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APPENDICES

Please note that the following statistical information may be obtained from the Institute on request, or from **http://www.newton.cam.ac.uk/reports/0506/appendices.html**

Director's Foreword

By the time this Report is published, I shall have handed over the Directorship to Sir David Wallace, whom I wish a very successful term of office. It is appropriate now to take a longer view than just the year covered by the Report, and to reflect on the progress of the Newton Institute since I took over from Keith Moffatt in 2001.

At that time the Institute had already established itself as a major player on the world mathematical stage, and as a strong asset to the mathematical sciences community in the UK. The concept of bringing the best international mathematical scientists to work together on a theme chosen for its timeliness and promise, for a period of up to six months, had proved to be a highly successful one. It gave space and time for interdisciplinary collaboration to develop and for new ideas to germinate, and research often continued long after the formal programme ended.

I therefore decided that, with such a successful formula, revolutionary change would be inappropriate, that the Institute should try new variants in a cautious way, but that it should be adventurous in exploring new fields of application and new synergies within mathematics. This has been the characteristic of the last five years. We have experimented with programmes of varying lengths within the six month maximum and with different structures of workshops in Cambridge and outside, but the real innovation has been in the subject matter of the programmes.

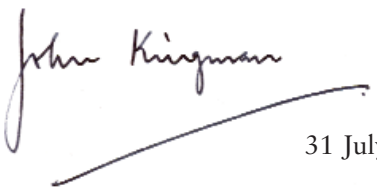
On page 5 you will find a list of all the programmes since 2001, including those approved up to 2008. Notable are the applications of mathematics to different areas of biology, and the appearance for the first time of programmes in statistical methodology. At the same time more traditional areas of applied mathematics, mathematical physics and astronomy have not been neglected, and there have been highly successful programmes in 'pure' mathematical topics.

We have been fortunate in having a rich stream of proposals from which to choose. All serious proposals are sent to international referees, whose reports are then discussed by the Scientific Steering Committee. The Committee ensures not only the high scientific quality of the chosen proposals, but also the balance over time between the many different areas of mathematical science. This is a heavy responsibility, and I have been most fortunate to work with a group of scientists broad in their interests, rigorous in their scrutiny, and perceptive in their judgement. I thank them all most warmly for the crucial contribution they have made to the success of the Institute.

Once a programme is accepted and allocated a time slot two to three years ahead, the next priority is to secure the commitment of the best scientists in the field. The Institute's reputation is such that we can achieve the participation of world class researchers, because they know that they will find an environment in which they can develop their ideas and form lasting and fruitful collaborations. That environment is very largely due to the helpfulness of our support staff, who are dedicated to helping all our visitors to make the most of their time at the Institute. To them also, and especially to those loyal members who have been here for most of the life of the Institute, I offer the most heartfelt of thanks.

World class science rarely comes cheap, and the maintenance of the scientific quality of our programmes inevitably costs money. As I write, we are seeking continuing support, under the new full economic cost arrangements, from the Research Councils. The Councils have a proud record of funding the best science the nation can produce, and I am sure that they will recognise in the Newton Institute an unrivalled facility for keeping the UK at the cutting edge of world mathematics. As that mathematics underpins almost all modern science and technology, the value of the Institute to the well-being and prosperity of the nation is undeniable.

It has been a great privilege to lead the Isaac Newton Institute through the first half of its second decade, and I am confident that the decades to come will see yet more exciting progress.



31 July 2006

Brief Scientific Report on Programmes

For full scientific reports see pages 19 to 41.

Pattern Formation in Large Domains

Pattern formation is the study of the spontaneous appearance of structure in nature and in the laboratory. Natural examples include sand ripples, geological structures such as the Giant's Causeway, cloud formations, animal coat markings, the synchronous flashing of fireflies and animal gaits. Laboratory examples span a diverse range of disciplines including fluid mechanics, granular media, chemistry (both at macroscopic and nanometre scales) and nonlinear optics.

Although regular patterns with a single length-scale such as stripes and hexagons are well understood, many systems naturally generate more complex structures when given the freedom to fill an experimental or computational domain that is large compared to the pattern length-scale. Examples of these more complex structures include rotating spiral waves, spatially quasiperiodic patterns and 'spatiotemporal chaos' (of many kinds).

This broad range of motivating examples is mirrored in the similarly broad range of techniques that have been brought to bear on their analysis: dynamical systems theory, group representations, asymptotic analysis for differential equations and computational methods. A key aim of the programme was to bring experts in these different mathematical areas together with experimental scientists.

The programme was structured around a series of five one-week workshops (four at the Newton Institute and a satellite meeting at the University of Surrey) which covered both theoretical and experimental aspects of classical and contemporary problems in a wide range of novel scientific applications, including ones in the fields of physics, chemistry, biology and engineering. One workshop was a training course aimed specifically at research students and post-doctoral researchers, and was particularly successful.

It was clear that theoreticians and experimentalists had interacted during the programme in unexpected and mutually beneficial ways that provoked renewed interest both in understanding particular physical phenomena, and in extending the available theoretical techniques. Particularly interesting progress was made in the areas of Rayleigh–Bénard convection, Taylor–Couette flow, localisation, de-wetting patterns, large-scale dynamics of pattern formation, identification of model equations, quasipatterns, heteroclinic dynamics, symmetry and coupled cell networks.

Global Problems in Mathematical Relativity

Einstein's theory of Special Relativity celebrated its centenary in 2005. Its younger sibling, General Relativity, turned 90; its predictions are verified to many significant figures, classically in the solar system, particularly in the observation of planetary orbits, and more recently in observations of binary pulsars. These latter observations provide indirect evidence of the existence of gravitational radiation, behaving just as the theory predicts.

There are two approaches to mathematical problems in General Relativity: one may ask how this geometrically-based subject relates to other mathematical disciplines involving geometry, or one may ask how one sets about using the theory. The aim of the programme was to address questions arising from these two approaches.

The programme was structured into emphasis weeks, which can be grouped roughly into five categories: evolution problems (including numerical ones), constraint problems, global problems, quantum problems, and the remaining approaches (Riemannian and Lorentzian geometry, inverse scattering methods). There were also three workshops, one a satellite meeting at the University of Southampton, covering mathematical, observational and numerical aspects.

The programme attracted a large number of participants, experts in all aspects of the field. Special care was taken to include promising young scientists; this will have a long-term influence on the development of the field. During the preparation of

the programme it was recognised that the field is under-represented in UK universities, except perhaps in Oxford and in Cambridge itself. Efforts were made to alleviate this by inviting a wide spectrum of UK participants. In additions to the seminars at the Newton Institute, members of the programme gave 34 seminars throughout the UK.

New collaborations were initiated, many more were continued, and extremely positive feedback was received concerning the impact of the programme on many participants. Several very significant publications have appeared as a direct result of the research during the programme.

Principles of the Dynamics of Non-Equilibrium Systems

Although the subject of collective phenomena in equilibrium systems is a mature one, systems that are not in thermal equilibrium are less well understood: indeed, a general theoretical framework is lacking and our understanding to date has relied on the study of specific models. By "non-equilibrium systems" we refer both to systems held far from thermal equilibrium by an external driving force and to the complementary situation of systems relaxing towards thermal equilibrium.

The study of non-equilibrium systems arises in many different contexts such as reaction–diffusion processes, interacting particle systems, driven diffusive systems, and the slow dynamics of both ordered and disordered glassy systems. It is a major research area which is represented in many different scientific communities. The programme was centred around three main themes: glassy constrained dynamics and ageing; driven diffusive systems and interacting particle systems; and coarsening and persistence.

Three workshops were held during the programme, each devoted to one of the themes. The second of these brought together young researchers from different backgrounds for a two week long school at the forefront of a broad and rapidly developing field; it consisted of 16 mini-courses plus four seminars and four poster sessions.

The programme was extremely productive and the mixture of people with different backgrounds and scientific interests resulted in many fruitful discussions and cross-fertilisation. Many new ideas and collaborations on a wide range of topics are now being pursued by the participants. Particular mention should be made of a special issue of the *Journal of Statistical Mechanics: Theory and Experiment* to be published in 2007 devoted to the programme.

Logic and Algorithms

The aim of this programme was to focus attention on areas of research that bridge the gap between two central concerns of theoretical computer science: (i) how to ensure and verify the correctness of computing systems (formal methods, semantics); and (ii) how to measure the resources required for computations and ensure their efficiency (algorithmics, computational complexity). The specific areas chosen for this focus were Computer-Aided Verification, Algorithmic Model Theory, Proof Complexity, Constraint Satisfaction, and Games, which cross-cut the divide in interesting ways.

Six workshops, each of one week's duration, were held over the course of the programme. Four of these were at the Isaac Newton Institute, while one was a satellite workshop in Durham and another was held in Oxford. In addition, a regular seminar series was held at the Institute with between two and five seminars per week. Several short tutorial courses were also offered.

The programme generated a great deal of research activity and the Institute was abuzz with intense discussions. A number of publications will emerge from activity initiated or carried out during the programme. However, the greatest benefits of the programme may be the less tangible ones of "community creation". The programme brought together researchers from several distinct research communities in theoretical computer science and mathematics, and helped expose the common underlying elements of their problems and methods. There are plans in place to produce a volume of expository articles based on the workshop on *Finite and Algorithmic Model Theory* held at Durham. It is anticipated that this volume will become a standard reference work describing the current state of the field.

Introducing Sir David Wallace

Sir David Wallace CBE FRS FREng has been appointed as the next Director of the Isaac Newton Institute for Mathematical Sciences from 1 October 2006, on the retirement of the current Director, Sir John Kingman FRS, who has held the post since 2001. Sir David will become the second NM Rothschild and Sons Professor of Mathematical Sciences. He has also been appointed by the Queen to the Mastership of Churchill College, Cambridge from the same date, where he will succeed Sir John Boyd KCMG.

Following undergraduate and postgraduate study in theoretical physics at the University of Edinburgh, Sir David continued research at Princeton University as a Harkness Fellow. In 1972 he was appointed lecturer in the Physics Department at the University of Southampton, and in 1979 he returned to the University of Edinburgh as Tait Professor of Mathematical Physics. He was also Director of the Edinburgh Parallel Computing Centre.

Sir David was Vice-Chancellor of Loughborough University from 1994 to 2005. He is Treasurer and Vice-President of the Royal Society, immediate past President of the Institute of Physics and a Fellow of the Royal Academy of Engineering. He has served as a member of the Engineering and Physical Sciences Research Council and the Scottish Higher Education Funding Council, and as an Expert to the European Commission in a number of areas. He is Chair of the UK e-Science Steering Committee. His non-executive Directorships have included the Scottish Life Assurance Company and Taylor & Francis Group PLC. He was awarded a CBE for services to parallel computing in 1996, and was knighted in 2004 for services to UK science, technology and engineering.

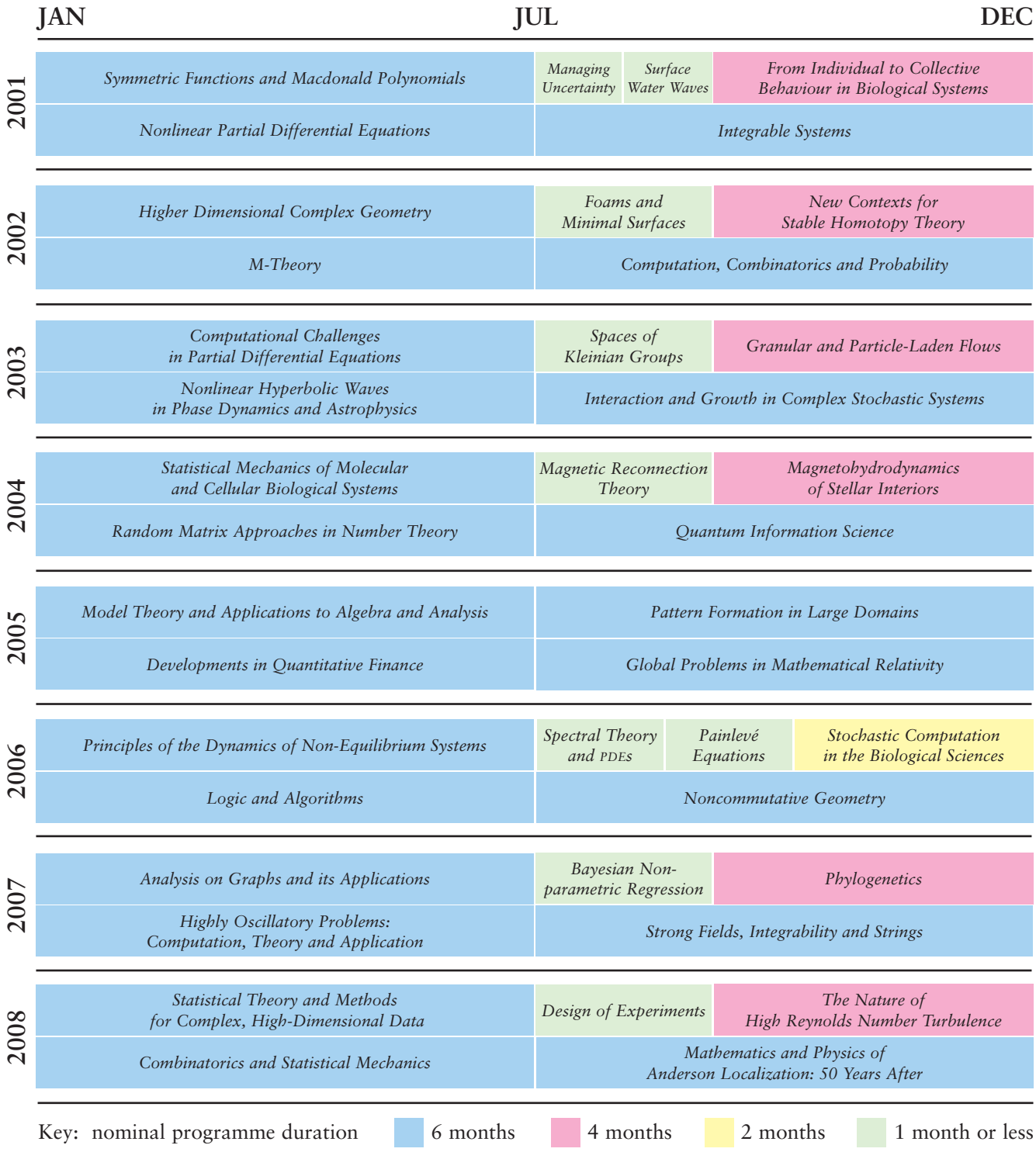
"I am delighted to welcome Professor Wallace as the new Director of the Isaac Newton Institute for Mathematical Sciences," said Professor Alison Richard, Vice-Chancellor of the University of Cambridge, upon his appointment. "He brings with him a wealth of knowledge and experience from his links with both academia and industry. His breadth of vision and distinguished academic career are a wonderful combination for the leader of the Institute, which is devoted to research in the Mathematical Sciences in the broadest sense."

"The Isaac Newton Institute is a national centre of international significance and I am fortunate and privileged to be joining it as its Director," replied Sir David. "My 12 years at Loughborough have been immensely fulfilling and I could not imagine a more exciting prospect to follow them."

Sir David is married to Elizabeth, and they have one daughter, Sara.

Recent and Future Programmes

The schematic below shows the programmes that have taken place at the Institute since 2001 together with the forthcoming programmes that have so far been selected by the Scientific Steering Committee. To participate only in a workshop, registration is all that is required. For fuller, long-stay participation in a programme, an invitation is usually required, and applications are best made directly to the programme organisers in the first instance. Further details on each of these programmes can be found on the Newton Institute's website at **http://www.newton.cam.ac.uk/programmes/** and further information on how to participate can be found at **http://www.newton.cam.ac.uk/participation.html**



Scientific Steering Committee

Membership of the Scientific Steering Committee at 31 July 2006 was as follows:

Professor S Abramsky FRS FRSE	University of Oxford
Sir John Ball FRS FRSE (Chairman)	University of Oxford
Professor KG Binmore CBE	University College London
Professor M Broué	Institut Henri Poincaré
Professor PV Coveney FInstP FRSC	University College London
Professor SK Donaldson FRS	Imperial College London
Professor CS Frenk FRS	University of Durham
Sir John Kingman FRS (Secretary)	Director, Newton Institute
Professor JG McWhirter FRS FREng	QinetiQ
Professor EB Martin	University of Newcastle
Professor C Series	University of Warwick
Professor BW Silverman FRS	University of Oxford
Professor M-F Vigneras	University of Paris 7
Professor M Vingron	Max Planck Institute for Molecular Genetics

The Institute invites proposals for research programmes in any branch of mathematics or the mathematical sciences. 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. Proposals to be considered at these meetings should be submitted by 31 January or 31 July respectively. Successful proposals are usually developed in a process of discussion between the proposers and the SSC conducted through the Director, and may well be considered at more than one meeting of the SSC before selection is recommended. Proposers may wish to submit a shorter 'preliminary' proposal in the first instance with a view to obtaining feedback from the SSC prior to the submission of a full 'definitive' proposal.

