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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/0405/appendices.html**

Director's Foreword

I am proud to report another year of high scientific achievement at the Isaac Newton Institute. The pages that follow record the programmes that have attracted mathematical scientists, from all over the world, to programmes of intensive research collaboration. The success of these programmes in establishing fruitful collaboration, often across disciplinary boundaries, and pushing forward the frontiers of knowledge, shows the wisdom of our founding fathers in creating the template, and in providing an environment in which research flourishes.

That success is also due to the hard work and scientific judgement of those who propose new programmes and who, when their proposals are approved, attract the best participants and organise the workshops and other research activities that make up the final project. It is no mean task to organise a successful programme, and the Institute is grateful to those who carry through their commitment. I am pleased to report that we have an excellent pipeline of programmes for the future, approved up to the end of 2007 and under consideration for 2008 and beyond.

The organisers are well supported by the permanent staff of the Institute, who give a warm welcome to our visitors and seek to solve all their problems except the mathematical ones. My thanks to all the staff, ably led by Christine West, are heartfelt; the Institute could not succeed without their loyalty and enthusiasm.

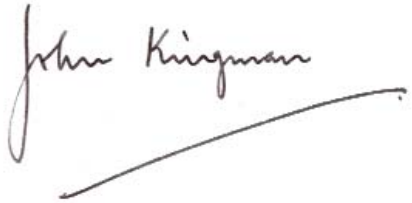
I hope that those who read this Report, and see how conducive the environment of the Institute is to research in the mathematical sciences, will be encouraged to consider submitting their own ideas. I shall be pleased to hear from anyone interested, and to offer advice on the sort of proposal likely to survive our rigorous peer review.

As I write, the University has just announced the success of its search for a new Director, to succeed me in October 2006. He is Sir David Wallace, Vice-Chancellor of Loughborough University and a most distinguished mathematical physicist. This is excellent news for the Institute, and for the whole mathematical community, which benefits from the ability of the Institute to attract world class visitors.

If there is a cloud on the horizon, it is financial. The Institute benefited in its early years from great generosity, from individuals and trusts, and from Cambridge University and its Colleges. Much of this was of its nature start-up funding, and has now run its course. At the same time, some of the sources of public funding, including NATO and the European Union, have changed their policies in such a way as to make their support less available to us. The return on our modest endowments has suffered from the general economic situation. These factors combine, despite tight management, to make our accounts less healthy than they should be.

However, the UK Government has recognised that past methods of funding research in universities have failed to take account of the real costs, and have therefore caused great financial difficulty in universities with strong research activity. Research councils and other funding bodies will in future be expected to fund a large proportion of the full cost of the research they support. If this policy is properly applied, it will enable the Institute to bid for a higher level of grant, to enable it to cover the cost, for instance, of the workshops that form a crucial part of our programmes.

I am confident that the scientific quality of the work of the Institute, and the exciting programmes promised for future years, will constitute a very strong case for increased funding. These activities form a crucial component of mathematical research in the UK, and must not be crippled by lack of money.



31 July 2005

Brief Scientific Report on Programmes

For full scientific reports see pages 18 to 38.

Magnetic Reconnection Theory

Magnetic reconnection is a fundamental process in a plasma of high magnetic Reynolds number, whereby magnetic field lines (which are normally attached firmly to the plasma as it moves) become detached, break and rejoin. During this process, the topology of the magnetic field can sometimes change and magnetic energy is converted into other forms. Since the process involves topology, advection, diffusion, boundary layers and sometimes shock waves, the mathematical problems associated with describing it are formidable.

There is a wide variety of physical phenomena where magnetic reconnection is important. There have been two main strands of theory, one based on magnetohydrodynamics (MHD) and the other based on collisionless plasma theory. Until recently, the MHD and collisionless theories and the solar and geomagnetic applications have been studied by four separate communities. The aim of the programme was therefore to bring together the world's main theorists in these four distinct areas.

The programme was an enormous success in many respects. A sense of vitality, ferment and excitement pervaded the programme as many new ideas were born and thrown around, which will continue to bear fruit for years to come. In addition, several new collaborations were developed, and a major monograph was written by the main participants.

Quantum Information Science

Quantum information science is a new field of science and technology to which physicists, mathematicians, computer scientists and engineers have made major contributions. It undertakes to develop the theory and practice of information processing for information carriers (in the simplest case, 2-state quantum systems or 'qubits') that, unlike the bits of classical information theory, but like the real physical systems they exemplify, are capable of superposition and entanglement. Deep links between the previously unrelated disciplines of quantum physics and computer science/information theory have been forged, leading on the one hand to insights into fundamental issues in physics and on the other to hitherto unsuspected kinds of computation and communication. New technologies have arisen offering the potential for unconditionally secure communications and dramatic speedups of some computational tasks such as integer factorisation and search.

This programme facilitated the transfer of ideas between the usual narrow fields of specialisation, which allowed unexpected common themes to emerge with different people applying the same idea in different domains. Some such major themes were locking of resources, general non-locality, additivity properties of channels and fault-tolerant quantum computation. Interesting progress was also made in quantum cryptography and quantum algorithms. A very positive outcome of the programme was the emergence of the connection of quantum information with mathematical statistics. Many important new results have been obtained, as well as a systematisation of the old results. A number of pure mathematicians were also invited and some of them spent extensive time on the programme. While it is yet early days, some notable results have been obtained.

Overall, the programme has initiated many fruitful collaborations, and it is already clear that they are having lasting impact on the scientists involved.

Magnetohydrodynamics of Stellar Interiors

At the heart of all observed stellar magnetic activity – whether as dark spots, bright flares or X-ray emission from a hot corona – lies the dynamical behaviour of the magnetic field in a star's interior. This programme focussed on the complex nonlinear interactions between convection, rotation and magnetic fields in the interiors of stars with deep outer convection zones, like the Sun, and aimed to confront theory with observations. This was timely because research into the magnetohydrodynamics (MHD) of stellar interiors is currently at an extremely exciting stage, with ever-improving observations posing a number of new theoretical challenges, such as the unexpectedly strong rotational shear (the tachocline) at the

interface between the convection zone and the underlying radiative zone. Understanding these observations, and the physical questions to which they give rise, requires a combination of computational and analytical approaches.

The programme addressed all the fundamental issues concerning the magnetic fields of stellar interiors, bringing together not only theoreticians and observers, but also experts on numerical techniques and experimentalists studying the MHD of liquid metals. The central question was the nature of the dynamo responsible for maintaining a magnetic field against its natural tendency to decay.

Part of the programme was carefully structured, with meetings and seminars, while the rest was left free for more intensive informal collaboration and discussion. These informal discussions proved extremely fruitful both in generating ideas and in getting new work done. A volume arising out of one of the workshops will be published by Cambridge University Press.

Model Theory and Applications to Algebra and Analysis

Model theory is a branch of mathematical logic dealing with 'definability' in various forms. As well as having a rich internal development including stability theory and its generalisations, there have been interactions with and applications to other areas of mathematics for many years. The model-theoretic study of valued fields such as the p-adics has a long history. The model-theoretic study of differential fields also goes back a long way, but the past 12 years have seen a new level of applications to diophantine geometry. The model-theoretic notion of o-minimality, which was isolated and developed twenty years ago or so, has led to very close interactions with real analytic geometers.

The main purpose of the programme was to bring together model theorists in these and other 'applied' topics, with mathematicians from the related areas, so as to solve existing problems as well as open up and explore new areas of research. We also welcomed the presence of model theorists working on the 'purer' side of the subject.

The overall consensus of participants and organisers was that the programme was an overwhelming success. Significant progress was made in the areas of continuous model theory, o-minimality, motivic integration, groups of finite Morley rank, number theory and geometry, and model theory and non-commutative geometry. Several important and beautiful results were obtained, and tutorial lectures and informal discussions played a large part in disseminating these new results and led to further developments. A volume edited by the organisers, based on the programme, is in preparation.

Developments in Quantitative Finance

Mathematical finance sprang to life in the early 1970s with the development of the now-legendary Black–Scholes–Merton option pricing formula. This formula was quickly extended into a general theory for the pricing of options, showing that the fair price of an option is the expected discounted payoff of the option where the expectation is taken not with respect to original probability measure, but rather with respect to an equivalent martingale measure under which the discounted price process is a martingale. The field of financial mathematics provides fertile grounds for collaboration between researchers with different backgrounds.

In 1995 the Newton Institute hosted a programme entitled *Financial Mathematics*. After a gap of a decade, in which new problems of interest such as securitisation, credit derivatives, risk measures and model uncertainty have come to the fore, the subject was ripe for a further programme. This new programme attracted an extremely large participation, including many from the finance industry. There were several workshops, theme weeks and industry events.

The main themes of the programme, and the main achievements in terms of publications, preprints and collaborations, only became apparent as the programme progressed. In the event the topics of greatest interest included option pricing and portfolio optimisation in incomplete markets, real options and endogenous exercise, full equilibrium models and dynamic risk measures. Credit risk modelling was another important theme, and the presence of many of the world's experts at the Institute led to several fruitful interactions.

Programme Participation

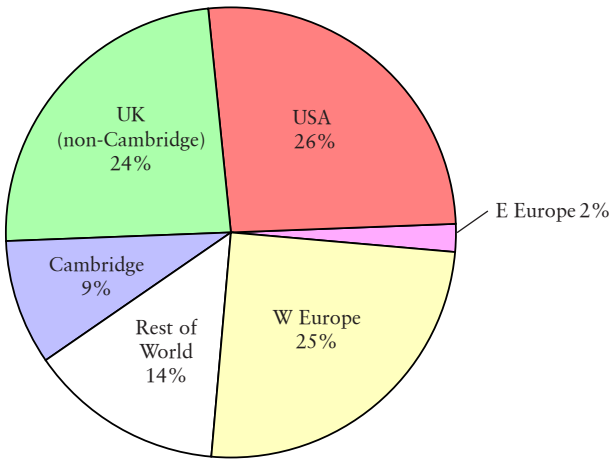
A total of 1276 visitors was recorded for 2004/05. This includes 254 long-stay participants, each staying between two weeks and six months (just over 8 weeks on average), and 377 short-stay participants who stayed for two weeks or less. Within the five completed programmes there was a total of 24 workshops (periods of intense activity on specialised topics) which attracted a further 441 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-stay visitors, so further opening the activities of the Institute to the UK mathematical community. An additional 204 visitors attended informally at these events as well as at talks for the general public and other occasions.

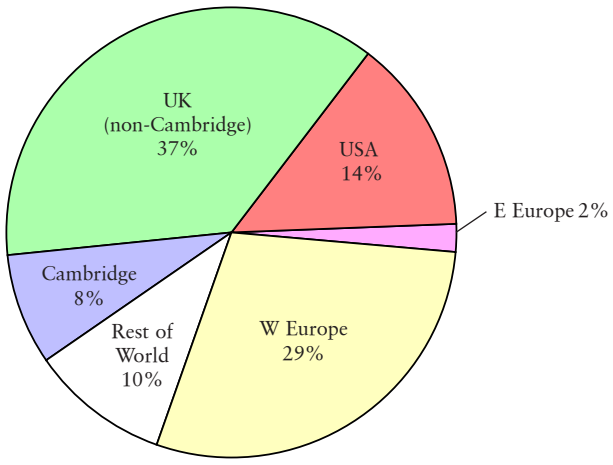
Within all the programmes, workshops and other activities, 1053 seminars were given in total at the Institute during the year. The Institute also funds visits by overseas programme participants to other UK institutions to give seminars (see page 9), and 192 such seminars took place last year.

