundary Problems and Related Topics* (see pages 12–13).

[1] *Computation of two-phase biomembranes with phase dependent material parameters using surface finite elements.* CM Elliott and B Stinner *Commun. Comput. Phys* 13. pp 325–360 (2012).

[2] *A surface phase field model for two-phase biological membranes.* CM Elliott and B Stinner - SIAM Journal on Applied Mathematics 70. pp 2904–2928 (2010).

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