Further details of the call for proposals, including guidelines for submission, can be found on the Institute's website at

http://www.newton.cam.ac.uk/callprop.html

The scientific planning and organisation of each programme are the responsibility of a team of three or four Organisers (aided in some cases by an Advisory Committee). The Organisers recommend participants in the programme, of whom up to twenty can be accommodated at any one time; they also plan short-duration workshops and conferences within the programme, to which many more participants may be invited. Each programme is allocated a budget for salary support, subsistence allowances and travel expenses.

The following members of the Scientific Steering Committee stepped down at the end of their term of service on 31 December 2005:

- Professor C Bernardi (Paris 6)
- Professor EG Rees FRSE (Edinburgh)
- Professor G Ross FRS (Oxford)

The following new members were elected:

- Professor KG Binmore CBE (UCL)
- Professor M Broué (Institut Henri Poincaré)
- Professor CS Frenk FRS (Durham)
- Professor M Vingron (Max Planck Institute)

S Wilkinson

Sir John Ball, Chairman of the SSC

Scientific Policy Statement

From its inception, it has been intended that the Newton Institute should be devoted to the Mathematical Sciences in the broad sense. In this respect the Institute differs significantly from similar institutes in other countries. The range of sciences in which mathematics plays a significant role is enormous, too large for an Institute of modest size to cover adequately at any one time. In making the necessary choices, important principles are that no topic is excluded *a priori* and that scientific merit is to be the deciding factor.

Research in mathematics, as in many other sciences, tends to consist of major breakthroughs, with rapid exploitation of new ideas, followed by long periods of consolidation. For the Newton Institute to be an exciting and important world centre, it has to be involved with the breakthroughs rather than the consolidation. This means that, in selecting programmes, a main criterion should be that the relevant area is in the forefront of current development. Since the Institute's programmes are chosen two to three years in advance, it is not easy to predict where the front line will be at that time. The best one can do is to choose fields whose importance and diversity are likely to persist and to choose world leaders in research who are likely to be able to respond quickly as ideas change.

One of the main purposes of the Newton Institute is to overcome the normal barriers presented by departmental structures in Universities. In consequence, an important, though not exclusive, criterion in judging the 'scientific merit' of a proposed research programme for the Institute is the extent to which it is 'interdisciplinary'. Often this will involve bringing together research workers with very different backgrounds and expertise; sometimes a single mathematical topic may attract a wide entourage from other fields. The Scientific Steering Committee therefore works within the following guidelines:

(*a*) the mixing together of scientists with different backgrounds does not *per se* produce a successful meeting: there has to be clear common ground on which to focus;

(*b*) each programme should have a substantial and significant mathematical content;

(*c*) each programme should have a broad base in the mathematical sciences.

Although the novelty and the interdisciplinary nature of a proposed programme provide important criteria for selection, these must be subject to the overriding criterion of quality. With such a wide range of possibilities to choose from, the aim must be to select programmes which represent serious and important mathematical science and which will attract the very best mathematicians and scientists from all over the world. However, the Institute is receptive also to proposals of an unorthodox nature if a strong scientific case is made.

Although the Institute operates on a world-wide basis and contributes thereby to the general advancement of mathematical science, it must also be considered in the context of UK mathematics. A natural expectation of all those concerned is that each programme will be of benefit to the UK mathematical community in a variety of ways. If the UK is strong in the field, UK scientists will play a major part in the programme; if the UK is comparatively weak in the field, the programme should help to raise UK standards, and instructional courses aimed primarily at younger researchers and research students will play a vital role here.

Because of the wide base of support for the Newton Institute in the EPSRC and elsewhere, the Institute's programmes shall as far as possible represent an appropriate balance between the various mathematical fields. In order to retain the backing of the mathematical and scientific community, the Institute runs programmes over a wide range of fields and, over the years, achieves this balance. Such considerations, however, are secondary to the prime objective of having high quality programmes.

Programme Participation

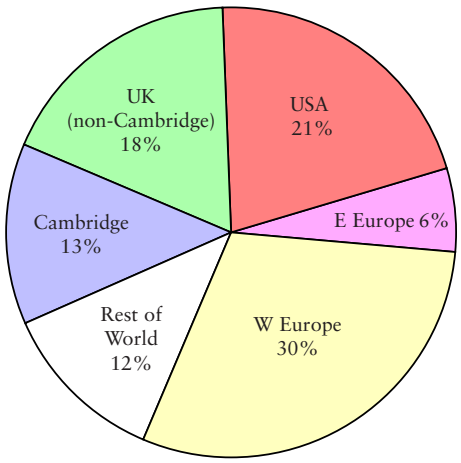
A total of 1183 visitors was recorded for 2005/06. This includes 250 long-stay participants, each staying between two weeks and six months (just under 9 weeks on average), and 220 short-stay participants who stayed for two weeks or less. Within the four completed programmes there was a total of 19 workshops (periods of intense activity on specialised topics) which attracted a further 496 visitors (i.e., those who were not already attending the programme as long-stay or short-stay participants).

In addition to workshops, which serve to widen UK participation in programmes, programme organisers are encouraged to arrange less formal special days, short meetings or intensive lecture series that can attract daily or short-term visitors, so further opening the activities of the Institute to the UK mathematical community. An additional 217 visitors attended informally at these events as well as at talks for the general public and other occasions.

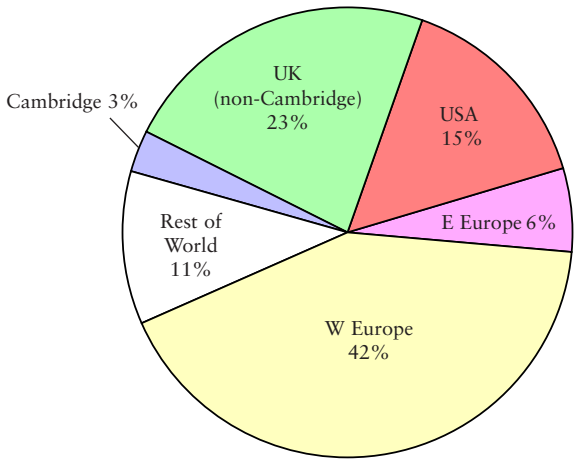
Within all the programmes, workshops and other activities, 605 seminars were given in total at the Institute during the year. The Institute also funds visits by overseas programme participants to other UK institutions to give seminars (see page 15), and 179 such seminars took place last year.

Programme	Long-stay participants	Mean stay (days)	Short-stay participants	Mean stay (days)
Pattern Formation in Large Domains	47	55	38	10
Global Problems in Mathematical Relativity	68	60	94	9
Principles of the Dynamics of Non-Equilibrium Systems	62	54	26	9
Logic and Algorithms	73	76	62	8
Totals	**250**	**62**	**220**	**9**

The pie charts below show the percentages of long-stay and short-stay/workshop participants broken down by country of residence:

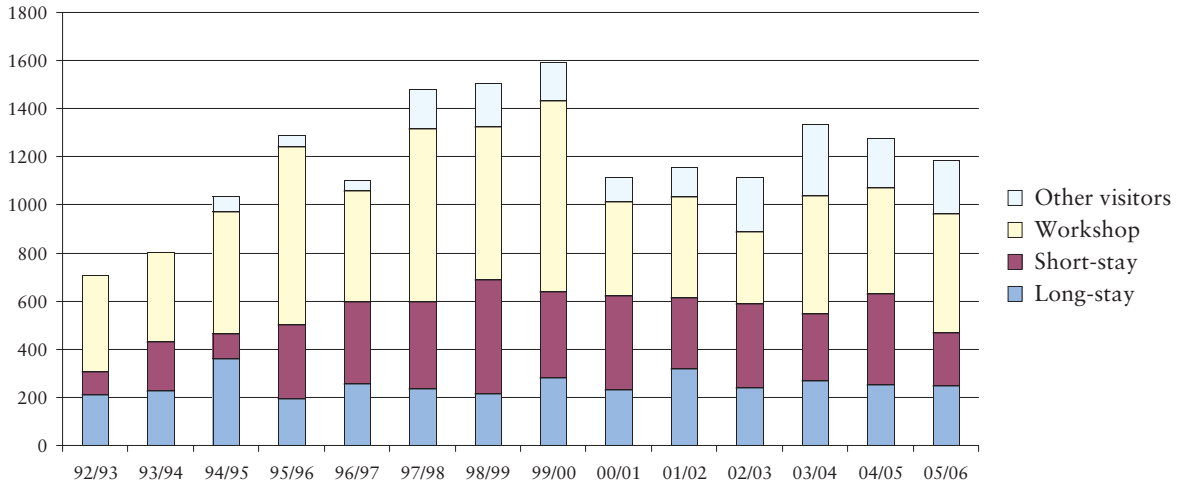


Long-stay participants

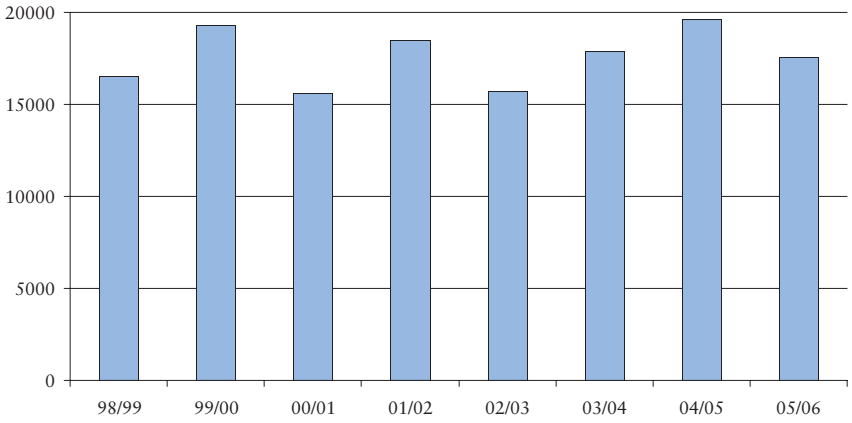


Short-stay and workshop participants

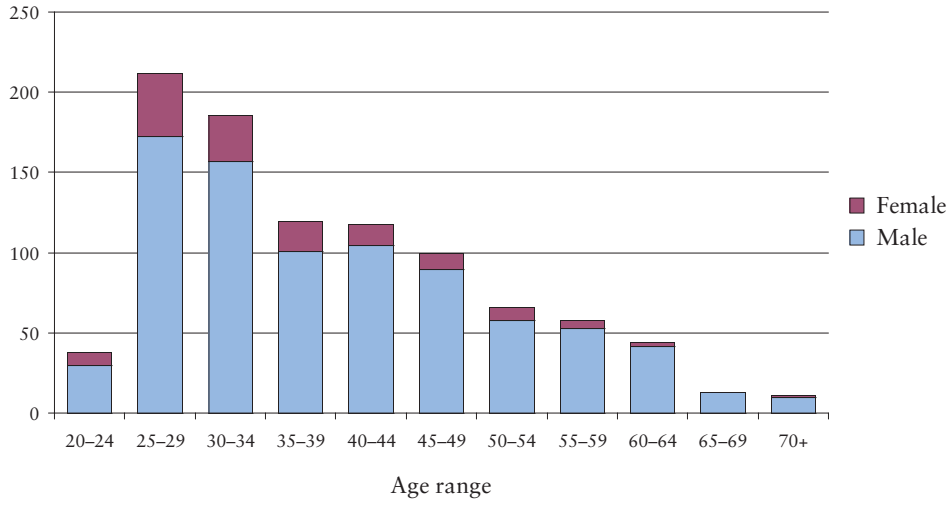
The following chart summarises the total participation figures since the Institute began:



The chart below summarises the total number of person-days for long- and short-stay participants combined, *excluding* workshop participants:

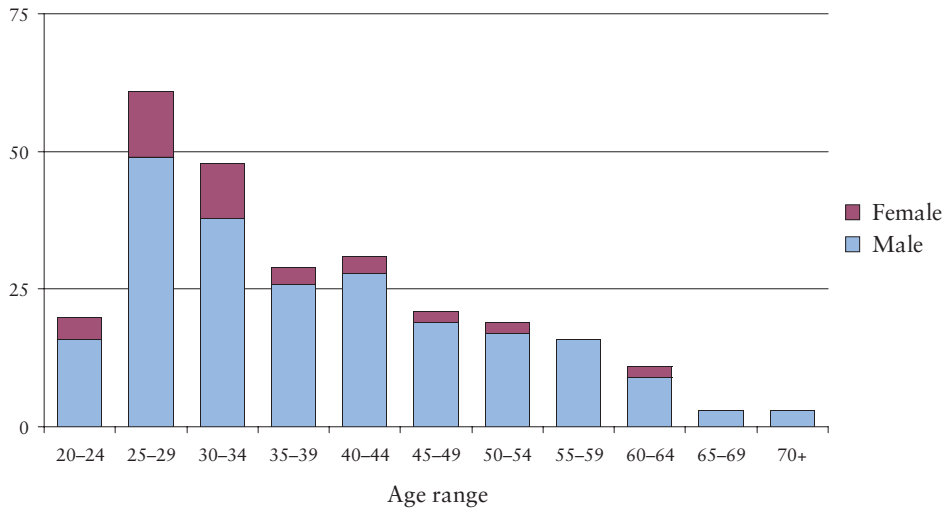


The numbers of long-stay, short-stay *and* workshop participants combined in 2005/06 are shown below, broken down by age and gender:

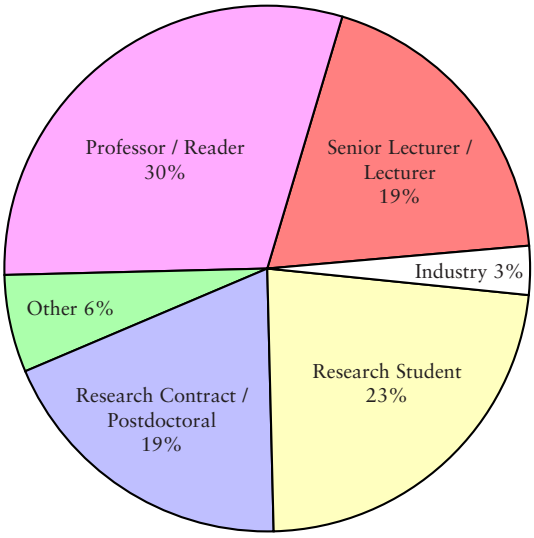


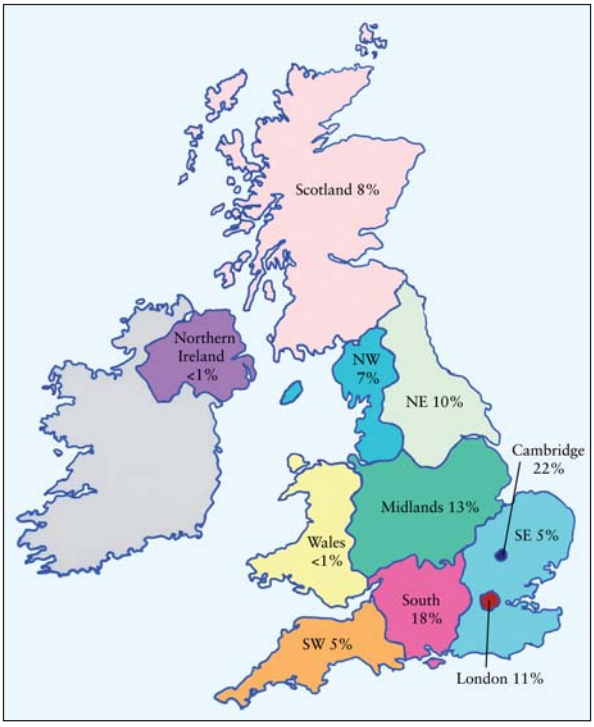
The statistics presented on this page relate only to participants whose home institutions are in the UK: overseas participants have been excluded.