Programme	Long-stay participants	Mean stay (days)	Short-stay participants	Mean stay (days)
Magnetic Reconnection Theory	20	24	27	7
Quantum Information Science	47	52	113	7
Magnetohydrodynamics of Stellar Interiors	50	66	44	12
Model Theory and Applications to Algebra and Analysis	82	66	40	12
Developments in Quantitative Finance	55	63	153	7
Totals	**254**	**59**	**377**	**8**

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

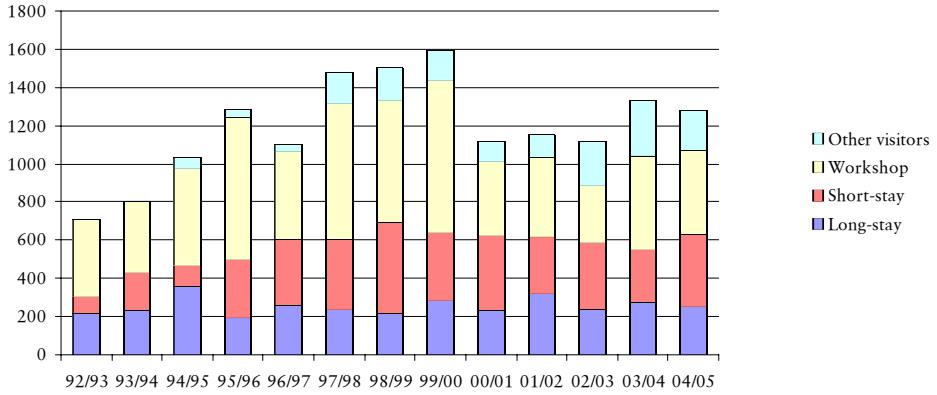


Long-stay participants

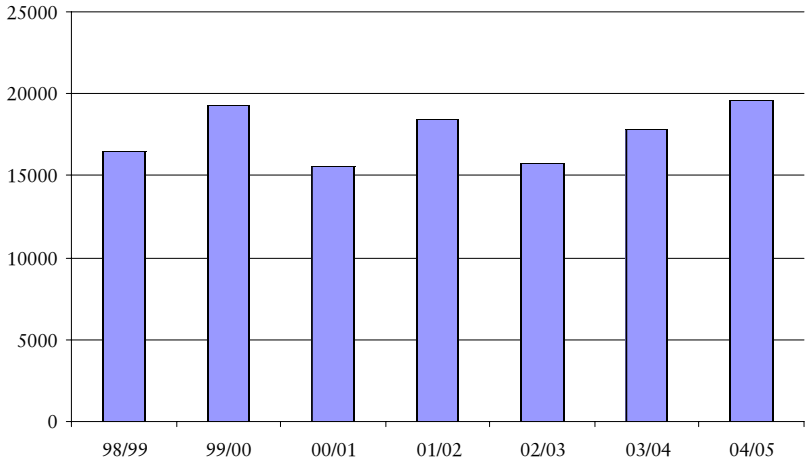


Short-stay and workshop participants

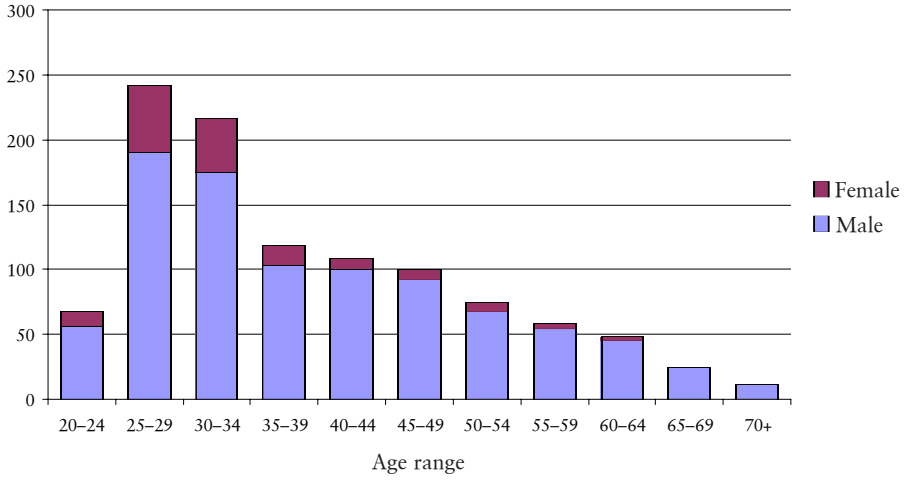
The following chart summarises the total participation figures since the Institute began:



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

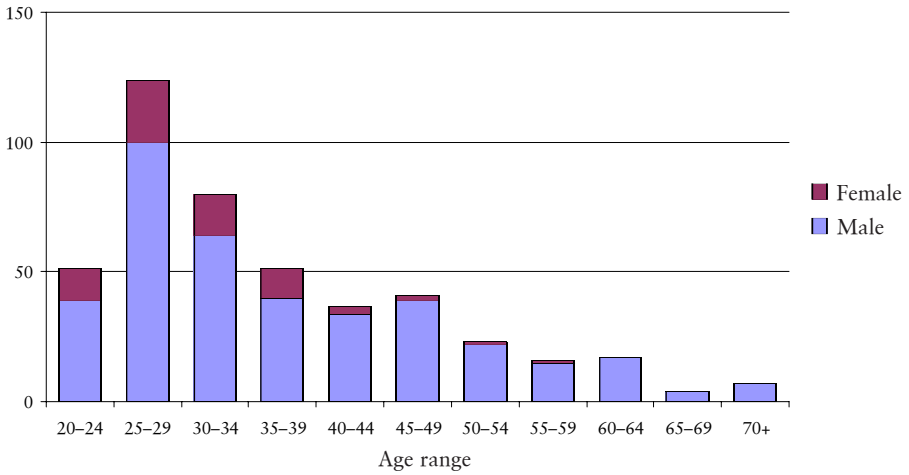


The numbers of long-stay, short-stay *and* workshop participants combined in 2004/05 are shown below, broken down by age and gender:

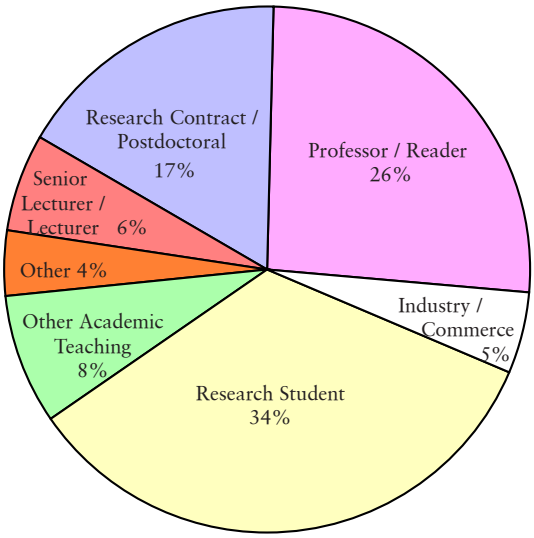


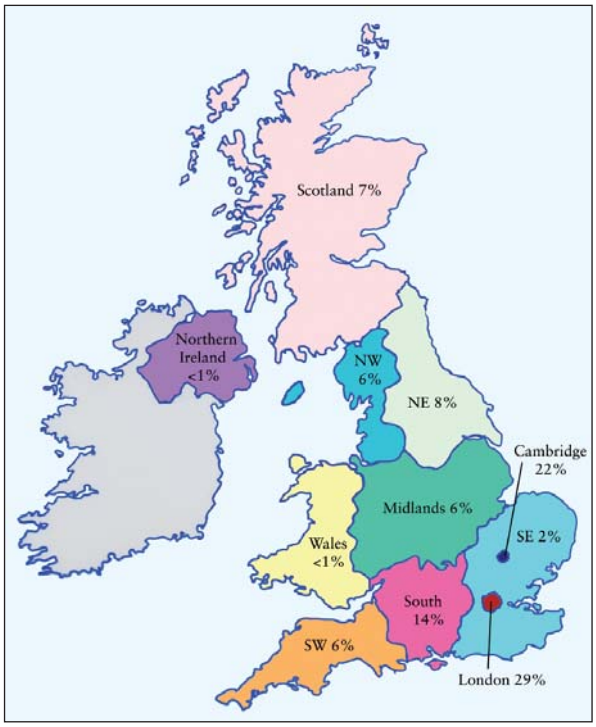
The statistics presented on this page relate only to participants whose home institutions are in the UK: overseas participants have been excluded.

The age range and gender balance of long-stay, short-stay and workshop participants from UK institutions in 2004/05 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 2004/05:





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/0405/appendices.html

Future Programmes

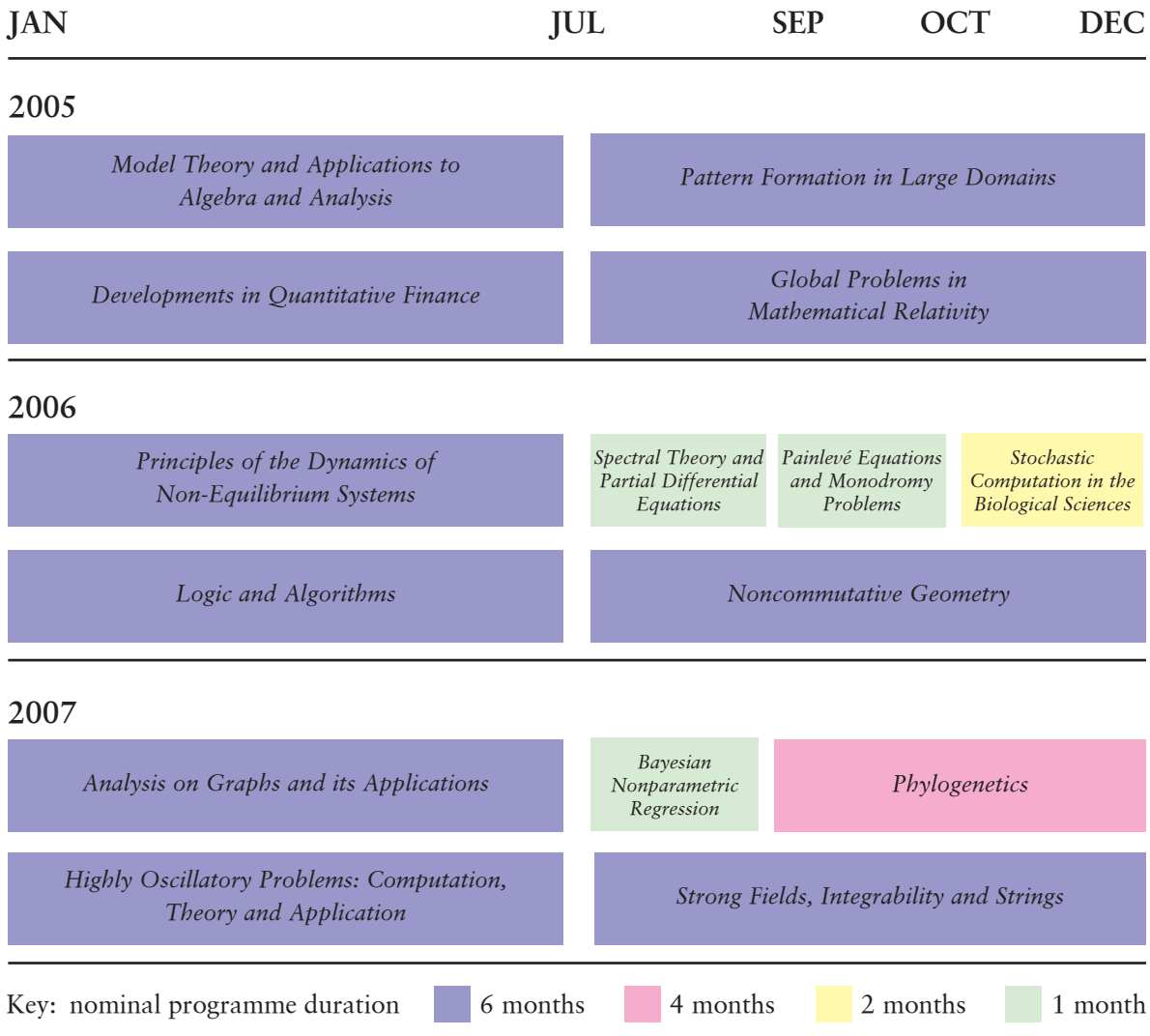
The schematic below shows the forthcoming programmes that have so far been selected by the Scientific Steering Committee. To participate only in a workshop, registration is all that is required. For fuller, long-stay participation in a programme, an invitation is usually required, and applications are best made directly to the programme organisers in the first instance.