The age range and gender balance of long-stay, short-stay and workshop participants from UK institutions in 2005/06 are illustrated below:



The following diagrams indicate the academic status and geographical distribution of long-stay, short-stay and workshop participants from UK institutions during 2005/06:





More detailed statistics, including visit dates and home institutions of participants and a complete list of seminars given and papers written, are shown in the Appendices, available at

http://www.newton.cam.ac.uk/reports/0506/appendices.html

Young Scientists

The Institute holds a number of events each year that include activities specifically targeted at young scientists. In 2005/06 these events included:

- Marie Curie Training Course on *Pattern Formation*
- Marie Curie Conference on *Developments in Experimental Pattern Formation*
- Workshop on *Theory and Applications of Coupled Cell Networks*
- Satellite Meeting at the University of Southampton on *New Directions in Numerical Relativity*
- Marie Curie Conference on *Global General Relativity*
- Spitalfields Day on *Einstein and Beyond*
- Marie Curie Conference on *Einstein Constraint Equations*
- Marie Curie Conference on *Relaxation Dynamics of Macroscopic Systems*
- Marie Curie Training Course on *Non-Equilibrium Dynamics of Interacting Particle Systems*
- Marie Curie Conference on *First-Passage and Extreme Value Problems in Random Processes*
- Satellite Meeting at the University of Durham on *Finite and Algorithmic Model Theory*
- Workshop on *Games and Verification*

The Institute recognises that junior researchers have much to contribute to and much to gain from Institute programmes and events. In order to maximise the information available to junior researchers, and to facilitate their involvement in Institute activities by offering additional funding opportunities, there is a special scheme for Junior Membership of the Newton Institute. To be eligible for membership 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 become Junior Members should consult the Institute's web site at

http://www.newton.cam.ac.uk/junior.html

Junior Members will receive regular advance information about programmes, workshops, conferences and other Institute events via a Junior Members' Bulletin; detailed information about any workshops of an instructional or general nature likely to be of special interest to young researchers; and information about suitable sources of funding to support visits to the Institute, when available.

The Institute makes available some of its general funds specifically to support junior researchers in Institute activities. Junior Members may apply for grants from these funds. The types of involvement supported include attendance at workshops, conferences, etc., and visits of up to two weeks to work or study with longer-stay participants in the Institute's programmes. The Institute registered 72 new Junior Members in 2005/06; the current total is 489 as at the end of July 2006.

Another source of funding for young scientists is provided by the Cambridge Philosophical Society. The following were recipients of bursaries from the Society in 2005/06:

Pattern Formation in Large Domains

- D Bloemke (Aachen)
- A Comanici (Houston)
- E Crooks (Oxford)

Global Problems in Mathematical Relativity

- M Heinzle (Max-Planck)
- D Maxwell (Alaska)
- H Ringstroem (KTH Stockholm)

Principles of the Dynamics of Non-Equilibrium Systems

- A Rakos (Weizmann Institute)
- C Toninelli (ENS Paris)

Logic and Algorithms

- K Rozier (Rice)
- D Tabakov (Texas)

Institute News

Awards and Achievements

John Ball, Sedleian Professor of Natural Philosophy at the University of Oxford and current Chairman of the Institute's Scientific Steering Committee, was knighted by Her Majesty the Queen in the New Year Honours List 2006 for services to science. Sir John has served for many years on the Scientific Steering Committee, being one of its founder members in 1990, and also now sits on the Management Committee and National Advisory Board.

John Brindley, Research Professor at the University of Leeds and a member of both the Management Committee from 1998 and the National Advisory Board from its inception in 2000 until he stepped down in 2004, was awarded the OBE for services to Higher Education in the same Honours list.

Lord Rees, a member of the Institute's Management Committee continuously since 1992, began his five-year term as President of the Royal Society. He was one of three recipients of the 2005 UNESCO–Niels Bohr Gold Medal at the Royal Danish Academy of Sciences and Letters on 15 November 2005 for "his outstanding contributions to the development of modern astrophysics and especially to the explanation of the nature of gamma-ray bursts, the physics of supermassive black holes and the theory of the physics of the Cosmic Microwave Background." Niels Bohr Gold Medals are awarded for outstanding contributions to the field of basic science, to the dissemination of the ideas and ideals of science and to the peaceful development of science in the world.

Professor Sir Peter Swinnerton-Dyer, former Executive Director of the Newton Institute and currently a Senior Fellow, has been awarded the Royal Society's Sylvester Medal for "his fundamental work in arithmetic geometry and his many contributions to the theory of ordinary differential equations." The award will be presented on 30 November 2006, the anniversary of the inauguration of the Royal Society.

Professor Elmer Rees, Chairman of the National Advisory Board, has been appointed Director of the Heilbronn Institute for Mathematical Research. This new Institute, based at the University of Bristol, was founded in October 2005 and is a partnership between the University and the UK Government Communications Headquarters (GCHQ).

S Wilkinson

Dr Robert Hunt delivering his public lecture on 'Maths at Work in the Real World'

Public Understanding of Mathematics

During the Cambridge Science Festival, associated with National Science Week, a public lecture was given on 25 March 2006 by Dr Robert Hunt, Deputy Director of the Institute. The lecture, entitled *Maths at Work in the Real World*, took a light-hearted tour around the many everyday applications of higher mathematics and tried to explain some reasons for studying maths to the younger members of the audience. Dr Hunt concluded with a challenge to find any aspect of life, the world or the Universe which is not intimately related to mathematics. His talk was delivered to an overflowing seminar room, and many comments were received from the public regarding how much they had enjoyed the event and had appreciated the involvement of the Institute in the Cambridge Science Festival.

The Institute continues to have strong links with the Millennium Mathematics Project (MMP), a national project jointly organised by the Faculties of Mathematics and Education at the University of Cambridge. Dr Hunt is the Executive Editor of *Plus*, an online magazine run by the MMP which features

articles on the applications of mathematics aimed at sixth-formers and the general public. On 16 February 2006, the MMP received one of the 2005 Queen's Anniversary Prizes for Higher and Further Education from Her Majesty the Queen in a ceremony at Buckingham Palace.

Posters in the London Underground

Interest in the poster series designed for the *Maths in the Underground* project (see *Annual Reports* for 1999–2001 and subsequent years) continues to be very high, with the Institute receiving many requests for copies. Reprints of the entire poster series may be purchased from the Mathematical Association through its website; the agreement between the Institute and the MA has recently been extended for a further 3 years. A pocket-sized *Maths Goes Underground* booklet (see the *Annual Report* for 2002/03) is also available directly from the Institute.

The posters were used by BBC Wales as colourful and visually arresting set-dressing for the computer classroom in an episode of the ever-popular science-fiction drama *Dr Who*. The episode, entitled *Friends Reunited*, was first broadcast on 29 April 2006 and starred David Tennant, Billie Piper, Elisabeth Sladen and K9.

BBC

Rehearsals for 'Dr Who' featuring two of the 'Posters from the London Underground' series (far right). Left to right: David Tennant as the Doctor, Billie Piper as Rose Tyler and Elisabeth Sladen as Sarah Jane Smith

Publications arising from Newton Institute Programmes

Participants in Institute programmes reported during 2005/06 that, in total, 349 papers had been submitted or published that had arisen out of work either initiated during the programme, or of which a substantial part was carried out during the programme. A complete list is given in Appendix 5 (see the contents page).

A number of these papers were published in the Newton Institute's own Preprint Series which participants are encouraged to use to ensure rapid dissemination of new results. A web page giving details of the Preprint Series is available at

http://www.newton.cam.ac.uk/preprints.html

Work carried out at the Newton Institute during the programme on *Turbulence* (January to July 1999: see the *Annual Report* for 1998/99) has been included in a recently published book: *Prediction of Turbulent Flows* (ed. GF Hewitt and JC Vassilicos), Cambridge University Press, 2005 (ISBN 0521838991).

A themed supplement of the *Journal of the Royal Society Interface* (volume 3, number 6, February 2006), published during the year, highlighted results arising from collaborations within the programme on *Statistical Mechanics of Molecular and Cellular Biological Systems* held at the Institute from January to July 2004 (see the *Annual Report* for 2003/04).

J. R. Soc. Interface 3, number 6

National Advisory Board and UK Mathematics

Membership of the National Advisory Board as at 31 July 2006 was as follows:

Sir John Ball FRS FRSE	University of Oxford
Professor JW Bruce	University of Hull
Professor P Grindrod CBE	Lawson Software, Oxford
Dr RE Hunt	Deputy Director, Newton Institute
Sir John Kingman FRS	Director, Newton Institute
Sir Peter Knight FRS	Imperial College London
Professor PV Landshoff	University of Cambridge
Professor JG McWhirter FRS FREng	QinetiQ
Professor EG Rees FRSE (Chairman)	University of Edinburgh
Professor GO Roberts	University of Lancaster
Dr FA Rogers	King's College London
Professor SM Schaefer	London Business School
Professor JF Toland FRS FRSE	Director, ICMS

National Advisory Board

The National Advisory Board (NAB) advises the Director in all matters relating to the role of the Newton Institute as a National Institute for the Mathematical Sciences. In particular, it plays an invaluable part in ensuring that the Institute's activities are at all times geared towards maximum benefit for the entire UK mathematical community.

The membership, as at 31 July 2006, is given in the table above. The overlap with the Scientific Steering Committee and Management Committee is deliberate and intended to ensure good communication with the Board.

Some of the issues addressed by the NAB in the current year have been:

- Involvement of research students and post-doctoral researchers in Institute programmes, including take-up of the Junior Membership scheme (see page 11)
- Training courses as part of Institute workshops
- Distribution of information about Institute events to colleagues, especially those in non-mathematics departments, via correspondents (see page 17)
- Distribution of background information for non-experts about Institute programmes
- Difficulties encountered in obtaining leave to attend Institute events, including for family and gender-related reasons
- Response to the consultation document *Science and innovation investment framework 2004–2014: next steps* issued by the Chancellor of the Exchequer, and to the suggested use of metrics
- Online dissemination of seminars held at the Institute, including the possibility of real-time webcasting
- Follow-up meetings held several years after an Institute programme
- How the Institute should work with and react to the creation of new institutes with different structures and missions at other UK universities, such as those at Imperial College and in Wales
- The close relationship with the International Centre for Mathematical Sciences (ICMS)

Anyone with views about the national role of the Institute is invited to make these known to any member of the NAB.

The following members of the National Advisory Board stepped down at the end of their term of service on 31 December 2005:

- Sir Michael Berry (Bristol)
- Dr H Ockendon (Oxford)
- Professor AFM Smith FRS (Queen Mary)
- Professor DM Titterington FRSE (Glasgow)

The following new members were elected:

- Sir John Ball FRS FRSE (Oxford)
- Sir Peter Knight FRS (Imperial College)
- Professor GO Roberts (Lancaster)
- Professor SM Schaefer (London Business School)

UK Correspondents

The Newton Institute has for several years maintained a list of correspondents in UK Universities to act as a channel of communication between the Institute and the mathematical sciences community in the UK. This list has in recent years been extended to include relevant learned societies, commercial organisations and institutions not attached to Universities. All correspondents are regularly informed about activities of the Institute, and it is their responsibility to ensure that the information is disseminated to relevant individuals within their institution, whether in mathematics departments or in other scientific groups appropriate to each event. Correspondents also provide invaluable feedback, particularly at the annual meeting of correspondents held at the Institute. The names of all current correspondents can be found on page 17.

Seminars in the UK

Long-stay participants in Newton Institute programmes are strongly encouraged to visit other UK institutions during their stay at the Institute, and many did so during 2005/06 (see page 8). To promote this activity, the Institute covers on request the travel costs within the UK for any overseas participant.

The Institute has set up a register of overseas participants 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 register, which can be found at

http://www.newton.cam.ac.uk/programmes/Speakers.html

Alternatively, advice on suitable speakers may be obtained from the organisers of any Institute programme via the Institute.

Rothschild Visiting Professor Seminars

Through the generosity of NM Rothschild & Sons, each 4- or 6-month programme at the Institute is able to appoint a Rothschild Visiting Professor. These Professors are invariably among the most eminent world-wide in their field, and their presence at the Institute is inspirational.

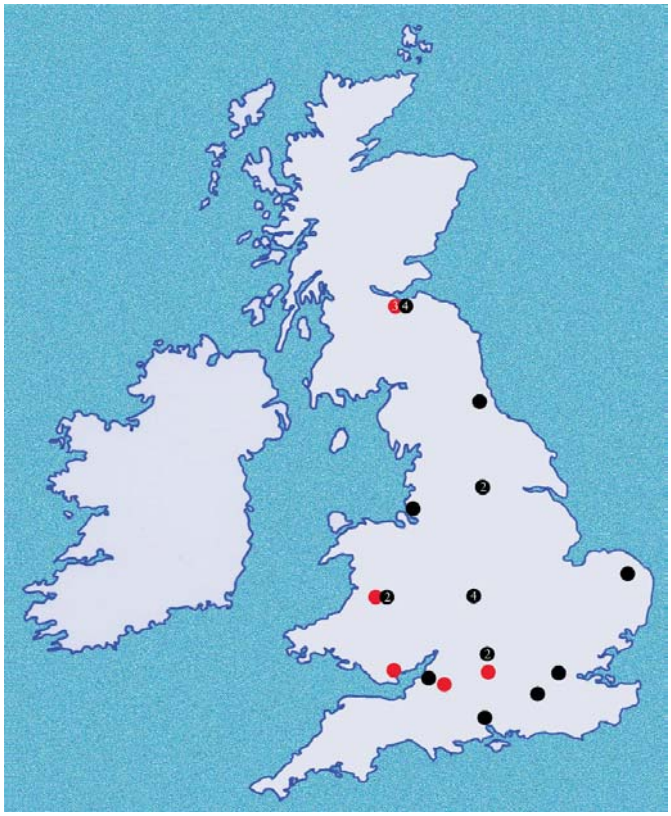
Each Rothschild Visiting Professor is required to deliver one seminar during their tenure that is of general interest and will attract a wide range of mathematical scientists (not just those on the relevant Institute programme). This year's seminars were:

- *Pattern formation in coupled systems*
  M Golubitsky (Houston)
- *Curvature propagation in general relativity*
  V Moncrief (Yale)
- *Picocanonical ensembles: a theoretical description of metastable states*
  D Dhar (Tata Institute)
- *Computational complexity and proofs of combinatorial principles*
  S Cook (Toronto)

These seminars can be heard again on the web (see below).

Seminars on the Web

To increase the benefit of Institute programmes to the UK mathematical community, seminars delivered during workshops or at special events at the



Distribution of Satellite Workshops

● *Planned* ● *Held*

Institute are recorded and made available on the web at

http://www.newton.cam.ac.uk/webseminars/

In many cases, audio files together with accompanying transparencies can be downloaded, and the facility has received widespread praise. At current rates over 500 seminars are being added *per annum*.

Satellite Workshops

The Institute encourages organisers of 4- or 6-month programmes to cooperate with local organisers in holding 'satellite' workshops at UK Universities and institutions outside Cambridge. Satellite workshops are on themes related to an Institute programme, and involve a significant number of longer-stay overseas participants from the Institute. 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.

Satellite workshops have, to date, been held at Bristol, Brunel, Durham, East Anglia, Edinburgh, ICMS, Leeds, Liverpool, Oxford, Southampton, Surrey, Wales and Warwick. Future workshops are currently being planned at Bath, Cardiff, ICMS, the National e-Science Centre, Reading and Wales.

Costs for satellite workshops are typically approximately £10,000 (excluding the overseas travel costs of Institute participants, which are covered separately) and are shared evenly between the Institute and the host institution. Both EPSRC and LMS welcome applications from host institutions for grants to cover their share of the costs (subject to the usual review procedures), and we are extremely grateful to both organisations for the fact that all such applications have so far been successful.

The Institute is keen to continue to expand the geographical range of satellite workshop locations. Institutions interested in holding a workshop should contact either the organisers of the relevant programme or the Deputy Director, Dr RE Hunt (R.E.Hunt@newton.cam.ac.uk).

Newton Institute Correspondents

Newton Institute Correspondents act as a channel of communication between the Institute and the UK mathematical sciences community (see page 14). Further nominations are encouraged.