Further details of each of these programmes, including

- the scientific content and background
- the names of the organisers
- the names of those who have so far been invited to take part in the programme
- contact details
- dates of workshops that will take place during the programme, with detailed topics and further information

can be found on the Newton Institute website at **http://www.newton.cam.ac.uk/programmes/**

Further information on how to participate in Newton Institute programmes can also be found on the website at **http://www.newton.cam.ac.uk/participation.html**



National Advisory Board and UK Mathematics

Membership of the National Advisory Board as at 31 July 2005 was as follows:

Professor Sir Michael Berry FRS	University of Bristol
Professor B Bruce	University of Hull
Professor P Grindrod CBE	Lawson Software, Oxford
Dr RE Hunt	Deputy Director, Newton Institute
Professor Sir John Kingman FRS	Director, Newton Institute
Professor PV Landshoff	University of Cambridge
Professor JG McWhirter FRS FREng	QinetiQ
Dr H Ockenden	University of Oxford
Professor EG Rees FRSE	University of Edinburgh
Dr A Rogers	King's College London
Professor AFM Smith FRS (Chairman)	Queen Mary, University of London
Professor DM Titterington FRSE	University of Glasgow
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 2005, 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:

- The Institute's strategy vis-à-vis its national role, interdisciplinarity and outreach
- The response to the *International Review of Mathematics*
- Participation in Institute programmes from different geographical areas of the UK
- The attendance of young UK scientists and training opportunities
- The balance between different mathematical subject areas in Institute programmes
- Satellite workshops and UK Correspondents
- How the Institute should work with and react to the creation of new institutes with different structures and missions at other UK Universities
- The Institute's interface with industry
- 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.

UK Correspondents

During 2000/01, at the suggestion of the National Advisory Board, the Newton Institute established 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 since been extended to include a number of relevant *non*-University institutions and learned societies. All correspondents are regularly informed about activities of the Institute, and it is their responsibility to ensure that the information is disseminated to relevant groups and individuals within their institution, in both mathematics and other appropriate departments. 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 10.

Seminars

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 2004/05 (see page 4). 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. It is hoped that organisers of seminar series will consult this register when planning their schedule of speakers and will contact potential speakers directly. The register can be found at

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

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 the Institute programmes, 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.

Satellite workshops have, to date, been held at Bristol, Brunel, Edinburgh, ICMS, Leeds, Liverpool, Norwich, Oxford, Wales and Warwick. Plans are already finalised for future workshops at Durham, Southampton and Surrey.

Costs for satellite workshops are typically approximately £10,000 (excluding the overseas travel costs of Institute participants) 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.

Institutions interested in holding satellite workshops should contact either the organisers of the relevant programme or the Deputy Director, Dr RE Hunt (R.E.Hunt@newton.cam.ac.uk).

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:

- *Burning stars in one's office*
  R Rosner (Chicago)
- *Information is quantum*
  CH Bennett (IBM)
- *Portfolio optimisation: the quest for useful mathematics*
  S Pliska (University of Illinois at Chicago)
- *Integration and logic*
  E Hrushovski (Hebrew University)

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 Institute are recorded and made available on the web at

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

Audio files together with accompanying transparencies and stills can be downloaded.

Newton Institute Correspondents

Newton Institute Correspondents act as a channel of communication between the Institute and the UK mathematical sciences community (see page 9). Universities and other relevant organisations not yet represented on the respective lists below are encouraged to provide a suitable nominee.

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

Association of Teachers of Mathematics		Mathematical Association	Mr RH Barbour
	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	Smith Institute	Dr H Tewkesbury

Other Institute News

Royal Visit

The Newton Institute was honoured on Wednesday 8 June 2005 by a visit from Her Majesty the Queen. His Royal Highness the Prince Philip, Duke of Edinburgh, was principal host to Her Majesty in his role as Chancellor of the University of Cambridge. She was also attended by the Lord Lieutenant and the High Sheriff of Cambridgeshire.

The Queen was welcomed to the University by the Vice-Chancellor, Professor Alison Richard, in an ancient ceremony. Her Majesty was then introduced to Sir John Kingman, Director of the Institute. Inside the building, Sir John introduced her to three key members of the Institute's staff: Christine West, Institute Administrator, Tracey Andrew, Programme and Visitor Officer, and Dr Mustapha Amrani, Computer Systems Manager.

After signing the Institute's visitor book, Her Majesty was invited to the seminar room where a lecture on closed fields was being given as part of the *Model Theory and Applications to Algebra and Analysis* programme. The Duke of Edinburgh took a particular interest and spoke to several of the younger researchers listening to the lecture. Afterwards, the royal party left the building for a tour of the Centre for Mathematical Sciences and other sections of the University of Cambridge.

The occasion was a highlight of the year for the Institute, its staff and those participants who were lucky enough to be in residence on the day.

N Luckhurst

Her Majesty being introduced to three members of the Institute staff: (left to right) Christine West, Tracey Andrew and Mustapha Amrani

N Luckhurst

HM The Queen watching a lecture on 'Model Theory and Applications to Algebra and Analysis', accompanied by Sir John Kingman

Awards and Achievements

Professor Keith Moffatt, Director 1996–2001 and now a Senior Fellow of the Institute, has been awarded the 2005 Hughes Medal of the Royal Society for his contributions to the understanding of magnetohydrodynamics, especially to the mechanisms determining how magnetic fields can develop from a low background level to substantial amplitude. Professor Moffatt also received the Senior Whitehead Prize of the London Mathematical Society for his outstanding contributions to applied mathematics, especially in the field of theoretical fluid mechanics, and for his substantial and long-lasting influence on, and service to, the UK mathematical community.

Professor Sir Martin Rees, Astronomer Royal, Master of Trinity College, Cambridge and a long-standing member of the Institute's committees as well as a supporter of the Institute since its foundation, has been awarded the Crafoord Prize 2005, jointly with James Gunn and James Peebles of Princeton, for contributions towards understanding the large-scale structure of the Universe. The Crafoord Prize is awarded by the Royal Swedish Academy of Sciences in recognition of basic research in scientific disciplines that fall outside the categories of the Nobel Prizes. He also

received the 2004 Royal Society Michael Faraday Prize for science communication.

Sir Martin has been elected President of the Royal Society for five years from November 2005. He has also been appointed as a non-political cross-bench peer in the House of Lords and will take his seat later in the year.

Professor Peter Grindrod, a member of the Institute's National Advisory Board, received a CBE in the Queen's Birthday Honours for services to mathematical research and development.

Professor Sir Andrew Wiles, who famously announced his proof of Fermat's Last Theorem at a series of lectures in the Institute's seminar room during the programme on *L-Functions and Arithmetic* in 1993, has been awarded the 2005 Shaw Prize in Mathematical Sciences for the proof. The prize is administered by the Shaw Prize Foundation based in Hong Kong and carries a cash award of one million US dollars. Exterior and interior shots of the Institute were filmed by TVB Pearl for a documentary profile of Professor Wiles to be shown on Hong Kong television in conjunction with the award ceremony.

Public Understanding of Mathematics

Dr Robert Hunt, Deputy Director of the Institute, gave a public lecture on Saturday 19 March 2005 as part of National Science Week. In his lecture, entitled *Mathematics Past, Present and Beyond*, he explained how abstract mathematical ideas conceived by ancient civilisations have led step-by-step to a deeper understanding of the Universe as well as to everyday modern technologies such as television and international communications. The talk demonstrated the potential long-term impact of abstract thought on real-world problems and was well attended by adults and children alike.

Dr Hunt took part in a programme about Sir Isaac Newton's seminal 1704 publication on the subject of light, *Optiks*, for the Science Channel on Japanese television. He also recorded an interview with Adam Hart-Davis for an episode of *The Eureka Years* on Radio 4, which focussed on Newton's work during his *annus mirabilis* in 1665.

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 many further requests for their use. Reprints of the entire poster series may be purchased from the Mathematical Association through its website. A pocket-sized *Maths Goes Underground* booklet (see the *Annual Report* for 2002/03) is also available directly from the Institute.

BBC Wales will be using the posters as set dressing for an episode of a high-profile, prime-time television series to be broadcast on BBC1 in 2006.

Publications arising from Newton Institute Programmes

Work carried out at the Newton Institute during the programme on *Strongly Correlated Electron Systems* (January to July 2000; see the *Annual Report* for 1999/2000) has been included in a recently published book:

SG Ovchinnikov and VV Val'kov
Hubbard Operators in the Theory of Strongly Correlated Electrons
Imperial College Press, 2004
241pp, ISBN 1860944302, (Hbk) £43.00

Two volumes arising from programmes in 2004/05 are also currently in preparation: for further information, see the reports on *Magnetic Reconnection Theory* (pages 18–21) and *Model Theory and Applications to Algebra and Analysis* (pages 34–37).

In total, 297 papers were produced by or in preparation by participants at the Institute during 2004/05. A complete list is given in Appendix 5 (see the contents page). Many of these are included in the Newton Institute's Preprint Series to which participants are encouraged to submit their papers. A web page giving details of the Preprint Series is available at

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

Scientific Steering Committee

Membership of the Scientific Steering Committee at 31 July 2005 was as follows:

Professor S Abramsky FRS FRSE	University of Oxford
Professor JM Ball FRS FRSE	University of Oxford
Professor C Bernardi	University of Paris 6
Professor PV Coveney FInstP FRSC	University College London
Professor SK Donaldson FRS	Imperial College London
Professor Sir John Kingman FRS (Secretary)	Director, Newton Institute
Professor JG McWhirter FRS FREng	QinetiQ
Professor EB Martin	University of Newcastle
Professor EG Rees FRSE (Chairman)	University of Edinburgh
Professor G Ross FRS	University of Oxford
Professor C Series	University of Warwick
Professor BW Silverman FRS	University of Oxford
Professor M-F Vigneras	University of Paris 7

The Institute invites proposals for research programmes in any branch of mathematics or the mathematical sciences. The Scientific Steering Committee (SSC) meets in May and October 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

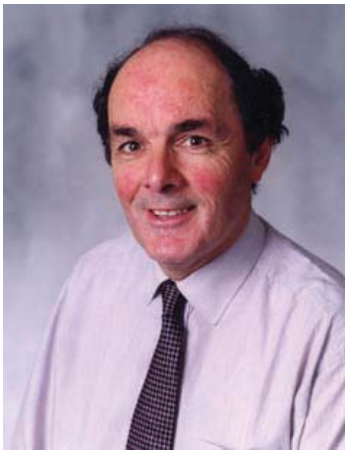
The scientific planning and organisation of each programme are the responsibility of a team of three or four Organisers (aided in some cases by an Advisory Committee). The Organisers recommend participants in the programme, of whom up to twenty can be accommodated at any one time; they also plan short-duration 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 2004:

- Professor TCB McLeish (Leeds)
- Professor JR Whiteman (Brunel)

The following new members were elected:

- Professor PV Coveney FInstP FRSC (UCL)
- Professor C Series (Warwick)



Professor EG Rees,
Chairman of the Scientific Steering Committee

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.

Management Committee

Membership of the Management Committee at 31 July 2005 was as follows:

Dr A Bramley	EPSRC
Professor B Bruce	London Mathematical Society
Professor WJ Fitzgerald	Council of the School of Technology
Professor GR Grimmett	Head of Department, DPMMS
Professor EJ Hinch FRS	Trinity College
Dr RE Hunt (Secretary)	Deputy Director, Newton Institute
Professor PT Johnstone	St John's College
Professor Sir John Kingman FRS	Director, Newton Institute
Professor PV Landshoff (Chairman)	General Board
Professor TJ Pedley FRS	Head of Department, DAMTP
Professor EG Rees FRSE	Chairman of the Scientific Steering Committee
Professor Sir Martin Rees FRS	Council of the School of 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 (full-time and part-time) of the Institute at 31 July 2005 was as follows:

- Dr Mustapha Amrani, Computer Systems Manager
- Tracey Andrew, Programme and Visitor Officer
- Jonathan Chin, Deputy Computer Systems Manager
- Jennifer Dorkings, Programme and Visitor Assistant
- Esperanza de Felipe, Housing Officer
- Kate Gilbert, Director's Administrative Assistant
- Steve Greenham, Technical Assistant
- Dr Robert Hunt, Deputy Director
- John Keating, Catering Assistant
- Professor Sir John Kingman FRS, Director
- Terry Metcalf, Information Assistant
- Doreen Rook, Finance and Clerical Assistant
- Christine West, Institute Administrator
- Sara Wilkinson, Information Officer
- Stephen Williams, Senior Finance Officer

S Pliska

The Institute Staff on the occasion of HM The Queen's visit, 8 June 2005 (see page 11)

International Activity

EMS

The European Mathematical Society (EMS) was founded in 1990 in Madralin, near Warsaw (Poland). The meeting which created the EMS was held under the auspices of the European Mathematical Council, chaired by Sir Michael Atiyah before he came the first Director of the Newton Institute.

The purpose of the Society is 'to further the development of all aspects of mathematics in the countries of Europe.' In particular, the Society aims to promote research in mathematics and its applications, as well as concerning itself with the broader relation of mathematics to society. The membership consists of about 50 mathematical societies throughout Europe and around 2000 individual members who have joined through their national societies. The EMS has been closely involved with the discussions leading to the establishment of the European Research Council, whose membership includes EMS Vice-President Professor Pavel Exner. For more information on this and other activities, visit **http://www.emis.de/**

The current Director of the Newton Institute, Sir John Kingman, became President of the EMS in January 2003. His term of office runs until the end of 2006.

ERCOM

ERCOM ('European Research Centres On Mathematics') is a committee of the EMS consisting of the directors of all the research centres and institutes throughout Europe that have a substantial visitor research programme in the mathematical sciences. ERCOM was founded in 1997 and meets annually. The purposes of ERCOM are:

- to constitute a forum for communication and exchange of information between the centres themselves and with EMS
- to foster collaboration and coordination between the centres and with EMS
- to contribute to the visibility of the EMS
- to foster advanced research training on a European level
- to advise the Executive Committee of the EMS on matters relating to activities of the centres
- to cultivate contacts with similar research centres within and outside Europe

ERCOM is particularly concerned at present with the European Research Area and the European Research Council; with the plight of young researchers in disadvantaged geographical areas, specifically parts of Africa, Asia and the former Soviet Union; with the participation of female scientists in research institute activities; and with the underpinning nature of mathematics in the sciences and more widely, specifically via a recently approved European NEST project entitled *Shaping New Directions in Mathematics for Science and Society*.

More information about ERCOM can be obtained from its website at **http://www.crm.es/ERCOM/** or from the Newton Institute. European visitors are particularly encouraged to pick up a leaflet.

EPDI

The European Post-Doctoral Institute for Mathematical Sciences (EPDI) was founded in 1995 by the Newton Institute, the Institut des Hautes Études Scientifiques (Bures-sur-Yvette, France) and the Max-Planck-Institut für Mathematik (Bonn, Germany). Since then six more centres have joined the group, in Leipzig, Vienna, Djursholm, Warsaw, Barcelona and Zurich.

Each year, EPDI offers five two-year grants to young European scientists who have recently completed their PhDs, on condition that they spend from 6 to 12 months at one of the EPDI institutes. Competition is strong and the scientific quality is high. British applicants, who are currently underrepresented, are particularly encouraged.

Further information, including full conditions for grant applications, can be found at the EPDI website, **http://www.ihes.fr/EPDI/**

Young Scientists

The Institute holds a number of events each year that include activities specifically targeted at young scientists. In 2004/05 these events included:

- Spitalfields Day on *Magnetic Reconnection Theory*
- Hewlett-Packard Day on *Magnetic Reconnection in the Sun and Magnetosphere*
- Focus Week on *Quantum Gravity and Quantum Information*
- Marie Curie Training Course on *Magnetohydrodynamics of Stellar Interiors*
- Conference on *Large-scale Computation in Astrophysics*
- Spitalfields Day on *Magnetic Fields in Plasmas, Stars and Galaxies*
- Spitalfields Day on *Groups of Finite Morley Rank*
- Marie Curie Training Course on *An Introduction to Recent Applications of Model Theory*
- Satellite workshop at the University of East Anglia on *Pure Model Theory*
- Spitalfields Day on *Risk Management of Hedge Funds*
- Marie Curie Training Course on *Quantitative Finance: Developments, Applications and Problems*

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 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 (but are not limited to) 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 172 new Junior Members in 2004/05; the current total is 417 as at the end of July 2005.

Another source of funding for young scientists is generously provided by the Cambridge Philosophical Society. The following were recipients of bursaries from the Society in 2004/05:

Quantum Information Science

- I Devetak (Southern California)
- T Osborne (Bristol)

Magnetohydrodynamics of Stellar Interiors

- A Courvoisier (Leeds)
- J Nanglu (Leeds)

Model Theory and Applications to Algebra and Analysis

- R Elwes (Leeds)
- T de Piro (Edinburgh)

Developments in Quantitative Finance

- D Becherer (Imperial)
- A Cherny (Moscow State)

Magnetic Reconnection Theory

2 August to 27 August 2004

Report from the Organisers:
ER Priest (St Andrews), TG Forbes (Durham, USA) and J Birn (Los Alamos)

T Andrew

Left to right: TG Forbes, ER Priest and J Birn

Scientific Background

Magnetic reconnection is a fundamental process in a plasma of high magnetic Reynolds number, whereby magnetic field lines (which are normally attached firmly to the plasma as it moves) become detached, break and rejoin. During this process, the topology of the magnetic field can sometimes change and magnetic energy is converted into other forms, such as heat, plasma kinetic energy and fast particle energy. Since the process involves topology, advection, diffusion, boundary layers (resolved by, for instance, magnetic diffusion) and sometimes shock waves, the mathematical problems associated with describing it are formidable.

There is a wide variety of physical phenomena where magnetic reconnection is important, including: solar flares and coronal heating on the Sun; geomagnetic substorms and flux transfer events in the Earth's magnetosphere; disruptions in laboratory tokamaks; and many dynamic processes in distant astrophysical objects. Indeed, wherever the magnetic Reynolds number is large and the magnetic field dominates the plasma pressure, it is bound to be a common process.

As well as these different applications, there have been two main strands of theory, one based on magnetohydrodynamics (MHD) and the other based on collisionless plasma theory. Until recently, the MHD and collisionless theories and the solar and geomagnetic applications have been studied by four separate communities. The aim of the programme was therefore to bring together the world's main theorists in these four distinct areas and to explore common ground.

Overview

The four-week programme involved 47 participants, many of whom stayed for the whole time. Virtually all of those we asked did accept the invitation, and so we were highly fortunate to have most of the major world figures in the field present.

The programme was an enormous success in many respects. This was the first time that many of the key researchers had been able to have in-depth discussions with those from the other areas, so there was an initial phase of learning. A sense of vitality, ferment and excitement pervaded the programme as many new ideas were born and thrown around, which will continue to bear fruit for years to come. It is clear that this was a landmark occasion marking the start of many new developments in the field.

Structure of the Programme

In view of the short length of the programme and the need to come up to speed rapidly, we spent the first day with each person introducing themselves and throwing in ideas on which they would like to focus. The second day was spent listening to a series of overviews of the key outstanding problems and questions in reconnection theory, given by ER Priest (MHD and coronal heating), JF Drake (collisionless theory), TG Forbes (solar flares and coronal mass ejections) and J Birn (the

magnetosphere). This was followed for the remaining three mornings of the first week by a series of tutorial lectures on the basic concepts of reconnection (G Hornig) and on collisionless reconnection (MH Hesse and P Pritchett).

At the start of the second week we held two highly stimulating, well attended meetings: a Spitalfields Day on basic theory and a Hewlett-Packard Day on applications (see below). Thereafter we held just two in-depth seminars each morning, so as to enable the participants plenty of time to interact as they wished. The emphasis was very much on the sharing of ideas and genuine cross-fertilisation on the basic theory of 3D MHD and collisionless reconnection.

Magnetic Reconnection Theory

Spitalfields Day, 9 August 2004

Organisers: TG Forbes and ER Priest

This highly successful and stimulating one-day meeting was attended by 65 people. Its purpose was to discuss the mathematical aspects of reconnection theory that have been developed for various applications in laboratory and space plasmas. Each application tends to have different scientific objectives and this has led to different mathematical developments of the theory which are little known outside the specific area of application. Presentations and discussion periods during the day allowed participants to obtain a global overview of reconnection theory and to learn of recent mathematical developments over a wide range of applications.