Aberdeen	Dr A Sevastyanov	Manchester (Mathematics)	Prof M Prest
Anglia Polytechnic	Dr P O'Donnell	Manchester (Physics)	Prof AJ McKane
Bath	Prof JF Toland	Napier	Prof T Muneer
Birmingham	Dr IV Lerner	Newcastle	Dr J Stoyanov
Brighton	Prof SW Ellacott	Nottingham	Dr Y Mao
Bristol	Dr F Mezzadri	Open University	Prof D Brannan
Brunel	Prof J Kaplunov	Oxford	Dr J Norbury
Cambridge	Dr C Teleman	Plymouth	Dr C Christopher
City	Dr O Kerr	Portsmouth	Dr AD Burbanks
Dundee	Prof TNT Goodman	Queen Mary	Prof PJ Cameron
Durham	Prof WJ Zakrzewski	Queen's	Prof AW Wickstead
East Anglia	Prof G Everest	Reading	Dr SE Belcher
Edinburgh	Dr A Olde Daalhuis	Royal Holloway	Dr CS Elsholtz
Essex	Prof PM Higgins	St Andrews	Prof D Dritschel
Exeter	Prof AM Soward	Salford	Prof RD Baker
Glasgow	Dr C Athorne	Sheffield	Prof JPC Greenlees
Heriot-Watt	Dr S Foss	Southampton	Dr CJ Howls
Hull	Dr JW Elliott	Staffordshire	Prof BL Burrows
Imperial College London	Prof M Plenio	Stirling	Prof P Rowlinson
Keele	Dr JJ Healey	Strathclyde	Prof M Ainsworth
Kent	Prof PA Clarkson	Surrey	Dr PE Hydon
King's College London	Dr A Recknagel	Sussex	Prof K Zhang
Lancaster	Dr S Power	Ulster	Dr M McCartney
Leeds	Prof A Pillay	University College London	Prof ER Johnson
Leeds Metropolitan	Dr E Guest	West of England	Dr K Henderson
Leicester	Dr F Neumann	Wales (Aberystwyth)	Dr R Douglas
Liverpool	Prof PJ Giblin	Wales (Cardiff)	Dr KM Schmidt
Liverpool John Moores	Prof PJG Lisboa	Wales (Swansea)	Prof A Truman
LSE	Prof SR Alpern	Warwick	Prof M Reid
Loughborough	Prof AP Veselov	York	Dr N MacKay

ATM	Dr P Andrews	Met Office	Dr MJP Cullen
British Computer Society	Dr M Rodd	Microsoft Research Group	Prof CM Bishop
Edinburgh Mathematical Society		OR Society	Mr R Hibbs
	Prof TH Lenagan	Proudman Oceanographic Laboratory	
EPSRC	Dr C Batchelor		Prof PJM Huthnance
ICMS	Prof J Toland	RAL	Prof I Duff
Institute of Actuaries	Ms P Simpson	Rothamsted Research	Dr M Semenov
IMA (Academic)	Prof D Abrahams	Royal Academy of Engineering	
IMA (Organisational)	Mr D Youdon		Prof J McWhirter
Institute of Physics	Dr G Watts	Royal Society	Prof M Taylor
LMS	Mr P Cooper	Royal Statistical Society	Mr A Garratt
Mathematical Association	Mr RH Barbour	Smith Institute	Dr H Tewkesbury

Management Committee

Membership of the Management Committee at 31 July 2006 was as follows:

Sir John Ball FRS FRSE	Chairman of the Scientific Steering Committee
Dr A Bramley	EPSRC
Professor JW Bruce	London Mathematical Society
Professor WJ Fitzgerald	Council of the School of Technology
Professor GR Grimmett	Head of Department, DPMMS
Professor PH Haynes	Head of Department, DAMTP
Professor EJ Hinch FRS	Trinity College
Dr RE Hunt (Secretary)	Deputy Director, Newton Institute
Professor PT Johnstone	St John's College
Sir John Kingman FRS	Director, Newton Institute
Professor PV Landshoff (Chairman)	General Board
Lord Rees of Ludlow PRS	Council of the School of the Physical Sciences
Dr C Teleman	Faculty of Mathematics

The Management Committee is responsible for overall control of the budget of the Institute, and for both its short-term and long-term financial planning. The Director is responsible to the Management Committee, which provides essential advice and support in relation to fund-raising activity, employment of the staff of the Institute, appointment of the organisers of programmes, housing, library and computing facilities, publicity, and general oversight of Institute activities.

Its aim is to facilitate to the fullest possible extent the smooth and effective running of the visitor research programmes of the Institute and all related activities. The Committee is especially concerned with the interactions between the Institute and its funding bodies, particularly the UK Research Councils, Cambridge University, the Cambridge Colleges, the London Mathematical Society, the Leverhulme Trust and others. It generally meets three times a year.

Staff of the Institute

The staff of the Institute at 31 July 2006 was as follows:

- Dr Mustapha Amrani, Computer Systems Manager
- Tracey Andrew, Programme and Visitor Officer
- Josie Camus, Information Assistant
- Jonathan Chin, Deputy Computer Systems Manager
- Jennifer Dorkings, Programme and Visitor Secretary
- Esperanza de Felipe, Housing Officer
- Kate Gilbert, Director's Administrative Assistant
- Steve Greenham, Technical Assistant
- Dr Robert Hunt, Deputy Director
- Sir John Kingman FRS, Director
- Gaenor Moore, acting Librarian and Information Officer
- Doreen Rook, Finance and Clerical Assistant
- Christine West, Institute Administrator
- Sara Wilkinson, Librarian and Information Officer (on leave from 11 August 2006)
- Stephen Williams, Senior Finance Officer

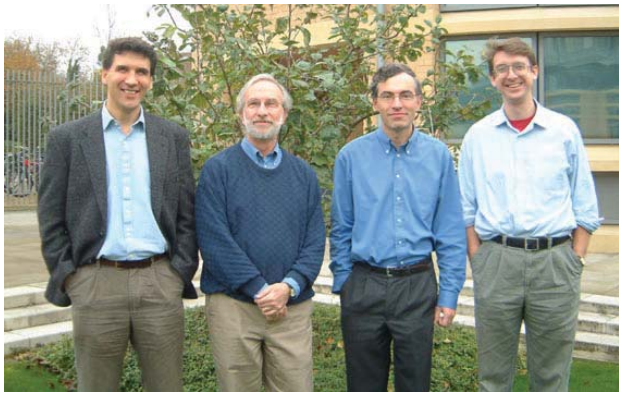
Professor PV Landshoff
Chairman of the Management Committee

Pattern Formation in Large Domains

1 August to 23 December 2005

Report from the Organisers:
JHP Dawes (Cambridge), M Golubitsky (Houston), PC Matthews (Nottingham) and AM Rucklidge (Leeds)

S Wilkinson



AM Rucklidge, M Golubitsky, PC Matthews and JHP Dawes

Scientific Background

Pattern formation is the study of the spontaneous appearance of structure in nature and in the laboratory. Natural examples include sand ripples, geological structures such as the Giant's Causeway, cloud formations, animal coat markings, the synchronous flashing of fireflies and animal gaits. Laboratory examples span a diverse range of disciplines including fluid mechanics, granular media, chemistry (both at macroscopic and nanometre scales) and nonlinear optics.

This broad range of motivating examples is mirrored in the similarly broad range of techniques that have been brought to bear on their analysis: dynamical systems theory, group representations, asymptotic analysis for differential equations and computational methods. The field is thus well suited to the kind of multidisciplinary interaction that an Isaac Newton Institute programme encourages.

Observations of similar features in many different natural and experimental systems point to a kind of universality that should be manifest in the underlying mathematics, and to the possibility of scientific progress.

Although regular patterns with a single length-scale such as stripes and hexagons are well understood, many systems naturally generate more complex structures when given the freedom to fill an experimental or computational domain that is large compared to the pattern length-scale. Examples of these more complex structures include rotating spiral waves, spatially quasiperiodic patterns and 'spatiotemporal chaos' (of many kinds). These present challenges to our current theoretical understanding. A key aim of the programme was to bring experts in these different mathematical areas together with experimental scientists who work directly in the areas of application.

Structure of the Programme

The programme was structured around a series of five one-week workshops (four at the Newton Institute and a satellite meeting at the University of Surrey) which introduced and developed the central themes of the programme.

An additional two-day workshop on *Pattern Formation in Growing Domains* coincided with the visits of various participants concerned with pattern formation problems where system parameters naturally vary over time. Such problems occur naturally in many pattern-forming systems motivated by mathematical biology.

A one-day workshop in memory of Prof L Kramer of the University of Bayreuth was held on 11 December 2005, organised by A Newell and A Buka. Friends and family gathered to discuss Lorenz Kramer's life and work and his seminal contributions to pattern formation across many disciplines.

M Golubitsky gave a stimulating and very well attended Rothschild Visiting Professor lecture with the title *Pattern Formation in Coupled Systems*.

The organisers are grateful to the Leverhulme Trust for funding the visit of M Cross for the entire

programme, through a Leverhulme Visiting Professorship.

A total of 42 long-stay participants provided continuity in the programme. Together with the 38 short-stay participants, a purposefully lower level of activity between workshops enabled time for reflection and digestion of the workshop topics, and for new ideas and collaborations to emerge. A regular timetable of two seminars and two pub visits per week struck a balance between formal discussions and informal collaborative work.

Programme participants travelled extensively through the UK, giving seminars and forging links with many researchers in related disciplines.

Workshops

Pattern Formation

Marie Curie Training Course, 1–5 August 2005

Organiser: JHP Dawes

The programme began with a training course designed for research students and post-doctoral researchers from many scientific backgrounds to appreciate and absorb the standard mathematical techniques in the field, and to point the way to current open questions and challenges. The 71 participants at the workshop included 38 research students and 11 post-doctoral researchers, from 10 countries. Much of the support for the workshop was provided by the EC.

The variety of techniques used by theorists encompasses pure mathematical areas, such as representation theory; traditional 'applied mathematics' areas, for example multiple scales asymptotics; and, increasingly, numerical simulation. With this in mind, the course was structured around three sets of four lectures each, given by JHP Dawes (symmetric bifurcation theory), M Cross (spatially extended pattern formation) and jointly by L Tuckerman and D Barkley (numerical methods). The morning lectures were complemented by afternoons spent in less formal problem-solving sessions and computing labs using interactive software written by M Cross and D Barkley. Three late afternoon lectures covered the experimentalist's viewpoint (G Ahlers and R Ecke), and theoretical developments in the dynamics of coupled cell systems (M Golubitsky).

As well as providing a succinct summary of the state of the art, the course provoked lively interactions between longer-term participants and younger scientists, particularly during the poster sessions. The broad mixture of subject areas and international diversity of the participants, both students and longer-term participants resident during the week, made for a thoroughly enjoyable and extremely successful start to the programme.

Developments in Experimental Pattern Formation

Marie Curie Conference, 8–12 August 2005

Organisers: R Ecke, AM Rucklidge and H Swinney

The aim of this workshop, which was supported by the EC, was to bring together experimentalists working on disparate systems in physical science in order to focus on the common issues of pattern formation and provide theoretical challenges for the remainder of the programme. The workshop attracted 68 researchers from 12 countries, of whom 23 were from the UK. The workshop consisted of a series of 50-minute invited lectures from the world leaders in the field. These talks covered a wide range of problems, from the classical ones of thermal convection and the Faraday wave experiment, to situations where insights from a pattern formation perspective are only just being applied: granular flows, turbulence, electric discharges in plasma, nonlinear optics, foams, columnar joints, slime-mold aggregation and patterns in the arrangement of leaves and seeds in plants. In addition there were two poster sessions and, courtesy of S Morris, two experimental demonstrations. Many of the talks and posters provoked animated discussion, and the workshop closed with an overall summary and discussion session led by P Hohenberg; this highlighted some of the common features and theoretical challenges, including chaos in spatially extended systems, localised states and the influence of noise.

Theoretical Aspects of Pattern Formation

Satellite Meeting at the University of Surrey, 19–23 September 2005

Organisers: I Melbourne, AM Rucklidge and B Sandstede

This workshop was supported jointly by the London Mathematical Society, EPSRC and the

S Wilkinson

Participants at the workshop on 'Theory and Applications of Coupled Cell Networks'

Institute of Advanced Studies (IAS) at Surrey. It consisted of 19 lectures and 7 posters, covering a broad range of topics. A total of 51 participants, including 5 research students, attended the workshop, with 21 of them participating in the parent programme at the Isaac Newton Institute either before or afterwards.

Among the presenters were experimentalists, theoretical physicists and chemists, and applied and pure mathematicians. The five lectures on 20 September were sponsored by the IAS and were aimed at a broader audience, with the goal of surveying the state of the art in the field and outlining promising future directions.

The workshop focussed mainly on theoretical aspects of pattern formation and discussed problems arising from, amongst other topics, the formation of bacterial colonies, excitable media and reaction-diffusion systems, bifurcations of spiral waves, flows in thin liquid films, temporal intermittency and spatiotemporal chaos, coarsening and the dynamics of defects, and the formation of patterns in turbulent flows.

Theory and Applications of Coupled Cell Networks

Workshop, 26–30 September 2005

Organisers: P Ashwin, S Coombes, JHP Dawes and M Golubitsky

The central idea motivating this workshop was that of a dynamical system distributed over the nodes (or 'cells') of a network. A total of 86 participants from 16 countries gathered for a rather hectic workshop schedule. Thirty-three participants were younger researchers, ensuring a lively poster session.

Comparing the local dynamics of individual cells in a network leads to notions of symmetry and synchrony in the overall dynamics, linking this workshop directly to the general themes of the programme. But the network structure also brings new mathematical questions and challenges. With the first presentation of the workshop, M Golubitsky gave an overview of recent extensions of equivariant local bifurcation theory to coupled cell systems where the idea of a symmetry group is replaced by that of a symmetry groupoid; this remained a theme for the week, with later speakers presenting sometimes surprising mathematical results developed in this new framework. Closely related to this were talks discussing the interplay between network architecture and dynamics. Other developing lines of mathematical attack include the measurement of topological characteristics of pattern formation and a systematic treatment of global bifurcation theory.

Interwoven with the mathematical questions, presentations by (mathematical) biologists discussed a host of specific applications: to neuroscience, to systems biology, and to cell physiology and development. Many participants wrote at the end of the week of the enormously stimulating variety of the talks and the sense of adventure and excitement about the challenges that lie ahead, both in the mathematics and in the potential for understanding, prediction and control in the applications.

The workshop was supported by the US Office of Naval Research Global, the European detachment of the US Air Force Office of Scientific Research, and EPSRC.

S Morris

Electroconvection pattern formed in an annular smectic liquid crystal film. Colour variations correspond to local variations in film thickness

Pattern Formation in Fluid Mechanics

Workshop, 12–16 December 2005

Organisers: E Knobloch, PC Matthews and MRE Proctor

Many of the key motivating examples for the study of pattern formation arise from fluid mechanics, in particular thermal convection in a horizontal fluid layer (the Rayleigh–Bénard problem), the Taylor–Couette experiment of flow between coaxial rotating cylinders, and Faraday waves at the free surface of a vertically vibrated horizontal fluid layer. This workshop addressed unsolved questions in these classic systems, such as the imperfect bifurcation at the onset of Taylor–Couette flow and pattern selection in the Faraday experiment. Talks on the Rayleigh–Bénard problem included novel effects such as non-uniform heating, the addition of time-dependent vertical acceleration, or closely related systems such as electroconvection in liquid crystals.

Talks and poster sessions covered many other fluid mechanical phenomena, including avalanches, magnetic fluids and de-wetting. Theoretical aspects discussed included mechanisms for localised patterns, behaviour of spiral waves, defect motion in patterns and the derivation and use of amplitude equations for travelling waves.

There were 48 participants: 13 from the UK and the remainder predominantly from France, Germany, Spain, Russia and the USA. Financial support from the ICIAM99 fund is gratefully acknowledged.

Outcome and Achievements

It was clear throughout the programme that participants had purposeful and productive visits. In the short summaries below we select some particular highlights, and must apologise to participants for not being able to provide a comprehensive account of the programme's activities in the space available.

Our broad overall aim was realised, in that theoreticians and experimentalists interacted in unexpected and mutually beneficial ways that has provoked renewed interest both in understanding particular physical phenomena, and in extending the available theoretical techniques. A major outcome of the programme is thus the establishment of many new international and interdisciplinary collaborations.

Rayleigh–Bénard Convection

The problem of thermal convection in a thin horizontal fluid layer continues to motivate the field. During the programme two particular issues were addressed, and the combinations of theorists and experimentalists involved in both provide good examples of the kinds of new interactions the programme generated. Intermittent 'bursting' dynamics in convection in an inclined layer has been investigated experimentally by K Daniels. She collaborated with E Knobloch and M Golubitsky in a project to explain this theoretically as the result of a mode interaction between stripe patterns in two different orientations to the inclination. For horizontal layers in medium-size domains, much remains to be done examining the onset of time-dependent dynamics with increasing thermal forcing: G Ahlers plans further experiments, following useful discussions with E Knobloch, M Golubitsky and AM Rucklidge.

Taylor–Couette Flow

It is illustrative of the complexity of nonlinear phenomena that there are still unresolved issues in this classic fluid mechanical problem, and it continues to be the focus of both experimental and theoretical work. Ongoing discussions between AM Rucklidge, A Champneys, M Cross, T Mullin

and A Cliffe synthesised a range of recent new theoretical ideas with experimental results, leading to new insights on the onset of the pattern-forming instability and the influence of the end walls in the apparatus.

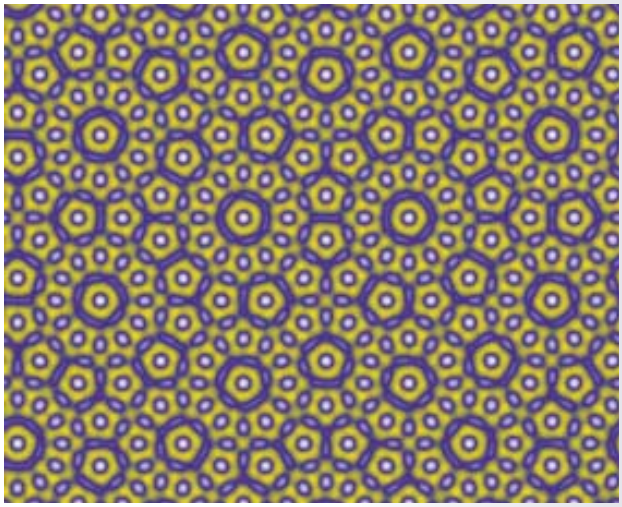
De-wetting Patterns

L Pismen and E Knobloch worked on the dynamics of liquid droplets on melting or freezing solid surfaces. Along with discussions between U Thiele and E Knobloch on drop motion in homogeneous inclined surfaces, and the strong likelihood of experimental interaction through R Richter using ferrofluids, this points to a promising new area of application for pattern formation methods. As observed above, such motivation for experimental investigation, and collaboration with theorists, would have been much harder without the programme.

Localised States

Many pattern-forming systems are observed to generate localised spots of activity. Experimental observations of this kind were discussed by several speakers at the second and fifth workshops, including S Residori and W Firth (in nonlinear optics), H-G Purwins (in dielectric gas discharge experiments) and R Richter (in a ferrofluid, near the Rosensweig instability). Numerical results showing localised patterns were presented by E Knobloch and D Lloyd.

Many authors, including participants A Champneys, G Lord and E Knobloch, have contributed to theoretical analysis of the existence of localised patterns near a subcritical bifurcation, and during discussions it was realised that there should be close connections with a rather different mechanism for localisation examined by PC Matthews, S Cox, MRE Proctor and JHP Dawes. Such a synthesis of ideas helps explain the origin of the localised states: for example combining the Ginzburg–Landau approach with the description of the set of steady solutions in terms of a spatial dynamical system. E Knobloch and JHP Dawes separately completed papers examining specific model problems in which localised states appear. New collaborations are under way involving several of the above participants and B Sandstede.



AM Rucklidge

Approximate quasipattern solution of a set of model equations designed to encourage mode interactions between waves oriented at 30° from each other. The resulting pattern has 12-fold rotational symmetry but no translational symmetry

Pattern Dynamics

One outstanding issue in pattern formation is the motion of grain boundaries and its influence on large-scale coarsening dynamics of the pattern. This topic was discussed by M Cross, A Newell, J Vinals, N Ercolani, M Paul, P Hohenberg, PC Matthews and B Sandstede, and new computational and analytical research was initiated.

More strongly driven pattern forming systems often exhibit spatiotemporal chaos in various forms. K Daniels, M Cross and M Schatz discussed the use of spatiotemporal chaos as a mechanism for passive scalar transport, and it is envisaged that further collaboration will combine experimental and large-scale numerical simulations of such dynamics.

More theoretical treatment of ideas of generic instabilities of patterns in large domains led to fruitful discussions between PC Matthews, AM Rucklidge, M Cross and I Melbourne. There are delicate theoretical questions concerning long-wavelength instabilities and the existence of spatially quasiperiodic solutions, and progress was made in identifying the difficulties in applying standard theoretical tools.

Theoretical Issues in Model Equations

The importance of simple, clearly defined, model problems in understanding and disentangling issues in nonlinear systems cannot be overstated. Two

particular examples of this came to light. Firstly, the 'Nikolaevsky equation' for so-called 'soft-mode' turbulence may or may not prove to be the generic equation of its kind. This issue was addressed by PC Matthews, M Tribelsky, R Wittenberg, S Cox, MRE Proctor and JHP Dawes, and collaborative work is continuing. In a similar vein, the typical dynamics of systems with stochastic forcing is of central importance in identifying those features of experimental results that are due to uncontrollable external noise. G Lord, M Cross and AM Rucklidge collaborated on this problem.

Faraday Waves and Quasipatterns

Understanding of the complex mode interactions involved in the Faraday experiment has improved as a result of a synthesis of experimental, theoretical and numerical work by J Fineberg, J Porter, A Skeldon, M Silber, PC Matthews and AM Rucklidge. In addition to the close comparison of experimental results and theoretical predictions, there are difficult technical issues surrounding the existence of spatially quasiperiodic structures. Discussions at the satellite workshop between AM Rucklidge, I Melbourne and E Wayne opened up new possibilities for establishing the existence of spatially quasiperiodic patterns using ideas related to KAM theory.

Heteroclinic Dynamics

Heteroclinic orbits are objects in phase space that account for the appearance of intermittent temporal dynamics. They appear naturally in symmetric systems and as such have been well studied, at least in low-dimensional problems. For higher-dimensional dynamical systems many questions are unanswered. The programme generated significant new interactions that should lead to deeper understanding of these issues. H Kori and P Ashwin collaborated on heteroclinic cycles in coupled oscillator networks. M Cross and JHP Dawes worked on a model for the 'domain chaos' state in rotating Rayleigh–Bénard convection. JHP Dawes and A Pikovsky discussed general issues in a new class of PDE problems that exhibit travelling wave dynamics with interesting similarities to heteroclinic dynamics in ODEs. These new directions should provide methods and techniques that enable greater general progress to be made in the study of higher-dimensional examples.

Symmetric Dynamics and Bifurcation Theory

One of the central pillars of the theory is the exploration of dynamical systems in the presence of symmetry. A range of new bifurcation phenomena appear and there are a number of subtle issues. D Chillingworth and R Lauterbach renewed their collaborative efforts on forced symmetry-breaking and the identification of heteroclinic orbits in such bifurcation problems. A seminar by R Lauterbach on group actions where bifurcation to steady states cannot be guaranteed led to further work with PC Matthews. In addition, collaborations between A Dias, F Antoneli and PC Matthews have resulted in a paper on new generally applicable methods for the computation of the number of invariant and equivariant polynomials for symmetric Hopf bifurcation. A Dias and PC Matthews collaborated with A Rodrigues on the particular case of S_n symmetry, relevant to the coupled cell theme below.

Coupled Cell Networks and Motifs

Together with I Stewart, T Elmhirst and many other collaborators, M Golubitsky continues to develop a general theory for the dynamics of coupled cell networks, extending the idea of global system symmetries to account for local 'symmetries' in a network of similar units. For the first time, experimental verification of his theoretical results for these systems was carried out by T Mullin and N McCullen using coupled electronic oscillators. This collaboration would not have come about without the Newton Institute programme, and provides clear impetus for further theoretical study of coupled cell systems. The 'feed-forward' network that was analysed seems to have a practical application, as a narrow bandwidth filter–amplifier.

Much additional motivation for the study of coupled cell systems comes from biology: in particular genetic regulatory and protein signalling networks. Discussions between M Golubitsky, J Tyson and U Alon enabled an extremely fruitful exchange of ideas in what could turn out to be a very important area for future research. E Crooks and M Golubitsky worked on the idea of 'objective structures' and hope to relate this to the groupoid approach investigated by M Golubitsky, I Stewart and co-workers. It is clear that these conversations, in particular, represent the beginnings of exciting new directions for the field.

Global Problems in Mathematical Relativity

8 August to 23 December 2005

Report from the Organisers:
PT Chruściel (Tours), H Friedrich (Golm) and P Tod (Oxford)

S Wilkinson

P Tod, H Friedrich and PT Chruściel

Scientific Background

Einstein's theory of Special Relativity celebrated its centenary in 2005. So completely successful has it been, that it is impossible to imagine physics without it. It is so much a part of our framework of thought that we almost don't see it as a theory. Special Relativity is completely understood and straightforward enough to be taught to second-year undergraduates, and it is hard to imagine that there could be unsolved mathematical problems in the theory awaiting solution.

Its younger sibling, Einstein's theory of General Relativity, turned 90 in 2005 and enjoys a rather different reputation. When Eddington, in the early days, was asked if it was true that only three people in the world understood Relativity, it was General Relativity that he was being asked about. For a long time it was seen as the last word in mathematical complexity, but along with that it was always clearly a theory of the physical world, and in fact a very successful one. Predictions of the theory are verified to many significant figures, classically in the solar system, particularly in the observation of planetary orbits, and more recently in observations of binary pulsars. These latter observations provide indirect evidence of the existence of gravitational radiation, behaving just as the theory predicts.

Now, in contrast to Special Relativity, there are very definitely mathematical problems in General Relativity awaiting solution, and that was the topic of this programme.

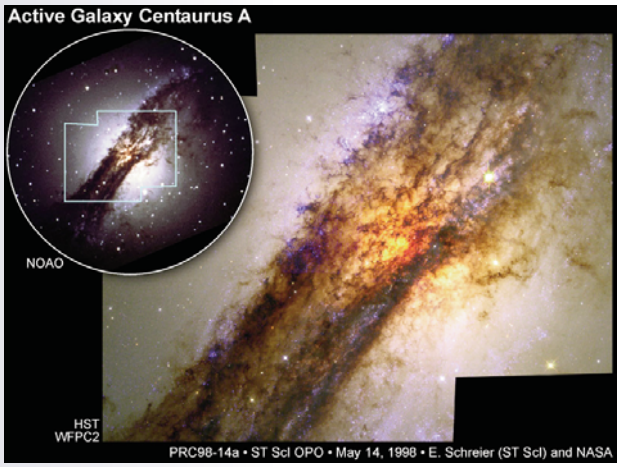
There are two approaches here: one may ask how this geometrically-based subject relates to other mathematical disciplines involving geometry, and how one sets about using the theory. For the first, it can be said that almost any idea useful in differential geometry will find application in General Relativity, but often with a distinctive slant because the geometry of GR is Lorentzian instead of Riemannian. For the second, one can think of GR as determining a space-time as a geometry evolving from suitable initial data. Now there are many problems: How does one construct the data? How does the evolution proceed and how may one reliably compute it, to extract quantitative predictions? What singularities may form, and are they 'censored' inside black holes? Indeed, what kinds of black holes are there?

The aim of our programme was to address all of the above questions.

Structure of the Programme

The programme was attended by 61 long-stay participants and 91 short-stay ones, with a core of 7 researchers, 2 affiliates and 2 graduate students who attended the whole programme. The two single events that were most enthusiastically received by the participants were the conference on *Global General Relativity* and the Spitalfields Day, *Einstein and Beyond*. A satellite meeting, *New Directions in Numerical Relativity*, took place in Southampton. The programme was closed by a topical conference, *Einstein Constraint Equations*.

The programme itself was structured into emphasis weeks, which can be grouped roughly into five categories: evolution problems (including numerical



Space Telescope Science Institute and NASA

A massive black hole hidden at the centre of the Centaurus A galaxy (NGC 5128), feeding on a smaller galaxy

ones), constraint problems, global problems, quantum problems, and the remaining approaches (Riemannian and Lorentzian geometry, inverse scattering methods). Ninety-one talks were given during these emphasis weeks, outside of the workshops.

Workshops

New Directions in Numerical Relativity

Satellite Meeting at the University of Southampton, 18–19 August 2005

Organisers: C Gundlach and H Friedrich

The aim of this satellite meeting was to discuss mathematical aspects of the continuum and discrete models and to present simulations at the edge of what is currently possible.

It was attended by 46 researchers, including 18 members of the parent programme at the Newton Institute and 7 participants from Southampton. The programme consisted of 12 invited plenary talks of 45 minutes each, with 15 minutes' discussion. The simulations of binary black hole space-times presented by F Pretorius attracted a lot of interest, and his talk was considered a highlight of the meeting.

In spite of the tight schedule the participants had lively discussions after the lectures and during the breaks. The convenient accommodation and dinner arrangements allowed them to extend their discussions during and after the meals. The meeting was generally considered to be very stimulating and useful. It provided an opportunity for several younger participants (PhD students from Germany, Poland and Greece) to meet leading researchers in the field and share their ideas.

A special issue of the journal *Classical and Quantum Gravity* on numerical General Relativity, centred around the Southampton meeting together with a meeting that took place in Banff in February 2005, is in preparation.

Global General Relativity

Marie Curie Conference, 22–26 August 2005

Organisers: PT Chruściel, H Friedrich and P Tod

The aim of this conference was to give a wide-ranging review of the current status of General Relativity, with emphasis on the mathematical aspects but including observational and numerical results. There were 97 participants in total, including 17 graduate students and 11 post-doctoral researchers. The conference was filled to capacity, with several well qualified applicants turned down because of lack of space.

The 18 talks were of a very high standard. Taken as a whole, they were pedagogically accessible and covered the field, with excursions into nearby subjects from which the motivation for mathematical relativity may be drawn (specifically astrophysics and cosmology, numerical relativity, and higher-dimensional space-times inspired by string theory). We shall briefly describe the organisers' favourites.

Sir Martin Rees reviewed knowledge about black holes derived from observations, distinguishing stellar (3–$100M_\odot$), intermediate (10^2–$10^4M_\odot$) and massive (10^4–$10^{10}M_\odot$), discussing evidence for each class. This was a wide-ranging talk of great scope and skill. Of particular interest to this audience was the possibility of establishing that some black holes are rotating, using astrophysical signals derived from properties of the Kerr solution.

Greg Galloway gave a review of 'dynamical horizons' and his recent work with Ashtekar, which introduces real mathematical substance into this physically-motivated area of investigation. In one of several talks on the theory of partial differential equations as it illuminates General Relativity (the other talks being by Klainerman, Bizoń, Dafermos

and Tao), Igor Rodnianski reviewed his 'new, economical' proof of the stability of Minkowski space. That is to say, data close to data for Minkowski space evolve to a give a space-time globally close to Minkowski space. The proof, with Lindblad, is remarkable in exploiting harmonic coordinates, which, as the conference heard from several speakers, are re-emerging as a valuable tool in both mathematical and numerical relativity. Other highlights included talks by Bob Wald on significant recent progress towards a rigorously defined, interacting quantum field theory in curved space-times using the ideas of micro-local analysis and local and covariant quantum fields; and Rick Schoen on analytic problems in the solution of the vacuum constraint equations, a subject which has made great progress in the last five years.

It is invidious to choose highlights, as very few talks were less than excellent. This view from the organisers was confirmed in conversations with participants and by comments in the end-of-conference questionnaires.

Einstein and Beyond

Spitalfields Day, 7 November 2005

Organiser: P Tod

This Spitalfields Day, sponsored by the LMS, was intended to mark the 90th birthday of General Relativity, and consisted of three talks on it and its extensions.

Under the title *Quantum Riemannian Geometry and its Ramifications*, Abhay Ashtekar described the programme for quantum gravity pursued by him and collaborators. Their aim is to construct a rigorous, background-independent quantisation of General Relativity. This leads to a striking new view of the physical universe in which, for example, area is quantised. For a system with finitely many degrees of freedom, it leads to a modified quantum mechanics and, in an application to cosmology, it becomes possible to evolve through the Big Bang, an idea which recurs below.

Karsten Danzman gave a very informative talk on *Gravitational wave astronomy: The large detectors are going into operation!*, with excellent graphics, including Einstein riding a laser beam on a bicycle. The subject is full of exciting prospects, as the observing run of the Geo 600 detectors starts at the end of this year and the project will be fully operational and collaborating with the LIGO project from next spring. Already, the teams are looking forward to the next generation of detectors, which includes the ambitious LISA project for a vast detector based on an array of satellites.

Two slides from Sir Roger Penrose's Spitalfields Day lecture. The entire lecture can be heard on the web *(see page 15)*

Finally, the hall was packed for Sir Roger Penrose on *Before the big bang? A new perspective on the Weyl curvature hypothesis*. Accepting the observations of a positive cosmological constant, and assuming that all massive particles decay eventually, Sir Roger proposes a new view of the Universe at very late times. The matter content is solely massless particles and radiation, and space-time is very simple conformally. Now, according to his Weyl Curvature Hypothesis, the initial singularity of the Universe has finite or possibly zero Weyl curvature and so, at the level of conformal structure, the very early and very late Universe are very similar. They are distinguished by the behaviour of the conformal factor but, Sir Roger suggests, the conformal structure at the end of a phase of expansion may be continued through infinity as a new Big Bang.

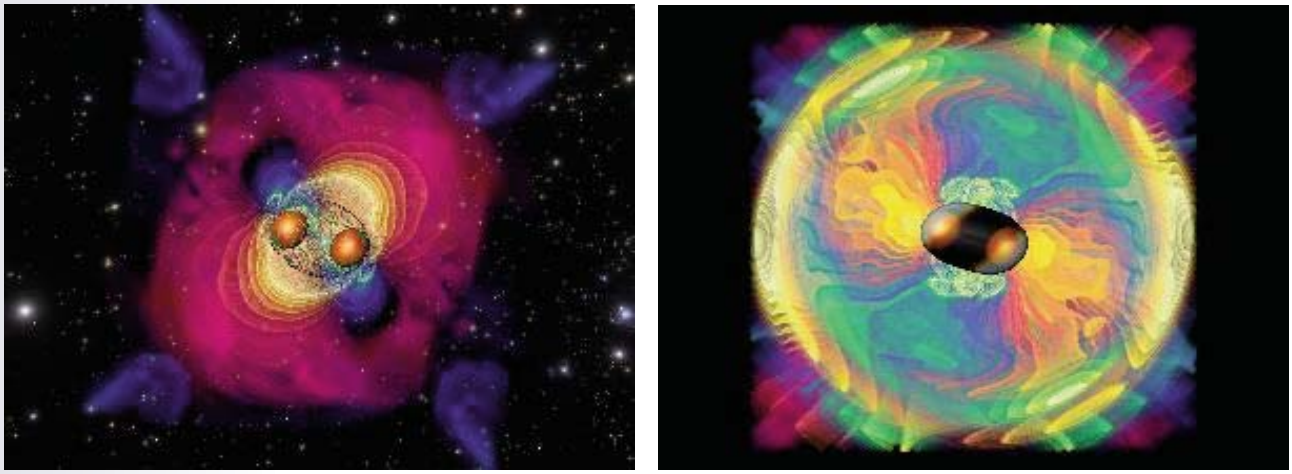
These were three excellent talks, whose different styles complemented each other well.