The day began with two reviews, one by G Hornig on the topology of 3D reconnection and another by JD Gibbon on singularities in 3D Euler and MHD, followed by three contributed talks: D Pontin on kinematic 3D reconnection at nulls, J McLaughlin on MHD wave propagation near a 2D null, and G Abel on fractal reconnection at the Earth's magnetopause. After coffee P Pritchett gave a review of collisionless reconnection theory, MH Hesse reviewed diffusion-region theory and J Huba gave a contributed talk on Hall reconnection.

After lunch there were two more reviews, the first by F Pegoraro on Kelvin–Helmholtz instability and the second by B Shivamoggi on critical exponents and universality in fully developed turbulence.

Some of the key participants

After tea C Watt gave a contributed talk on the basic theory of ion acoustic instability and P Petkaki gave a second on its nonlinear development. The last talk was a magnificent one delivered by A Bhattacharjee on impulsive reconnection dynamics. The day concluded with much lively discussion over wine and beer.

Magnetic Reconnection in the Sun and Magnetosphere

Hewlett-Packard Day, 10 August 2004

Organisers: J Birn, TG Forbes and ER Priest

This exciting one-day meeting followed on immediately from the Spitalfields Day by discussing the way in which magnetic reconnection is thought to operate in the Sun and the magnetosphere.

Two review talks on the Sun started the day, the first by L Culhane on observational evidence for reconnection in the solar corona and the second by C Parnell on reconnection and coronal heating. Three young people then each gave a contributed talk: S Higgins on impulsive heating of coronal loops, I Coleman on testing reconnection theories at the Earth's magnetopause, and M Kuznetsova on anti-parallel and component merging. After coffee B Kliem reviewed some open problems for reconnection in solar flares and H Hudson described the perturbations of active regions by flares, while R Maclean discussed the topology of magnetic breakout.

Lunch provided ample opportunity for lively discussion of these provoking talks and was followed by two reviews, the first by D Alexander on the nature of reconnection in coronal mass ejections and the second by K Trattner on merging and reconnection at the Earth's magnetopause.

Relaxing – but not always going in the intended direction!

Then after tea J Dorelli gave a fascinating review of reconnection at the dayside terrestrial magnetopause and W Baumjohann described Cluster results on bifurcated and thin current sheets. The day ended with two contributed talks from S Eriksson on shock analysis of flows in the magnetotail and T Moretto on Cluster observations of the high-latitude magnetopause.

Altogether, it was a rich experience of excellent presentations with plenty of time for lively discussion and exchange of ideas.

Outcomes

The main outcomes were: a series of new ideas that will be worked on in the months to come (see below); the development of a set of new collaborations; and the writing of a major monograph on reconnection by the main participants.

Limitations of space mean that we can only mention briefly a few of the new directions, but there were many more.

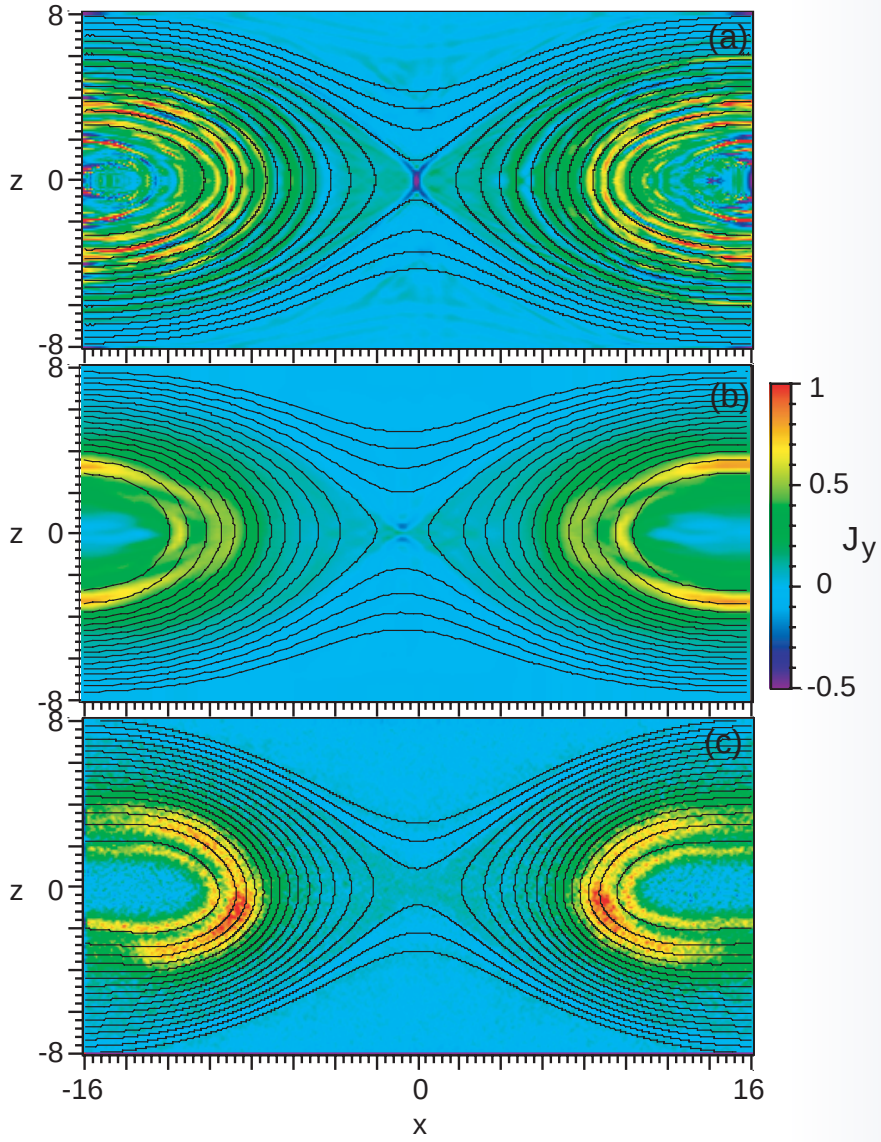
One important topic that engaged several of the participants was the nature of 3D reconnection. The outline of a theory had previously been developed by ER Priest and V Titov for reconnection at a 3D null by spine reconnection or fan reconnection or separator reconnection. However, this model was purely kinematic in the non-standard sense of satisfying the induction equation and deducing the steady state velocity and electric field in 3D for a given magnetic field. During the programme two new developments were initiated: the first a technique for also satisfying the equation of motion, and the second a full numerical resistive MHD experiment to test the validity of the model.

A second important topic was to understand the nature of 2D collisionless reconnection. So far there had been several intriguing numerical experiments by participants in the programme but no analytical model had yet been proposed. A group therefore decided to study the results of the numerical experiments in detail in order to understand physically the reasons for their different features, namely, the internal electron region and the intermediate ion region where Hall effects dominate. Having developed some such explanations they are now in the process of setting up an analytical model of the whole process, which hopefully will lead to a much deeper understanding of how reconnection in a collisionless plasma occurs.

A major new collaboration was begun during the programme on comparing the results of different codes on a model problem. A concerted effort involving 12 participants undertook a state-of-the-art numerical comparison of reconnection in the collisionless regime (to be published in *Geophysical Research Letters*). A test 'challenge problem' was designed to compare MHD, two-fluid Hall–MHD and full particle codes. The problem concerned the response of an initial current sheet to an external force that causes localised thinning and reconnection. The figure opposite illustrates the final states.

Despite the differences in dissipation mechanism, the reconnection rates and final states are surprisingly similar. The comparisons also revealed new details about the influence of the magnitude of the boundary deformation, the role of electron mass and the role of gradient scales. The results have important implications for the onset of reconnection in the Earth's magnetic tail and the solar corona.

A monograph, entitled *Reconnection of Magnetic Fields: Magnetohydrodynamics and Collisionless Theory and Observations*, edited by J Birn and ER Priest, is to be published by Cambridge University Press. Written by many of the participants, it



Late stages of the magnetic field (contour lines) and current distribution (colour coded) for various simulations: (a) MHD using localised diffusivity (J Birn); (b) Hall–MHD without explicit dissipation (J Huba); (c) PIC simulation (M Hesse)

summarises the state of the art and the advances made during the programme. Its chapter headings reflect the topics studied during the programme:

- Basic Theory of MHD Reconnection
- Basic Theory of Collisionless Reconnection
- Reconnection in the Magnetosphere
- Reconnection in the Sun's Atmosphere

The Future

In order to build on the links so usefully formed at the Newton Institute, we agreed to try to meet annually in a workshop format. In particular, we are holding a week-long workshop on reconnection in August 2005 in Santa Fe and are proposing to hold a series of ISSI workshops on reconnection in Berne in 2006.

Quantum Information Science

16 August to 17 December 2004

Report from the Organisers:
CH Bennett (IBM), DP DiVincenzo (IBM), N Linden (Bristol) and S Popescu (Bristol)

CH Bennett, N Linden and S Popescu

Scientific Background

Quantum information science is a new field of science and technology to which physicists, mathematicians, computer scientists and engineers have made major contributions. It undertakes to develop the theory and practice of information processing for information carriers (in the simplest case, 2-state quantum systems or 'qubits') that, unlike the bits of classical information theory, but like the real physical systems they exemplify, are capable of superposition and entanglement. Deep links between the previously unrelated disciplines of quantum physics and computer science/information theory have been forged, leading on the one hand to insights into fundamental issues in physics and on the other to hitherto unsuspected kinds of computation and communication. New technologies have arisen offering the potential for unconditionally secure communications and dramatic speedups of some computational tasks such as integer factorisation and search.

Quantum information science is one of the most dynamic areas in the physical sciences, with new ideas and phenomena appearing at a remarkable rate. There are also very many open questions and fundamental issues to be understood. Some of the questions and challenges on which the programme focussed were:

- characterising and quantifying non-local properties of quantum states and operations;
- understanding which features of quantum mechanics are responsible for the power of quantum computation and communication;
- developing new quantum algorithms;
- identifying novel tasks in which the physical nature of the qubit is important (recent examples include reference frame alignment and clock synchronisation);
- calculating the capacities of quantum channels, and identifying new communication tasks, particularly in multi-party settings;
- investigating distributed and interactive computation;
- identifying cryptographic tasks which are candidates for novel quantum protocols.

Structure of the Programme

The programme was large and multi-faceted, including 43 long-stay visitors (of whom 12 were from the UK), 112 short-stay visitors (40 from the UK), five workshops (several of which were filled to capacity or overbooked), a Rothschild lecture, other lectures and tutorials, regular seminars, satellite meetings, and new collaborations establishing links between different communities.

S Wilkinson

Participants at the 'Special Week on Quantum Cryptography'

Workshops

Quantum Information Theory: Present Status and Future Directions

Workshop, 23–27 August 2004

Organisers: S Massar, N Linden and S Popescu

This workshop, held strategically near the start of the programme in order to give an overview of the field, was one of the main events. It consisted of about 30 invited talks by the leading experts in the theory of quantum information, and brought together theoretical physicists, computer scientists and mathematicians to discuss the current status of the field and present important recent developments. Despite substantial progress in the last few years, there are also very many open questions and fundamental issues to be understood. For this reason the speakers were encouraged to review in their talks the major challenges in the field.

Subjects covered by the workshop included quantum algorithms and algorithmic techniques, quantum communication and quantum cryptography, quantum entanglement and non-locality, fault-tolerant quantum information processing and communication, quantum information processing and quantum operations under constraints (for instance imposed by the physical system in which they are realised).