Einstein Constraint Equations

Marie Curie Conference, 12–16 December 2005

Organisers: PT Chruściel and J Isenberg

This conference was attended by 65 researchers, and attracted substantially more interest than expected.



Albert Einstein Institute

Numerical simulation of a grazing collision of two black holes

Unlike the earlier wide-ranging *Global General Relativity* conference which was held at the beginning of the programme, this conference was focussed on just one area of mathematical relativity: the mathematical study of the Einstein constraint equations. All the lectures were related to this topic in some way, and the meeting had a working character. There were 18 talks on a variety of issues, including: (i) use of the conformal method to obtain rough solutions and solutions with scalar fields; (ii) mass and quasi-local mass; (iii) gluing; (iv) preservation of the constraints during numerical evolution; (v) the Yamabe problem; and (vi) the mathematical description of the space of solutions of the constraints in phase space.

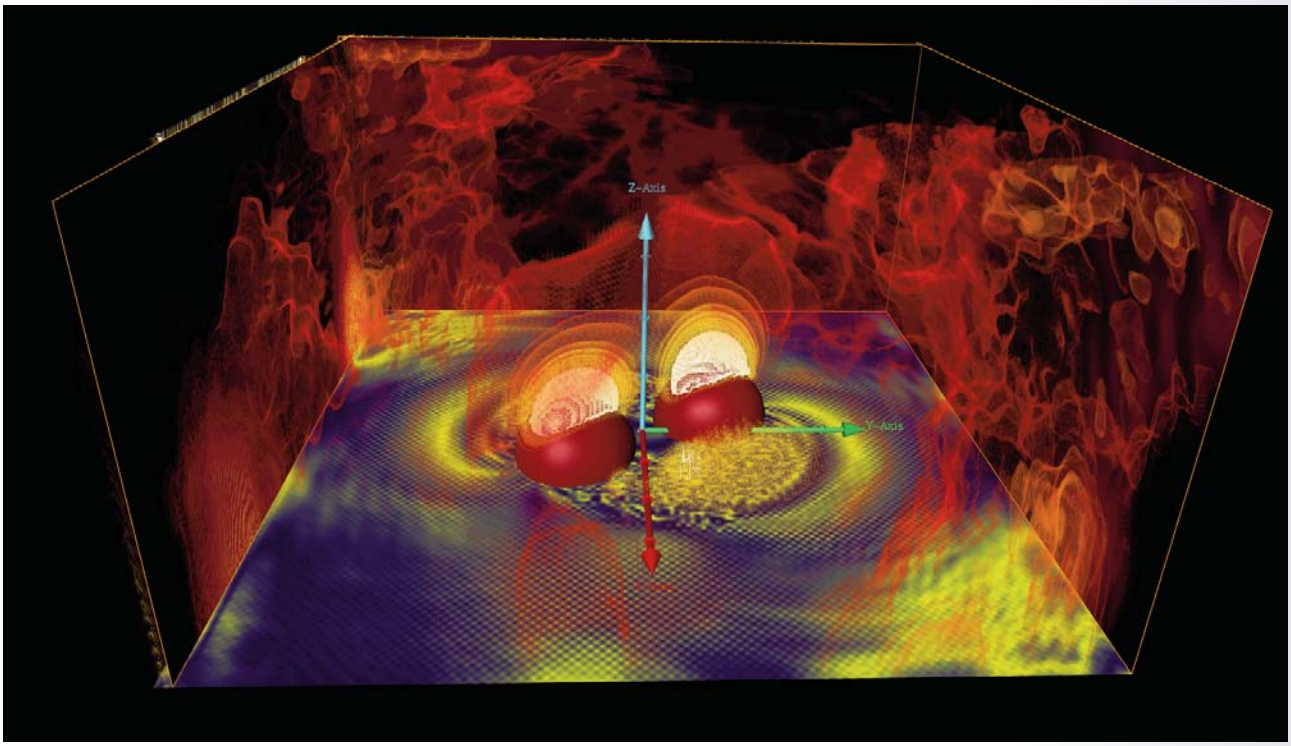
The talks of Dan Pollack, David Maxwell and Justin Corvino dealt directly with methods for finding solutions of the constraints. They showed that the conformal method for solving the constraints can now produce solutions of remarkably low differentiability, and can handle most matter source fields (including some that have caused difficulty in the past). They also showed how recent developments in the technology of scalar curvature deformation can be used to glue together solutions of the constraints in interesting ways.

Throughout the history of studies of solutions of the Einstein constraints, the concept of 'mass' has played a central role. At least five of the talks at the conference reflected the importance of mass. Noteworthy were Greg Galloway's discussion of a nonspinorial way to prove a positive mass theorem for hyperboloidal initial data, the analyses by Pengzi Miao and Niall O'Murchadha of difficulties with various notions of quasi-local mass, and Sergio Dain's study of the relation between spin and mass in axisymmetric black holes. Gerhard Huisken's excellent discussion of heat flow methods for generating special radial foliations of asymptotically flat initial data sets relates to the issue of mass as well.

Since the study of the constraint equations via the conformal method depends upon understanding conformal deformations of scalar curvature, there were three talks at the conference which discussed recent progress on the Yamabe problem. Taken together, the talks of Abbas Bahri, Simon Brendle, Marcus Khuri and Frank Pacard gave a rather complete picture of what is currently known about both singular and regular solutions of the Yamabe equation.

The constraint equations play a major role in current efforts to numerically model astrophysical events such as black hole collision. Two talks at the conference concerned the numerical treatment of the constraints. Lee Lindblom's talk provided some hope that we might some day be able to handle one of the big problems of numerical relativity: the exponential growth of the constraint functions during numerical evolution. The talk of Robert Bartnik, although not focused on numerical issues, provided a very nice mathematical structure for studying space-times in which the Einstein constraint equations are not satisfied.

The talks were all well attended by the conference participants, and the consensus was that they were generally of high quality.



Laboratoire de l'Univers et ses Théories, Meudon

Gravitational waves emitted by a binary system of neutron stars

Outcome and Achievements

The programme attracted a large number of participants, experts in all aspects of the field. Special care was taken to include promising young scientists, either as participants, junior members, affiliates or workshop participants. (All the graduate students who took part were enthusiastic about the insights they gained and the new perspectives opened for them.) This will have a long-term influence on the development of the field.

During the preparation of the programme it was recognised that the field is under-represented in UK universities, except perhaps in Oxford and in Cambridge itself. Efforts were made to alleviate this by inviting a wide spectrum of UK participants. In additions to the seminars at the Newton Institute, members of the programme gave 34 seminars throughout the UK.

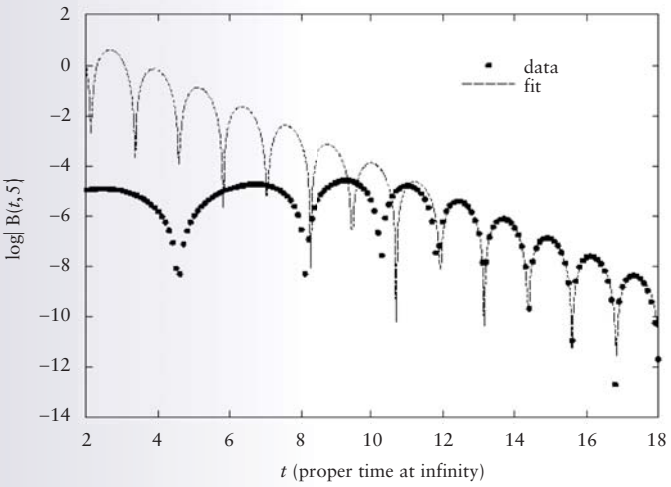
There was consensus about the outstanding level of many lectures. New collaborations were initiated, many more were continued, and extremely positive feedback was received concerning the impact of the programme on the research of many participants.

The participants of the programme submitted 31 papers to the Newton Institute preprint series.

Several very significant publications have appeared as a direct result of the research during the programme:

Mihalis Dafermos and Igor Rodnianski proved uniform decay bounds for solutions of the scalar wave equation on four-dimensional Schwarzschild space-time. This is a spectacular achievement, as this problem has been unsuccessfully studied by many researchers for years. The result is the starting point for any nonlinear stability analysis of black hole space-times. In related work, Mihalis Dafermos and Gustav Holzegel proved restricted nonlinear stability of a class of five-dimensional black holes found in June 2005 by Piotr Bizoń, Tadeusz Chmaj and Bernd Schmidt.

These solutions provide very interesting toy models, for which heuristic results from four dimensions can be rigorously established (the higher dimension making things easier): e.g., the existence of quasi-normal modes as illustrated in the figure overleaf. The stability of those black holes has been hinted at in numerical work by Piotr Bizoń during the programme. This is the first nonlinear stability result for the usual space-like Cauchy problem for black hole space-times. A follow-up to this work is another Newton Institute preprint by Piotr Bizoń



Quasi-normal ringing of Bizoń–Chmaj–Schmidt black holes (courtesy of Piotr Bizoń)

et al., analysing a nine-dimensional analogue of the Bizoń–Chmaj–Schmidt black holes. These papers will certainly start an avalanche of follow-up studies, including ongoing work by Bizoń and Gibbons.

Greg Galloway and Richard Schoen generalised Hawking's black hole topology theorem to all higher dimensions, showing that black hole horizons are necessarily of positive Yamabe type. This is a beautiful result, with an elegant proof published in the Newton Institute preprint series, of fundamental importance for the study of black holes.

Helmut Friedrich found necessary and sufficient conditions for the convergence of multipole expansions for static vacuum space-times. This closes a gap in our understanding of such metrics which has been open since the pioneering work by Geroch in 1970, together with its partial solution by Beig and Simon in 1980.

Piotr Chruściel and Paul Tod have closed the last gap of the 'static electro-vacuum no-hair theory', showing that the only regular static electro-vacuum black holes with degenerate components of the event horizon are the Majumdar–Papapetrou ones.

Vincent Moncrief finished writing his long-awaited paper on integral representation formulae for the curvature tensor with the associated *a priori* estimates. The result, published in a Newton Institute preprint, was discussed in detail during his lecture as Rothschild Visiting Professor at the Institute. The representation formula is widely expected to play a major role in the analysis of the dynamical properties of the Einstein equations. Variations and applications of Moncrief's result have already been discussed by Sergiu Klainerman in his lecture during the *Global General Relativity* conference. Another application, to self-force calculations, has been presented by Moncrief in a preprint.

Yvonne Choquet-Bruhat, Jim Isenberg and Dan Pollack have devised a very elegant (and natural) approach for describing the solvability of the constraint equations in the presence of a scalar field. This is done by introducing a generalised Yamabe-type invariant of the initial data, which provides necessary and sufficient conditions for the construction of the initial data using the conformal method.

The programme has been extremely stimulating. Several participants have indicated that the programme has already considerably affected their research, and there are clear indications that the programme will have a lasting impact.

Principles of the Dynamics of Non-Equilibrium Systems

9 January to 30 June 2006

Report from the Organisers:
MR Evans (Edinburgh), S Franz (ICTP), C Godrèche (CEA, Saclay) and D Mukamel (Weizmann Institute)

S Wilkinson

MR Evans, D Mukamel, C Godrèche and S Franz

Scientific Background

The subject of collective phenomena in equilibrium systems is by now a mature one. Extensive studies over the last six decades have produced a clear understanding of the phenomenology as well as many rigorous mathematical results. On the other hand, systems that are not in thermal equilibrium are more poorly understood. Indeed, a general theoretical framework for the study of non-equilibrium collective phenomena is lacking and our understanding to date has relied on the study of specific models. By "non-equilibrium systems" we refer both to systems held far from thermal equilibrium by an external driving force and to the complementary situation of systems relaxing towards thermal equilibrium. Such systems display a broad range of phenomena, such as phase transitions and slow collective dynamics, which we would like to understand at a deeper level.

The study of non-equilibrium systems arises in many different contexts such as reaction–diffusion processes, interacting particle systems, driven diffusive systems, and the slow dynamics of both ordered and disordered glassy systems. It is a major research area which is represented in many different scientific communities throughout the world. In recent years the study of specific model systems has led to important breakthroughs in a variety of areas. Mathematical tools have been developed and some rigorous results derived pertaining to specific systems. These developments bring us closer to the point where we can ask questions of generality, both of techniques and results. This programme brought together different communities of physicists and mathematicians working in this diverse field.

Structure of the Programme

The programme was centred around three main themes:

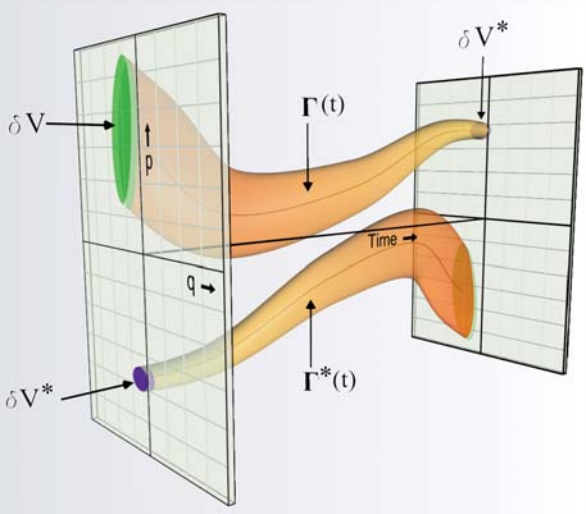
- Glassy constrained dynamics and ageing
- Driven diffusive systems and interacting particle systems
- Coarsening and persistence

Although these three themes are all concerned with systems governed by non-equilibrium dynamics, each explores a different aspect.

In the first, the systems are kept out of equilibrium not by external forces but rather as a result of a spontaneous failure of ergodicity. Glasses, either structural or spin glasses, are out of equilibrium due to the "rugged" character of the potential energy landscape, which traps them for long times in regions of the configuration space that have vanishing weight at equilibrium. In a wide variety of physical systems this results in a spectrum of long relaxation times.

In the second theme, the focus is on discrete models of non-equilibrium systems where the constituent elements (i.e., spins or particles) are driven by external forces and governed by dynamical rules that do not obey detailed balance or the equilibrium fluctuation-dissipation theorem. In driven diffusive systems a steady state held far from thermal equilibrium is eventually obtained and research has focussed on the novel properties of these non-equilibrium steady states.

D Evans and DM Carberry



An abstract (and highly schematic) representation of the time evolution of infinitesimal sets of phase space trajectories and their time reversed antitrajectories. The shrinkage and expansion of the cross-sectional area of these sets is associated with the loss and gain respectively of heat to a surrounding thermal reservoir. Understanding this diagram is key to understanding the proof of the Fluctuation Theorem

In the third theme, the approach to steady state is addressed. In many cases this approach takes place via a coarsening process where some spatial length grows unboundedly with time. There are time scales over which the local degrees of freedom remain unchanged during a coarsening process, and this results in persistence phenomena. Persistence phenomena in turn are closely related to the study of large deviations and extreme statistics in stochastic processes.

The programme's activities were organised around three workshops, each devoted to one of the themes. The first and last workshops each lasted a week and opened and closed the programme. The middle workshop was a two week long school forming a centrepiece for the programme. The activity of the programme naturally self-organised around these workshops, allowing the participants from various diverse communities to overlap and interact.

In total the programme had 60 long stay and 26 short stay visitors, with around 20 participants at any one time. We organised a seminar schedule of two seminars per week plus informal group discussions and expositions. Many participants gave seminars in other UK institutions including Bristol, Edinburgh, Heriot-Watt, Imperial, Manchester, Oxford and Warwick, as well as in various departments in Cambridge itself.

Workshops

Relaxation Dynamics of Macroscopic Systems

Workshop, 9–13 January 2006

Organisers: S Franz and J Kurchan

This workshop aimed to introduce the discussion on the dynamics of glassy and other relaxational systems out of equilibrium, which would be developed in the first two months of the programme.

The focus of the meeting was the off-equilibrium relaxational dynamics of systems with many degrees of freedom. The accent was on fundamental open problems in the theory of the dynamics of structural glasses, but also the dynamics of systems with non-equilibrium stationary states.

There were 25 seminars and 2 poster sessions. Among the seminars were a certain number of topical pedagogical reviews that served as introductions for students and young researchers: J-P Bouchaud presented an overview of the structural glass problem, with emphasis on phenomenological aspects and some theoretical scenarios; R Livi gave an introduction to the problem of heat conduction and the validity of the Fourier law in one-dimensional systems of interacting variables; C Godrèche discussed the dynamics of the zero-range process; and F Ritort discussed the application of recent off-equilibrium work theorems to compute free-energy differences between conformational states in biological systems.

The main topics that were discussed at the workshop were:

- Theoretical approaches to understanding the nature of the relaxation time in glasses, and its relationship with the growth of correlation scales
- Competing approaches based on kinetically constrained models and on spin glass theory
- Dynamical field theory for interacting particle systems on which some exciting new results have been reported by G Biroli
- Rigorous approaches to ageing dynamics presented by A Bovier, G Benarous and A Montanari

S Wilkinson

Participants at the workshop on 'Non-Equilibrium Dynamics of Interacting Particle Systems'

Non-Equilibrium Dynamics of Interacting Particle Systems

School, 27 March–7 April 2006

Organisers: JL Cardy, MR Evans, D Mukamel and H Spohn

This school, sponsored by the EC, consisted of a programme of mini-courses of typically three hours' duration. Each course was pedagogical and aimed to bring young researchers from different backgrounds to the forefront of a broad and rapidly developing field. The school was an outstanding success attracting around 120 participants from 17 different countries.

Sixteen lecturers covered a variety of topics in the broad area of the title. Among the more prominent themes we would list fluctuations and large deviations in non-equilibrium systems; theoretical and experimental aspects of fluctuation and work theorems; mathematical models of self-organised criticality; the dynamics of granular media and traffic; a model of stochastic mass transport and condensation; and stochastic Loewner evolution. In addition to the lectures there were four contributed seminars on specific topics, which complemented the broad reviews of the lecture programme, and four timetabled poster sessions. The poster sessions attracted over 40 contributions and proved a popular forum for discussion, particularly for postgraduate students and postdoctoral researchers. The general atmosphere was very conducive to discussion and this allowed communication between the different communities that were represented at the school. The reaction of participants was overwhelmingly enthusiastic and some rated it the best scientific meeting they had ever attended.

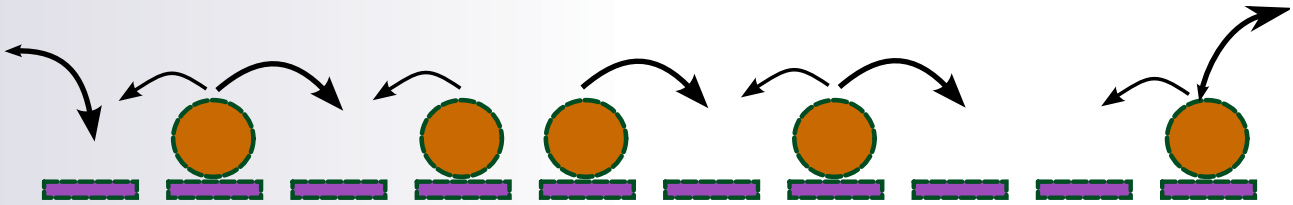
First-Passage and Extreme Value Problems in Random Processes

Workshop, 26–30 June 2006

Organisers: C Godrèche, S Majumdar and S Redner

This conference focussed on fundamental issues of first-passage processes and extreme value statistics, as well as on the applications of theory to granular matter, interfaces, biological processes, finance and the climate. It helped to develop connections between fundamental theoretical ideas and phenomenology by bringing together probability theorists, mathematicians and physicists. We anticipate that these interdisciplinary interactions will stimulate new collaborations and research initiatives in the near future.

On the theoretical side, a number of stimulating talks were given that provided a good snapshot of the current state of the art in the field. S Majumdar highlighted an unexpected relationship between first-passage properties of random walks in three dimensions and the maximum of a random walk in one dimension. A Comtet gave a stimulating and pedagogical talk that explained deep connections between the statistical properties of Brownian excursions, rooted trees and fluctuating interfaces. A Bray gave a comprehensive survey of first-passage phenomena in complex stochastic processes, such as random acceleration and random walks in shear flows. He also discussed first-passage properties of the persistence problem and various prototypical diffusion-controlled reactions. T Burkhardt gave a



The asymmetric exclusion process: a deceptively simple system of hopping particles which forms a fundamental non-equilibrium model

thorough discussion of some of the intriguing solved and unsolved problems in random acceleration processes, with applications to granular matter and polymers. Finally, C Godrèche discussed extensions of the Lévy arc-sine law for occupation time statistics in coarsening spin systems.

A wide range of applications of fundamental theory were presented by a complementary subset of the speakers. M Kearney outlined a number of basic problems in queuing theory that can be formulated as first-passage phenomena with exact solutions. O Benichou presented a novel approach for intermittent searching that combines two disparate components: a diffusive searching state and a ballistic-motion relocation state. Optimising a search that consists of these two components leads to novel scaling laws. J-P Bouchaud gave a nice overview of the role of long tails in microscopic distributions on the eigenvalue statistics of random matrices and in the statistical mechanics of disordered systems. Y Klafter discussed the application of Lévy flights and their influence on the first-passage statistics of biological processes, such as DNA translocation through pores, enzyme activity and dynamic force spectroscopy. Both Z Rácz and S Redner discussed the application of extremal ideas to understand the statistics of record temperature events in long-time climatological data.

C Dasgupta and H Taitelbaum highlighted how the theory of first-passage properties can be successfully employed in understanding experimental observations regarding the temporal behaviour of growing interfaces in fluctuating steps of crystals and growing droplets. These talks made a bridge between the theoretical and experimental studies of persistence and first-passage properties.

The overall atmosphere of the workshop was highly interactive and we believe that a variety of collaborations has been initiated as a direct result of the conference. There were also many young researchers and students in attendance and the conference provided these people with an invaluable introduction to the state of the art in the field. Finally, an important, but hard to quantify, element of the conference was its breadth, which afforded researchers the opportunity to learn about unexpected connections and applications of first-passage and extreme statistics problems.

Outcome and Achievements

The programme brought together researchers, students and postdoctoral workers from three main areas: glassy and constrained dynamics, driven diffusive systems, and coarsening dynamics and persistence. This mixture of people with different backgrounds and scientific interests resulted in many fruitful discussions and cross-fertilisation. The two workshops and one school, each centred around one of the main topics, served as focal points. This structure provided ample opportunities for interaction among the various groups. The school allowed students and young researchers to meet leading figures in this field and to be exposed to pedagogical reviews. The two workshops brought

S Wilkinson

Participants at the workshop on 'First-Passage and Extreme Value Problems in Random Processes'

their participants to the forefront of research in these areas, raising many open problems and suggesting new directions.

The programme, school and workshops were extremely productive and resulted in many new ideas and collaborations on a wide range of topics, which are now being pursued by the participants. Here, we mention briefly some of these directions.

In the field of glassy dynamics, topics include the development of new multi-point dynamic susceptibilities which are able to capture the dynamical behaviour of glassy materials near the glass transition; better understanding of the role of interface free energy of structural glass, which is a key ingredient in modelling these systems; the study of the structure and landscape of random functions; and progress in studies of models of diffusion in random potentials.

In the area of driven diffusive systems and interacting particle systems we have seen the development of traffic models in which, unlike most commonly studied models, jammed flow takes place via a phase transition; various generalisations of the zero-range process, a model that captures many generic features of driven systems far from thermal equilibrium; and the exact solution of the asymmetric exclusion process with many species of particle, another archetypal driven model, through the connection of an algebraic matrix-product approach with queueing theory.

In the realm of coarsening and persistence, interest was stimulated in curvature-driven coarsening; the statistics of records; and models of epidemic spread and disease diffusion.

Bringing together people working on the work and fluctuation theorems, a subject which has been hotly debated in recent years, resulted in better clarification of some of the subtle issues in this growing field. In addition, progress was made on fluctuation theorems in stochastic models and periodically pumped systems.

We hope that the sum of this activity and its current development will leave a lasting legacy.

Publications

The programme has fostered many new collaborations which have already resulted in some publications, but which should come fully to fruition over the next few years. A special issue of the *Journal of Statistical Mechanics: Theory and Experiment* is planned for 2007 containing invited papers representing the main themes and prominent directions that emerged during the programme.

Logic and Algorithms

16 January to 7 July 2006

Report from the Organisers:
A Dawar (Cambridge) and MY Vardi (Rice)

S Wilkinson

A Dawar and MY Vardi

Scientific Background and Themes

Two central concerns dominate the field of theoretical computer science: (i) how to ensure and verify the correctness of computing systems; and (ii) how to measure the resources required for computations and ensure their efficiency. These concerns have led to the development of fields of study in formal methods and semantics on the one hand, and in algorithmics and computational complexity on the other. The two fields have interacted little with each other, partly because of the divergent mathematical techniques they have employed. While semantics is based in large part on logic, complexity theory has relied mainly on combinatorial methods. This division runs deep, as can be seen, for instance, in the two volumes of the *Handbook of Theoretical Computer Science* published in the early 1990s, where Volume A deals with algorithms and complexity, while Volume B covers formal methods and semantics.

There are, however, areas of computer science that straddle the divide. The stated aim of this programme was to focus attention on areas of research that bridge the gap between the two broad divisions. The specific areas chosen for this focus were Computer-Aided Verification, Algorithmic Model Theory, Proof Complexity, Constraint Satisfaction and Games. These cross-cut the dichotomy between Volume A and Volume B methods in interesting ways. For instance, one important concern in finite model theory has been to bring logical, particularly model theoretic, methods to bear on the study of the complexity of computation. Similarly, work in computer-aided verification through model-checking has done much to make combinatorial, rather than just deductive, methods available for the verification of program properties. Proof complexity seeks to analyse the complexity of logical deduction and relate this to the structural properties of computational complexity classes. In constraint satisfaction, methods inspired by logic have found application in the study of the complexity of an important class of combinatorial problems.

Furthermore, the study of combinatorial games has emerged as an important field of research in its own right. The range and depth of mathematical methods that are deployed in these areas has also greatly increased over recent years.

Computer-Aided Verification

Computer-aided verification studies algorithms and structures for verifying properties of computing systems. More precisely, it aims to develop methods for verifying that a mathematical model of a system satisfies a formal specification. There are two distinct paradigms of verification. One, of *proof-based* methods, is based on attributing the design with assertions in a formal specification language and constructing a proof that relates these assertions. The other, of *state-exploration* or *model-checking* methods, depends on navigating through the mathematical model of the design.

State-exploration methods are restricted to finite-state models. Circuits and a large number of communication and synchronization protocols have, in essence, a finite state space, and many infinite-state designs can be abstracted to finite-state ones.

Research in computer-aided verification draws upon logic, especially the study of modal and temporal logics often used in formal specifications, as well as combinatorics. Moreover, the study of the expressive power of such logics, the complexity of algorithms for exploring the state space and of automating the verification process have drawn on techniques from areas of mathematics including graph theory, automata theory, complexity theory, Boolean functions and algebras, Ramsey theory and linear programming. Significant work has focussed on methods based on alternating automata, which are closely related to the study of combinatorial games.

Algorithmic Model Theory

The model theory of finitely presented structures has been a meeting point for research in computer science, combinatorics, and mathematical logic. The finite presentation allows one to consider algorithmic issues in relation to such structures, which leads us to call this area *algorithmic model theory*. Results and techniques from this theory have found interesting applications to several other areas, including database theory, complexity theory and verification. The theory is concerned with the expressive power of logical languages on finitely presented structures. Since first-order logic has rather weak expressive power when restricted to such models, a variety of extensions have been studied in the area, including second and higher-order logics, logics with fixed-point operators, temporal logics, infinitary logics and logics with cardinality and other generalised quantifiers. The relation with complexity theory comes from the fact that the expressive power of many logics on finite structures can be exactly characterised by natural complexity classes. Moreover, the methods developed within finite model theory for analysing the expressive power of logics, particularly centred on combinatorial games, have found application in other areas such as studying database query languages and the power and complexity of specification languages, and these methods are now being extended beyond finite structures to infinite, finitely presented structures.

Proof Complexity

Two related notions of *proof complexity* currently motivate research at the interface between computer science and logic. One notion centres on the length of a proof, and the other on the complexity of the inference steps within the proof. It is well known that NP = co-NP if, and only if, all propositional tautologies have short proofs. But the connection between proof length and complexity theory goes much deeper. Some of the most powerful methods of proving complexity lower bounds, those based on circuits, are closely tied to proof length in restricted systems, and advances on one front often lead quickly to progress on the other. By restricting the complexity of inference steps within a proof, one obtains a fragment of Peano Arithmetic called Bounded Arithmetic, which defines exactly the predicates in the polynomial hierarchy. It has been shown that if certain theories of bounded arithmetic can prove lower bounds in complexity theory, then corresponding cryptographic systems cannot be secure. Methods for proving lower bounds on proof complexity have drawn on sophisticated methods from algebra, combinatorics and logic.

Constraint Satisfaction

Since the pioneering work of Montanari in 1974, researchers in artificial intelligence have investigated a class of combinatorial problems that became known as *constraint-satisfaction problems*. The input to such a problem consists of a set of variables, a set of possible values for the variables, and a set of constraints between the variables; the question is to determine whether there is an assignment of values to the variables that satisfies the given constraints. Many problems that arise in different areas can be modelled as constraint-satisfaction problems in a natural way: these areas include Boolean satisfiability, temporal reasoning, belief maintenance, machine vision, and scheduling. In its full generality, constraint satisfaction is an NP-complete problem. It generalises well-studied problems such as graph colouring and graph homomorphism, where a classification of tractable cases has long been sought. An algebraic way of formulating the constraint satisfaction problem is: given two finite relational structures A and B, is there a

homomorphism $h : A \to B$? The grand challenge in the area is to obtain general classes of pairs (A, B) for which the problem has polynomial time solutions. Research in the area has drawn on a rich variety of techniques from algebra, logic and graph theory.

Games

The study of games is a thread that runs through all of the areas outlined above. Games have been used as a tool for analysing logics and systems and have also come to be the object of study in their own right. Here we are talking of two-person games on (finite or infinite) graphs with (finite or infinite) plays. Our focus is on their extensive form, rather than on the strategic form typically used in economics or in optimisation. Besides their role as a tool, as discussed above, games capture in a natural way the aspect of interaction between open systems and their environments. This approach has recently led to new algorithmic directions in verification. An emerging theory combines games with automata and logic into a powerful tool for the analysis of such systems. Some of the fundamental questions concern the algorithmic complexity of determining a winner or constructing a winning strategy, given a game and a winning condition. The methods have much in common with all the areas discussed above.

Workshops and Seminars

Six workshops, each of one week's duration, were held over the course of the programme. Four of these were at the Isaac Newton Institute, while one was a satellite workshop in Durham and one was held in Oxford. In addition, a regular seminar series was held at the Institute with between two and five seminars per week. All participants were invited to present a talk in the seminar series. In addition, several short courses were offered, including five lectures on *Game Semantics and its Applications* by Luke Ong, four lectures on *Basic Proof Complexity* by Jan Krajíček, four lectures on *Graph Searching Games and Graph Decompositions* by Stephan Kreutzer, three lectures on *Post's Lattice with Applications to Complexity Theory* by Heribert Vollmer and three lectures on *Analysis of Recursive Markov Chains, Recursive Markov Decision Processes and Recursive Stochastic Games* by Kousha Etessami. The Rothschild Visiting Professor, Stephen Cook, delivered a lecture of general interest on *Computational Complexity and Proofs of Combinatorial Principles*.

The six workshops were designed around topics that combined more than one of the themes identified as key areas of the programme.

Finite and Algorithmic Model Theory

Satellite Meeting at the University of Durham, 9–13 January 2006

Organiser: I Stewart

The programme kicked off with a satellite meeting at Durham that consisted entirely of tutorial presentations that touched on most of the themes of the programme. The goal was to explore both emerging and potential connections and applications between the two areas of finite and infinite model theory. In this respect, the workshop was extremely successful, involving around 60 participants, not including those local to Durham. The participants came from a mix of mathematics and computer science backgrounds and a large number were from overseas. Many are leading figures in the field.

The workshop consisted of 4 three- to four-hour tutorials and 6 two-hour and one-hour research expositions. This format was designed to introduce researchers and graduate students to those topics that are of fundamental interest and importance, to survey current research, and to discuss major unsolved problems and directions for future research. Four-hour tutorials were given by Richard Elwes, Bart Kuijpers, Dugald Macpherson, Martin Otto, Jan van den Bussche, Igor Walukiewicz and Thomas Wilke. Two-hour talks were given by Marko Djordjevic, Kousha Etessami, Erich Grädel, Stephan Kreutzer, Sasha Rubin and Nicole Schweikardt. One-hour talks were given by Albert Atserias and Manuel Bodirsky.