Special Week on Quantum Cryptography

Focus Week, 6–10 September 2004

Organisers: A Kent, J Oppenheim and R Colbeck

Twenty leading theorists gave seminars during this Special Focus Week, which also featured some memorable informal discussions. Among the topics considered were novel security proofs for quantum key distribution, the problem of composability of elementary quantum cryptographic primitives, quantum protocols which attain cheat sensitivity (a novel form of security with no precise classical analogue), the phenomena of quantum locking and unlocking and their uses, and the striking discovery of quantum key distribution protocols which are provably secure even if quantum theory is incorrect (so long as superluminal signalling is impossible). Extensive informal discussions covered these topics and many others, including the subtleties which arise in abstractly modelling the properties of mistrustful quantum cryptographic tasks such as quantum bit commitment, and various types of security that might be attainable in tasks such as secure multi-party quantum computation. The workshop was generally agreed to be a great success, and the scope for informal discussion alongside formal presentations was much appreciated.

Entanglement and Transfer of Quantum Information

Workshop, 26–30 September 2004

Organisers: DP DiVincenzo, M Plenio and A Briggs

Crucial to any implementation of quantum information processing are the controlled creation of entanglement between qubits and the controlled transfer of quantum information, in particular between stationary qubits and propagating qubits. Photons are the most natural candidates as propagating qubits for long-range communication, but for short-range communication other approaches may be taken such as moving matter qubits or excitations in systems of interacting particles. For static qubits there is a wide range of

possibilities, ranging from nuclear and electron spin to single and collective excitations. With many candidates being available, optimal choices have yet to be identified for both static and flying qubits. The workshop was organised by the Quantum Information Processing Interdisciplinary Research Collaboration (QIP IRC) together with the Isaac Newton Institute to provide a forum for discussions with the aims of reviewing leading experimental programmes within the theme of entanglement and transfer of qubits, relating these to theoretical developments in quantum information processing, and identifying promising roads towards the controlled entanglement and transfer of quantum information.

The workshop was very successful. It attracted a large enthusiastic participation, including many of the worldwide experts in the field. The interdisciplinary topics were carefully grouped. The following represent some (though by no means all) of the new results presented.

- Electron charge: Rabi oscillations can be demonstrated in a gated charge qubit in GaAs. Using the gate potentials, full manipulation over the Bloch sphere can be achieved. Phosphorous atoms can be deposited in subsurface sites in silicon to make a classical two-state charge system with potential as a qubit. Electron charge can be manipulated in nanotubes, and can demonstrate quantum spin-charge effects such as Kondo resonance and coulomb blockade.
- Electron spin: quantum information can be embodied in electron spins in compound semiconductors. The spins can propagate, and single electron spins in quantum dots can be measured through a nearby quantum point contact. Electron spins in molecular materials have long lifetimes, and can be manipulated with exquisite precision using pulse sequences derived from NMR such as BB1. Endohedral fullerenes give further quantum effects when placed inside nanotubes.
- Experimental and theoretical progress is being made in the use of atom chips to produce controlled and localised Bose–Einstein condensates with potential for quantum computing.
- Several matter-based qubits can be read out optically. Spin-qubits in N-V centres in diamond can be manipulated through ESR, and the result can be read out using a spin-dependent optical transition. A two-qubit operation has been performed with the nuclear spin of a ^{13}C atom in the vicinity.
- The interaction between photons and single ions is being exhibited in a range of systems. Entanglement of a photon and the qubit in a trapped ion has been demonstrated.
- Teleportation of quantum information in ion traps has been demonstrated in two laboratories, together with four-qubit algorithms. Scaleable schemes for ion trap computing have been developed, and simulations have been run. Distributed entanglement offers potential.
- Linear optical computing offers enormous challenges. Progress is being made in the conditional preparation of single photons, and there is both theoretical and experimental progress in reducing the considerable demands of efficient implementation.
- Superconducting qubits are perhaps the most mature solid-state implementation. There is now great control of flux qubits, with long ratios of coherence time to gate operation time, and potential for scaleable qubit–qubit interactions.
- New schemes have been developed for globally addressed quantum computing, which are now much more robust and versatile, and for quantum communication in rings of qubits with defined interactions.
- Quantum communication involving up to five qubits in optical fibres has been demonstrated, though without satisfactory photon-on-demand sources it is extremely slow.

Several of the delegates said that this had been the best QIP conference they had ever attended. They particularly commended the open structure of the conference, with plenty of discussion time both

inside and outside the formal sessions. The speakers were also commended on ensuring that their material was accessible to the whole of the multidisciplinary audience, while including many results announced for the first time. Where the invited 'big name' was unable to accept, we adopted a policy of encouraging them to nominate an active researcher in their group to come and give a presentation. In this way we achieved a good age distribution among the speakers, which further contributed to the lively debate and discussion. A number of new collaborations have arisen out of discussions at the workshop.

The original motive for the workshop was to foster dialogue with the mathematicians and theorists attending the Newton Institute programme. There were 122 delegates, including 22 programme participants. The organisers were deeply grateful to the Institute staff for superb organisation, and to DARPA and ONR for sponsorship. Many talks are available online at the Newton Institute website.

Quantum Statistics – Quantum Measurements, Estimation and Related Topics

Focus Week, 15–19 November 2004

Organisers: VP Belavkin, RD Gill and A Winter

The three organisers of this event came, roughly speaking, from mathematical physics, mathematical statistics, and quantum information proper. The meeting served to bring together the subcommunity in quantum information science of people interested in quantum statistical estimation (estimation or tomography of states or operations or even measurements), and was perhaps the first ever of such meetings. This is a scattered subcommunity, so many researchers had here an opportunity to meet colleagues they had not seen before (and in quite a few cases not heard of before!), and the meeting served as a forum to establish the state of the art. It certainly has initiated several new scientific collaborations.

In particular there was a major contingent of researchers from Japan, where there is a long-established and advanced school in quantum state estimation but whose works (rather mathematical and using sophisticated geometrical methods) are almost unknown to the theoretical physicists in the field.

CH Bennett

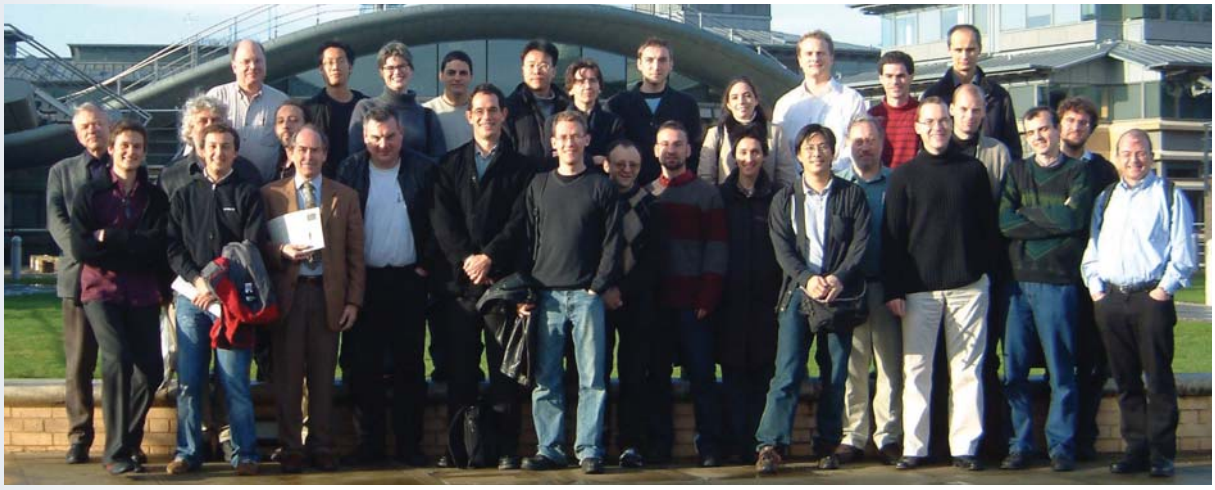
SW Hawking and colleagues

Particularly gratifying was the participation in the meeting of a number of mathematical statisticians, and among them several young people just starting doctoral or postdoctoral research without prior exposure to quantum information. We believe that the meeting has laid the seeds of important future cross-fertilisation between statistics and quantum information.

One of the scientific highpoints of the meeting was the presentation by Masahito Hayashi (Tokyo) of new results on Alexander Holevo's quantum Cramér–Rao bound, which was first published in 1980. This rather obscure (indeed, rather unappetising) bound has lain dormant for twenty-five years, no-one realising its significance. It now turns out to be *the* asymptotically sharp bound for the quality of the best possible reconstruction of a state based on collective (entangled) measurements. The connection goes via a quantum central limit theorem (approach to Gaussianity) and the fact that the bound is sharp for Gaussian states.

Further very exciting results were presented by Denes Petz on quantum sufficiency, and by Mauro D'Ariano on the tomography (calibration) of measurements. One particular unofficial topic of many discussions was the perspective for deriving a theory of distance between, and convergence of, quantum statistical models, which should generalise the classical statistical theory of L LeCam and give a framework that would organise the scattered results on asymptotic optimality. Another major unofficial topic was the question of $1/N^2$ rate estimation (for the fidelity or squared error) of an unknown unitary based on N copies, a kind of quadratic speed-up in a quantum estimation problem, derived from entanglement.

S Wilkinson



Participants at the workshop 'Quantum Gravity and Quantum Information'

Quantum Gravity and Quantum Information

Focus Week, 14–17 December 2004

Organiser: J Oppenheim

This meeting explored the interface between quantum gravity, quantum information and the foundations of quantum mechanics. Topics included black hole information, the measurement problem in a gravitational setting, quantum geometry, and big bang cosmology. Part of the objective was to provide a space where researchers in quantum gravity and quantum information could explore areas of common interest and identify worthwhile avenues of research.

There were some talks given by both well known and established researchers (Gerard t'Hooft, Roger Penrose, Seth Lloyd, Renate Loll, Neil Turok and Bill Unruh) and others given by up-and-coming researchers (Christophe Galfard, Daniel Gottesman, Fotini Markopoulou, Ralf Schützhold and Daniel Terno). Additionally, there were shorter, more informal talks (some at the public blackboards) designed to encourage interaction between researchers. These included talks by Florian Girelli, Ivette Fuentes Guridi, Louis H Kauffman, Viacheslav Belavkin, Jonathan Oppenheim, Martin Plenio, John Smolin and Charlie Bennett.

A number of the talks announced work being made public for the first time. Highlights included the talk of Christophe Galfard who presented his work with Stephen Hawking and Christiano Germani on the black hole information paradox. Since Hawking's public announcement and talk in Dublin at GR17, the work had generated considerable discussion, and this was the first time details were presented. Another highlight was the talk of Bill Unruh who presented a potential bound on determining the state of black hole radiation.

Outcome and Achievements

The programme and its associated workshops were extremely productive, and it is very difficult to summarise the results: we do apologise to those participants whose work we haven't succeeded in representing appropriately. Some of the highlights follow.

The Newton Institute provided a special atmosphere facilitating the transfer of ideas between the usual narrow fields of specialisation. At the Institute, people can learn ideas outside their area by having them explained slowly and repeatedly by their authors. This allowed unexpected common themes to emerge, with different people applying the same idea in different domains. Some such major themes that emerged were locking of resources, general non-locality, additivity properties and fault-tolerant quantum computation.

Locking

The Horodecki family, together with Jonathan Oppenheim, continued their investigation into the phenomenon of locking of entanglement measures that they discovered shortly before the start of the programme. Locking represents a paradigm shift in quantum information. Hitherto it was known that

different information resources can be traded one for another, but it was thought that in order to gain access to some resource one needs to pay a proportional amount of another resource. Unlocking means that one can gain access to arbitrarily large amounts of some resource by paying a very limited amount (say 1 bit) of another resource (the key).

Berry Groisman, Noah Linden, Sandu Popescu and Andreas Winter, together with the Horodecki family, investigated the implications of locking the entanglement of formation for multi-partite entanglement concentration. Multi-partite entanglement concentration is one of the most important open problems in quantum information. They analysed what is widely considered to be the simplest non-trivial problem in the field, a problem that defied solution for almost a decade. They showed that either entanglement of formation is lockable in a far simpler situation than the one suggested by Jonathan Oppenheim and the Horodecki family, or multi-particle reversible concentration is impossible, which then requires a drastic revisiting of the basic paradigm of quantum information, namely entanglement as a resource.

The very same problem, but from a completely different angle, was studied by John Smolin, Frank Verstraete and Andreas Winter. They derived the first general capacity theorems for multi-partite concentration and channels with classical assistance from the environment. Adrian Kent and Debbie Leung investigated the implication of locking in quantum cryptography. John Smolin considered the effect of locking of quantum information in quantum gravity, specifically on the black hole information paradox.

Finally, in related work right at the end of the programme, Michal Horodecki, Jonathan Oppenheim and Andreas Winter made their remarkable discovery that quantum information can be negative. The primitive they introduced, quantum state merging, also allowed them to solve several famous open problems in information theory, for example in distributed compression and quantum multiple access channels.

Non-locality

From the very early days, entanglement and quantum non-locality have been recognised as the most important aspects of quantum mechanics as far as quantum information is concerned. This year, however, witnessed a new twist – the study of non-locality *per se*, i.e., all kinds of non-local correlations, not only those arising from quantum mechanics. Of course, non-locality that cannot arise from quantum mechanics doesn't exist in Nature, if Nature is quantum mechanical; nevertheless, the study of these hypothetical correlations turned out to be very useful since it offers a new perspective over what quantum non-locality actually is. The discovery of non-quantum non-local correlations, initiated by Popescu and Rohrlich, dates back about fifteen years, but it was only during the Newton Institute programme that their study really took off; and indeed it became a major theme of the programme.

Harry Buhrman, Richard Cleve, Noah Linden and Falk Unger considered the extremal case of non-local correlations, 'maximally non-local boxes'. They showed that in the presence of such non-local boxes any communication complexity function can be computed with just 1 bit of communication even if the non-local boxes have error around 5%, significantly improving van Dam's original proof that required perfect boxes. Based on this result, they went on to establish a new threshold for fault-tolerant classical computation. In discussions with Dan Gottesman, this result was then generalised to show that a (distributed) Clifford circuit quantum computation can be simulated with just one bit of communication and quantum entanglement, and used this result to derive the best known upper bounds on the quantum fault-tolerant threshold error probability.

Nicolas Gisin, Serge Massar, Sandu Popescu and Tony Short invented the idea of non-local 'couplers', the equivalent in the space of generalised non-locality of the quantum measurements with entangled eigenstates.

Additivity Properties of Channels

Channel capacities and additivity properties have long been one of the core issues of quantum information. Charles Bennett and Andreas Winter characterised the tradeoff between sender–receiver shared randomness and classical forward communication required for simulating a classical channel. This long-neglected area of classical

S Wilkinson

The Horodecki family. Left to right: P Horodecki, K Horodecki, R Horodecki, M Horodecki

information theory has acquired new interest through its quantum generalisation, the problem of entanglement-assisted simulation of quantum channels. Further work at the Institute led to generalisation of the classical and quantum reverse Shannon theorem, especial to feedback channels in which the channel environment is returned to the sender in a manner called 'coherent classical communication' by Aram Harrow.

Mary Beth Ruskai considered questions about quantum channels, particularly capacity and related mathematical questions about p-norms and quantum entropy. She obtained a new additivity result; a simpler, alternative proof of the same result was then made by her together with Igor Devetak. Furthermore, Mary Beth Ruskai and Nilanjana Datta discovered and analysed a new class of channels in d dimensions. Keiji Matsumoto studied the additivity problem from a p-norm based approach. Alexander Holevo's main interest was in the additivity properties of channels, in particular the classical capacity, the minimal output entropy and the entanglement of formation. All known results are consistent with the conjecture that these quantities are additive. A proof of this conjecture would have important consequences in quantum information.

Fault-tolerant Quantum Computation

Since the presence of noise and faults in the functioning of gates is unavoidable, finding ways for performing fault-tolerant quantum computation is a most important issue. The basic principles were established about five years ago, but the results were very complicated and only a very small number of researchers actually understood them. This programme witnessed a renewed interest in the subject, with a large community becoming attracted to it. Many people were involved in almost daily discussions devoted simply to learning the subject. At the same time notable progress was made by John Preskill on a proof of the threshold theorem.

Other Topics

Quantum cryptography was another of the major subjects discussed during the programme. Nicolas Gisin, Daniel Gottesman, Adrian Kent, Masato Koashi, Debbie Leung and Hoi-Kwong Lo worked on various new cryptographic protocols.

Interesting progress was made not only in the main themes of the programme but also in a wide variety of other topics in the field. For example, during the last couple of years, continuous variables have proved very useful tools for quantum information processing. Peter Knight has been working on how to enhance the non-classical properties of Gaussian states; discussions with Nicholas Cerf and Serge Massar led to a new approach to this problem by Knight and Myungshik Kim. Using NMR techniques for quantum computation was one of the earliest methods in the area; Tim Havel worked on experimental methods of quantum control in nuclear spin systems; and Raymond Laflamme has been interested in the amount of noise that would destroy entanglement in a higher dimension GHZ state in order to use this as a criterion for the performance of NMR experiments. Richard Jozsa studied quantum algorithms from a novel point of view. Most work to date on quantum algorithms has focussed on time complexity benefits. However, it is believed that no quantum process will be able to solve any NP-hard problem efficiently. Hence he realised that it is of much interest to identify further kinds of computational benefit such as parallelisability and efficient use of space; both these properties, which have been studied in classical computation theory, show unexpected behaviour in the quantum domain. Tony Sudbery worked on compatibility of subsystem states; results on the same subject were obtained by Matthias Christandel, Graeme Mitchison, Sumit Daftuar and Patrick Hayden.

CH Bennett

Some of the key programme participants

Quantum information is a very interdisciplinary subject, with close interaction between theoretical physicists, experimental physicists from very diverse areas, researchers in (classical) information, cryptographers and computer scientists. However, historically, most major advances in physics have opened, or at least significantly encouraged the development of, entire new areas of mathematics. It was our feeling that the time is now ripe for interaction between researchers in the quantum information community and pure mathematicians, and we made this one of the explicit aims of the programme. A number of pure mathematicians were invited and some of them spent extensive time on the programme. While it is yet early days, some notable results have been obtained. Louis Kauffman studied issues in quantum computation from the point of view of topology and knot theory. He accomplished a reformulation of the Freedman–Kitaev–Fibonacci model for quantum computing in terms of *q*-deformed spin networks and the coloured Jones polynomial. Furthermore, Lomonaco and Kauffman worked on braiding, spin networks and topological quantum computation, while Lomonaco also worked on vector fields of quantum entanglement. Roger Howe studied the issue of mutually unbiased bases.

A very positive outcome of the programme was the emergence of the connection of quantum information with mathematical statistics. Estimating quantum states is one of the central problems in quantum information. The problem is very different from classical statistical ones because of the fact that sampling some parameters characterising the quantum states necessarily precludes sampling of other parameters. A number of major results have been obtained during the last couple of years; they were obtained with very simple tools, starting effectively from scratch. Very recently however, as became apparent during the programme and its associated workshop on statistics, a number of statisticians have joined the effort, adapting to these new problems powerful statistical methods hitherto unknown in the quantum information community. Consequently many important new results have been obtained, as well as a systematisation of the old results.

Conclusion

Overall, the programme has initiated many fruitful collaborations, and it is already clear that they are having lasting impact on the scientists involved. Work done during the programme has already resulted in many e-prints and manuscripts submitted for publication, and will likely be remembered as a high point in the development of the field. It will also be remembered for having given experts in related fields who were previously unfamiliar with quantum concepts the opportunity to familiarise themselves deeply with quantum concepts and begin contributing to this new field in their own right.

Magnetohydrodynamics of Stellar Interiors

6 September to 17 December 2004

Report from the Organisers:
DW Hughes (Leeds), R Rosner (Chicago) and NO Weiss (Cambridge)

S Wilkinson

NO Weiss, R Rosner and DW Hughes

Scientific Background

At the heart of all observed stellar magnetic activity – whether as dark spots, bright flares or X-ray emission from a hot corona – lies the dynamical behaviour of the magnetic field in a star's interior. This programme focussed on the complex nonlinear interactions between convection, rotation and magnetic fields in the interiors of stars with deep outer convection zones, like the Sun, and aimed to confront theory with observations. This was timely because research into the magnetohydrodynamics (MHD) of stellar interiors is currently at an extremely exciting stage, with ever-improving observations posing a number of new theoretical challenges. High-resolution observations of the solar surface and solar atmosphere, from the ground and from space, have yielded amazingly detailed images. Helioseismology has provided important information on the solar interior: in particular, the unexpectedly strong rotational shear (the tachocline) at the interface between the convection zone and the underlying radiative zone came as a surprise to theoreticians. Moreover, Doppler imaging is revealing starspots on the surfaces of more distant stars.

Understanding these observations, and the fundamental physical questions to which they give rise, requires a combination of computational and analytical approaches. The rapid development of high-performance computers is now making it possible to explore aspects of MHD turbulence that are of direct astrophysical interest. These results are not only of importance in themselves. They also provide crucial input into the formulation of new and general theories, for these problems are intrinsically nonlinear and there has been a strong overlap with research on nonlinear dynamics.

The programme addressed all the fundamental issues concerning the magnetic fields of stellar interiors, bringing together not only theoreticians and observers, but also experts on numerical techniques and experimentalists studying the MHD of liquid metals. The central question was the nature of the dynamo responsible for maintaining a magnetic field against its natural tendency to decay. Considerable attention was devoted to this problem, particularly with regard to how the dynamo mechanism may vary between different types of stars. For many purposes, astrophysicists still have to rely on mean field dynamo theory – which may capture the essential physics but relies on approximations that are not valid in a star. It remains important, therefore, to understand the behaviour of magnetic fields in highly turbulent fluids and to settle such questions as how the α-effect saturates and what is the corresponding effect on the turbulent diffusivity. These issues are crucial in trying to understand the generation of both large-scale and small-scale magnetic fields in stellar convection zones.