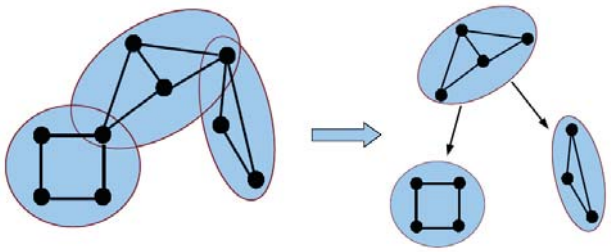
Logic and Databases

Workshop, 27 February–3 March 2006

Organisers: A Dawar and M Grohe

Logic and databases have been intimately linked since the rise of relational database systems in the 1970s. Relational databases can be modelled by finite relational structures, and first-order logic lies at the core of standard database query languages such as the Structured Query Language, SQL. As

S Kreutzer



The tree-width of a graph measures its similarity to a tree

another example, closer to current research, XML documents can be modelled by labelled unranked trees, and XML query languages as logics on trees.

The workshop focussed on recent research on logical aspects of the theory of database systems. Invited talks and tutorials presented a broad survey of the state of the art in the field. The speakers were Christoph Koch, Phokion Kolaitis, Leonid Libkin, Frank Neven, Nicole Schweikardt, Luc Segoufin, Dan Suciu and Victor Vianu. In addition there were 14 contributed talks covering a wide area of current research in database theory. In all, 85 participants took part in the workshop.

Mathematics of Constraint Satisfaction: Algebra, Logic and Graph Theory

Satellite Meeting at the University of Oxford, 20–24 March 2006

Organisers: A Krokhin and P Jeavons

The constraint satisfaction problem (CSP) provides a general framework in which it is possible to express, in a natural way, a wide variety of problems encountered in artificial intelligence, combinatorial optimisation, logic, algebra, graph theory and database theory. There are strong links between the study of CSPs and many areas of mathematics. One of the most striking features of current CSP research is that, despite computational aspects being its primary motivation, it influences (and is influenced by) many branches of mathematics. The theoretical side of CSP research has been dominated by the analysis of algorithms and computational complexity for constraint problems, and a number of deep mathematical approaches to this involving in particular algebra, logic and combinatorics have been suggested in the literature.

The workshop brought together, for the first time, all the leading specialists on various mathematical approaches to constraint satisfaction as well as many researchers from different areas of mathematics and computer science with an interest in this exciting interdisciplinary area. The programme included three substantial tutorials outlining the basics of the algebraic, logical and combinatorial approaches to the CSP, given by Peter Jeavons, Phokion Kolaitis and Pavol Hell respectively. These tutorials were designed to ensure that all participants were equipped with the necessary preliminary knowledge of all of the fundamental mathematical approaches. The main part of the programme consisted of 11 one-hour plenary lectures given by world-leading specialists in the above topics. This ensured that all participants gained a complete state-of-the-art picture of the research area. The plenary lectures were given by Andrei Bulatov, Hubie Chen and Peter Jonsson (algebra), Albert Atserias and Iain Stewart (logic), Georg Gottlob and Jaroslav Nešetřil (combinatorics), Victor Dalmau and Benoit Larose (combinations of the three approaches), and Nadia Creignou (Boolean CSP) and Johan Hastad (inapproximability of CSP). In addition to these plenary talks, there were 11 invited 30-minute talks which covered a broad range of other topics, including the use of mathematics in more applied CSP research. The workshop could be called a "community-creating event" because many leading researchers in different aspects of the area met for the first time and discussed and compared different approaches to a significant extent. As a result, researchers from different areas are more aware of the mathematical insights and challenges present in the theory of constraint satisfaction. In all, 81 participants took part.

New Directions in Proof Complexity

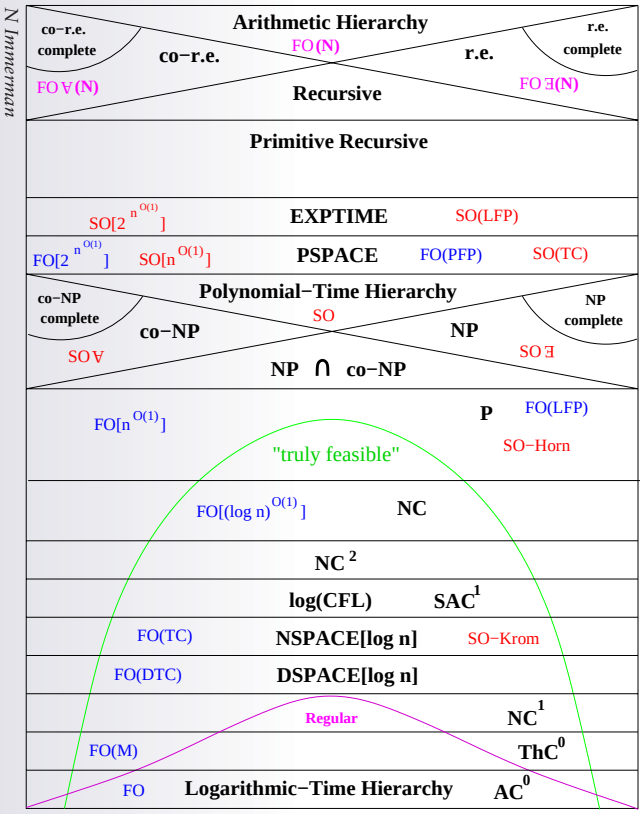
Workshop, 10–13 April 2006

Organisers: J Krajíček and SR Buss

Proof complexity is an area of mathematics centred around the problem of whether the complexity class NP is closed under complementation. With a suitable general definition of a propositional proof system this becomes a lengths-of-proofs question: Is there a propositional proof system in which every tautology admits a proof whose length is bounded above by a polynomial in the length of the tautology? The ultimate goal of proof complexity is to

show that there is no such proof system; that is, to demonstrate superpolynomial lower bounds for all proof systems.

The purpose of the workshop was to expose, through invited and contributed lectures, current developments in proof complexity as well as new ideas and directions of research pursued most recently. The ambitious dictum in the title, "new directions", was actually fully vindicated. In particular, quite a few of the speakers were young researchers with new results and new approaches to proof complexity. Several speakers (Pudlak, Thapen) reported on new approaches to an old problem of conservativity relations among fragments of bounded arithmetic, or described (Jerabek, Nguyen, Pollett, Soltys) expansions of the theory to include various combinatorial constructions. Vardi reported on new types of proof systems based on constraint propagation and Beckmann sketched basic ideas of uniform proof complexity, while Dantchev explained his ideas about parameterised proof complexity. Riis presented new ideas on a topic he calls sporadic propositional proofs and Naumov outlined the new concept of meta-complexity (of proofs). Tzameret presented his interesting work with Raz on algebraic systems which generalise traditional proof systems. There were also talks reporting new results for traditional proof systems like resolution (Bonet, Galesi, Nordstrom) or Lovasz–Schrijver system (Alekhnovich, Segerlind), as well as lectures discussing basic concepts and problems (Cook, Impagliazzo, Pitassi). In all, 66 people attended the workshop.



The world of descriptive and computational complexity, from Neil Immerman's talk at the 'Games and Verification' workshop

Constraints and Verification

Workshop, 8–12 May 2006

Organisers: M Vardi and A Podelski

In recent years there has been an increasing interest in the application of constraint-programming and constraint-solving technology to the verification of hardware and software systems. Constraint solvers for Boolean (SAT) and arithmetic domains (Presburger, polyhedra, linear constraints) are widely used as subprocedures of various model checkers. Constraint solving is also used for static analysis of programs with numerical data variables and for concurrent systems. Constraints are also used extensively in automated test generation. The aim of this workshop, attended by 95 people in all, was to bring together researchers working in constraints and verification and to investigate the theoretical foundations, new applications and future developments in this area.

Keynote talks were given by Ed Clarke (Carnegie Mellon), Patrick Cousot (ENS), Enrico Giunchiglia (Genoa), Ziyad Hanna (Intel), Marta Kwiatkowska (Birmingham), Zohar Manna (Stanford), Ken McMillan (Cadence), Yehuda Naveh (IBM), Jean-François Puget (ILOG) and Pierre Wolper (Liege).

Games and Verification

Workshop, 3–7 July 2006

Organisers: L Ong, E Gradel, C-H Long and CP Stirling

The aim of this workshop was to bring together researchers who use games in computer science and neighbouring disciplines. The workshop had some 110 participants, a good number of them doctoral students and postdoctoral researchers. The workshop was also the final annual meeting of "Games and Automata for Synthesis and

Validation", a research training network funded by the European Commission under the Fifth Framework Programme, linking research teams from Aachen University, University of Bordeaux I, University of Edinburgh, University of Paris 7, Rice University and Warsaw University.

The workshop had a strong training component. It featured 6 tutorials (of 90 minutes each) given by such prominent researchers in the field as Rajeev Alur (*Nested words and trees*), Johan van Bentham (*Dynamic-epistemic logic of games*), Didier Caucal (*Deterministic grammars*), Georg Gottlob (*Hypertree decompositions*), Dov Monderer (*Mechanism design*) and Moshe Vardi (*Games as an algorithmic construct*). The expositions, all beautifully presented, surveyed topics of intense current interests. In addition, 21 leading researchers gave lectures (of 30 minutes) on their recent work; there were also short talks (of 15 minutes) by 9 doctoral students. By general consensus, the workshop was a success. Two pleasing features are worth mentioning: firstly, the meeting attracted an unusually high concentration of key thinkers in related fields, and secondly, the quality of the talks was extremely high, as researchers presented their best recent work.

Outcomes and Achievements

The programme generated a great deal of research activity and, at most times during its course, the Institute was abuzz with intense discussions. It is expected that, over the coming months and years, a number of publications will emerge from activity initiated or carried out during the programme. However, the greatest benefits of the programme may be the less tangible ones of "community creation". The programme brought together researchers from several distinct research communities in theoretical computer science and mathematics, and helped expose the common underlying elements of their problems and methods. In the process, it helped create bridges and collaborations between these communities and to give shape to Logic and Algorithms as a subject area. The impact of this may be less measurable than concrete publications, but will be felt by the research community for years to come.

S Wilkinson

Participants at the workshop on 'New Directions in Proof Complexity'

More concretely, among the scientific and mathematical achievements the following might be especially mentioned: a new combinatorial characterisation of NP (Nešetřil and Kun); the best currently known algorithms for discounted payoff games (Andersson and Vorobyov); advances in our understanding of preservation properties and relationship to definability of constraint satisfaction problems (Atserias, Dawar, Kreutzer and Weinstein); extensions of our understanding of tractability of CSPs in terms of algebra (Bulatov, Chen, Jeavons, Krokhin and Valeriote), games (Atserias, Bulatov and Dalmau) and dualities (Dalmau, Krokhin, Szeider); synthesis algorithms for temporal specifications (Kupferman, Piterman and Vardi); a combinatorial characterisation of search problems definable in low fragments of bounded arithmetic (Krajíček, Skelley and Thapen); results on the topological complexity of recognisable tree languages (Niwinski); advances on the computational complexity of the membership problem for functional clones (Vollmer); a study of formula size as a measure of complexity (Hella and Väänänen); and a new perspective on Gödel's Completeness Theorem (Väänänen and Vardi).

Publications

There are plans in place to produce a volume of expository articles based on the workshop on *Finite and Algorithmic Model Theory* held at Durham.It is anticipated that this volume will become a standard reference work describing the current state of the field. In addition, a number of papers based on research carried out during the programme have been written, some of which have appeared in the Newton Institute preprint series, and more are expected to follow.

Finances

Accounts for August 2005 to July 2006 (Institute Year 14)

	2004/2005 Year 13 £'000	2005/2006 Year 14 £'000
Income		
Grant Income – Revenue[1]	925	1,005
Grant Income – Workshop[2]	223	327
Grant from the University of Cambridge	183	226
NM Rothschild and Sons Trust Funds[3]	107	110
Investment Income	118	121
Donations, Reimbursements and Other Income[4]	20	44
Total Income	**1,576**	**1,833**
Expenditure		
Scientific Salaries[5]	375	399
Scientific Travel and Subsistence[6]	410	456
Scientific Workshop Expenditure[2]	163	215
Other Scientific Costs[7]	21	16
Staff Costs	348	370
Net Housing Costs[8]	28	31
Computing Costs[9]	41	66
Library Costs	11	12
Building – Repair and Maintenance	10	14
Estates and Indirect Costs	250	250
Consumables	24	20
Equipment – Capital	18	11
Equipment – Repair and Maintenance	4	2
Publicity	5	5
Recruitment Costs	2	3
Total Expenditure	**1,710**	**1,868**
Surplus / (Deficit)	**(134)**	**(34)**

Notes to the Accounts

1. Grant Income – Revenue
This breaks down as follows:

	2004/2005 Year 13 £'000	2005/2006 Year 14 £'000
EPSRC/PPARC Salaries	4	492
EPSRC/PPARC Travel and Subsistence	318	322
Trinity College (Isaac Newton Trust)	50	50
PF Charitable Trust	22	24
Leverhulme Trust	77	90
London Mathematical Society	25	25
Cambridge Philosophical Society	2	2
Total	**925**	**1,005**

2. Grant Income – Workshop
Both income and expenditure on workshops were higher in 2005/2006 than in recent years because of increased workshop activity and higher success rates with sponsors.

3. NM Rothschild and Sons Trust Funds
The amounts received break down as follows:

Rothschild Visiting Professorships (drawdown)	30	31
Rothschild Mathematical Sciences (income)	77	79
Total	**107**	**110**

The income from the Rothschild Mathematical Sciences Fund supports the Professorship held by the Director of the Institute.

4. Donations, Reimbursements and Other Income
The figure for 2005/2006 includes additional sponsorship received from the National Science Foundation (USA), Microsoft, Intel, IBM and the Tomalla Foundation as well as income received from publications and the sale of merchandise.

5. Scientific Salaries
This includes stipends paid to EPSRC/PPARC Fellows, Rothschild Visiting Professors, the Director and the Deputy Director.

6. Scientific Travel and Subsistence
This includes expenditure incurred by programme participants, including Junior Members.

7. Other Scientific Costs
This includes costs relating to meetings of the Institute's committees, Institute Correspondents' expenses, programme organisers' expenses and entertainment, as well as the travel expenses of overseas participants for their visits to other UK institutions to give seminars (see page 15).

8. Net Housing Costs

These figures include the salary of the Housing Officer, and break down as follows:

	2004/2005 Year 13 £'000	2005/2006 Year 14 £'000
Income	301	313
Expenditure	329	344
Total	**(28)**	**(31)**

9. Computing Costs

Extra expenditure on computing hardware in 2005/2006 was funded by the Science Research Investment Fund (SRIF), paid through the University of Cambridge.

Cumulative Financial Grants and Donations above £10,000

SERC/EPSRC/PPARC	£10,574k	over 16 years
Trinity College (Isaac Newton Trust)	£2,610k	over 14 years
NM Rothschild and Sons	£2,083k	over 10 years
European Union	£1,370k	over 14 years
Anonymous Donation	£1,065k	
Hewlett-Packard	£1,065k	over 10 years
Dill Faulkes Foundation	£1,000k	
Leverhulme Trust	£865k	over 12 years
St John's College	£750k	over 5 years
NATO	£728k	over 10 years
Le Centre Nationale de la Recherche Scientifique	£435k	over 10 years
London Mathematical Society	£357k	over 14 years
Rosenbaum Foundation	£330k	over 7 years
PF Charitable Trust	£240k	over 3 years
Clay Mathematics Institute	£160k	
Gonville and Caius College	£100k	
Prudential Corporation plc	£100k	over 4 years
Institute of Physics	£69k	over 14 years
British Meteorological Office	£64k	
National Science Foundation	£63k	
Nuffield Foundation	£57k	
TSUNAMI	£40k	
Daiwa Anglo-Japanese Foundation	£36k	over 4 years
BNP Paribas	£35k	
American Friends (Hamish Maxwell): $50k	£32k	
American Friends (Anonymous Donation): $50k	£32k	
Office of Naval Research	£31k	
Emmanuel College	£30k	
Jesus College	£30k	over 6 years
British Aerospace	£25k	
Rolls Royce	£25k	
Microsoft Corporation	£25k	
Cambridge Philosophical Society	£25k	over 10 years
NERC	£22k	
Corporate Members (*Financial Mathematics* programme)	£22k	
British Gas	£20k	
DERA	£20k	
Magnox Electric	£20k	
Paul Zucherman Trust	£20k	
Thriplow Trust	£18k	
Schlumberger	£17k	
Bank of England	£15k	
Nomura Corporation	£15k	
Wellcome Trust	£15k	