Structure of the Programme

The programme began with a two-week conference that introduced the main themes that occupied us for the next three-and-a-half months, which were themselves punctuated by three one-week meetings on specialised topics. Most of the talks given at these meetings are accessible on the Newton Institute's website. Eleven of the participants (including all the organisers, together with A Brandenburg, PH Diamond, A Ferriz Mas, DJ Galloway, AD Gilbert, R Hollerbach, JH Thomas and SM Tobias) were present at the Institute throughout the whole programme; in addition there were 29 long-stay visitors and another 41 short-stay visitors, as well as 11 locals. At any time there were at least 20 resident participants at the Newton Institute, and numbers swelled to over 40 during the various conferences. Of the non-local long-stay participants, 15 came from the UK, 8 from other EU countries, 10 from the USA and 7 from elsewhere.

Outside the meetings, we had a regular diet of two seminars a week from participants in the programme, and these talks often led to vigorous and argumentative discussion that continued over coffee. Our Rothschild Visiting Professor was R Rosner, who gave a lecture on *Burning Stars in One's Office* to a fairly wide audience. The most important interactions, however, were informal, whether in individual offices or over coffee in the central space, which proved an extremely stimulating forum for discussion and arguments.

Conferences and Workshops

Magnetohydrodynamics of Stellar Interiors

Training Course, 6–17 September 2004

Organisers: DW Hughes, R Rosner and NO Weiss

This Marie Curie Training Course was very successful: it was attended by 87 participants from 15 countries, including 19 graduate students, 18 postdoctoral researchers and 50 experienced researchers. The course covered the interactions between convection, rotation and magnetic fields in the Sun and other stars with deep outer convection zones. Observers described both the new observations (from space and from the ground)

Bob Rosner, Henk Spruit and Jack Thomas at the first conference dinner

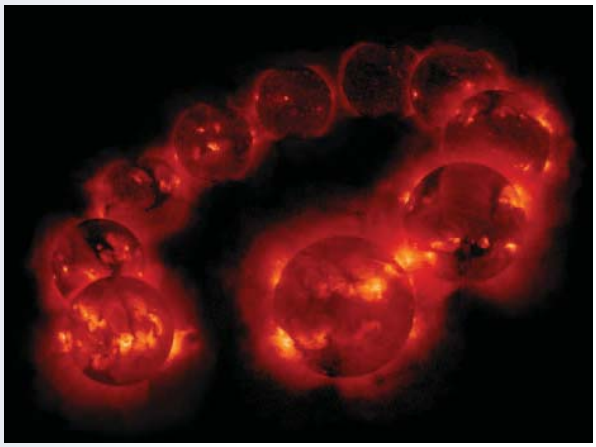
that are revealing fine details of surface features, and the helio- and astero-seismological techniques that probe the internal structure and rotation of the Sun and stars. Their lectures alternated with those from theoreticians, whose models are becoming increasingly more realistic and sophisticated as the availability of ever more powerful computers makes it feasible to follow nonlinear processes in much greater detail. The course ran for two weeks and was constructed around a series of invited lectures, each lasting one hour, followed by 10 minutes for discussion. In all there were 27 lectures, covering observations as well as theory, plus 28 contributed talks, each lasting 20 minutes with 5 minutes for discussion, and 6 poster presentations. Taken together, these talks provided not only an account of the underlying phenomena and the basis of their theoretical explanation, but also an up-to-date survey of current difficulties and controversies in this field. Having so many of the world's experts present for discussions made this meeting a remarkable experience for the younger participants. The course was structured so as to leave ample time and scope for free discussion, not only in the lecture hall itself but also during morning and afternoon coffee breaks, while the early afternoons were kept free for the same purpose.

Large-scale Computation in Astrophysics

Conference, 11–15 October 2004

Organisers: R Rosner, F Cattaneo, SAEG Falle, NE Hurlburt, E Müller and JM Stone

Astrophysical plasmas are typically in an extremely turbulent state, characterised by high values of the



Cyclic variation of solar magnetic activity revealed by Yohkoh X-ray images

key parameters, the Reynolds number and the magnetic Reynolds number. The aim of the conference was to cover the differing computational approaches to the problem of MHD turbulence, together with the many theoretical ideas that underly them, and to discuss in depth both strong and weak features of these various approaches. This meeting was particularly timely since the last few years have seen a dramatic leap in the nature of the problems that can be studied computationally. The advent of affordable parallel computing facilities, allied to techniques such as adaptive mesh refinement, now allow, essentially for the first time, realistic computational exploration of turbulent fluids.

Since there is a great concentration of expertise and experience in the United States, a major aim of the conference was to disseminate this knowledge among European research groups. It was therefore funded as a Marie Curie conference by the EU. There were 12 invited lectures, together with 15 contributed talks. In all there were 65 participants, 42 from EU countries, 19 from the USA and 4 from elsewhere; 14 of them were students, 16 were junior researchers and 35 had established posts. Thus the aim of spreading know-how was achieved. The talks covered the construction and verification of codes as well as applications of high-performance computing. Everyone emerged with an enhanced appreciation of the power of modern computing facilities and also of the need to focus on developing codes that are not only accurate but also properly validated.

Tachocline Dynamics

Workshop, 8–12 November 2004

Organisers: P Garaud, DO Gough, NO Weiss and J-P Zahn

The tachocline is the layer at the base of the Sun's outer convection zone where there is a steep radial gradient in angular velocity, Ω. Through most of the convection zone Ω varies with latitude but not significantly with radius, while the inner radiative zone rotates almost uniformly. The existence of the tachocline was revealed by helioseismology about 15 years ago, and it came as a complete surprise to theoreticians. Even now, there is no generally accepted theory of its origin and structure, or of its role in the solar dynamo. This was the first meeting ever to be entirely devoted to the subject and it brought all the key players together to discuss it. The workshop was informal, involving 48 invited participants who were taking part in the programme, and it was clearly a great success. Our aim was to maximise opportunities for argument and discussion. The number of invited lectures was therefore restricted, so as to leave plenty of time for structured discussions, led and organised by appropriate experts. This format worked extremely well. In all, there were 14 formal talks and eight hours of scheduled discussion, which continued informally outside the lecture room. The workshop certainly clarified the main issues, although no consensus was expected or achieved.

Magnetic Fields in Plasmas, Stars and Galaxies

Spitalfields Day, 6 December 2004

This event (supported by the London Mathematical Society) attracted over 40 participants. There were five lectures from members of the programme covering magnetic fields in ionised plasmas, on scales ranging from laboratory experiments, through stars like the Sun, to galaxies.

Stellar Dynamos

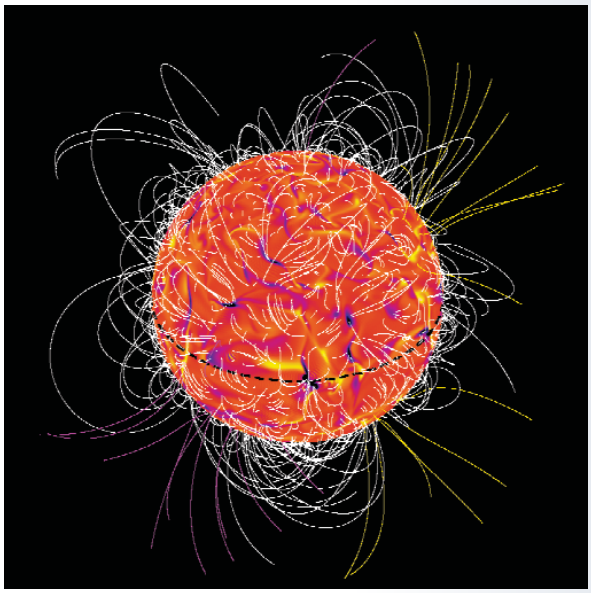
Satellite Meeting at the University of Leeds, 13–17 December 2004

Organisers: DW Hughes, SM Tobias, PJ Bushby and SC Cowley

This conference, funded by the London Mathematical Society and the Royal Astronomical Society,

was held at the University of Leeds during the final week of the programme and attracted 53 participants, many of whom had been at the Newton Institute earlier. The meeting concentrated on the generation of magnetic fields in astrophysical bodies, particularly stars. There were seven principal speakers, each of whom gave a one-hour lecture. The latest observations of stellar magnetic fields and of stellar differential rotation were presented in extremely accessible reviews, while other speakers dealt with the mathematical and theoretical aspects of astrophysical dynamo theory. In addition there were 26 contributed talks, covering a range of mathematical, computational and theoretical issues.

The University of Leeds hosted this conference extremely successfully, and it provided a stimulating finale to the programme.



Extrapolation of the radial field generated by dynamo action in a computational model (Brun, Miesch & Toomre)

Outcome and Achievements

Part of the programme was carefully structured, with meetings and seminars, while the rest was left free for more intensive informal collaboration and discussion. The structured part satisfied different needs. It allowed research students and postdocs to meet the leading figures in this field and to broaden their scientific understanding, especially through the more pedagogical reviews. Experienced researchers also appreciated being brought up to the forefront of research in a wide range of problems related to their individual interests. By giving proper attention to theory, numerical simulations and analyses of observations, these workshops encouraged better formulations of the fundamental problems that need focussed mathematical treatment, and also offered guidance to future observational programmes.

Participants welcomed the opportunity of working alongside key colleagues in a supportive research environment and away from the pressures and distractions of their regular teaching duties. Informal discussions proved extremely fruitful both in generating ideas and in getting new work done. Naturally, the subject that attracted most attention was dynamo theory, encompassing dynamo models for the Sun, rapidly rotating and fully convective stars, and supernova progenitors, as well as fundamental difficulties of describing the α-effect and transport properties in MHD turbulence (whether forced or convectively driven, and especially at low magnetic Prandtl numbers). Among the other topics discussed were kinetic and magnetic helicity, interactions of magnetic buoyancy with convective pumping and shear, chaotic mixing, magneto-rotational instabilities and of course the origin and structure of the tachocline.

A volume arising out of the workshop on *Tachocline Dynamics* will be published by Cambridge University Press, and three other publication proposals are being considered. Several major reviews were completed, and a total of 24 papers are so far projected to arise out of this programme.

Participants visited or gave seminars at Bristol, Exeter, Imperial College, Manchester, Newcastle, the Open University, Oxford, Portsmouth, St Andrews, Southampton, Sussex, UCL and Warwick, as well as in Cambridge.

Model Theory and Applications to Algebra and Analysis

17 January to 15 July 2005

Report from the Organisers:
Z Chatzidakis (CNRS), HD Macpherson (Leeds), A Pillay (Illinois), A Wilkie (Oxford)

S Wilkinson

Left to right: A Pillay, Z Chatzidakis, HD Macpherson and A Wilkie

Background

Model theory is a branch of mathematical logic dealing with 'definability' in various forms. As well as having a rich internal development including stability theory and its generalisations, there have been interactions with and applications to other areas of mathematics for many years. The model-theoretic study of valued fields such as the *p*-adics has a long history, from the Ax–Kochen solution of a problem of Artin, through Denef's proof of the rationality of certain Poincaré series, to current work around motivic and definable integration. The model-theoretic study of differential fields (fields equipped with a derivation) also goes back a long way, but the past 12 years have seen a new level of applications to diophantine geometry. The model-theoretic notion of *o*-minimality, which was isolated and developed twenty years ago or so, has led to very close interactions with real analytic geometers.

The main purpose of the programme was to bring together model theorists in these and other 'applied' topics, with mathematicians from the related areas, so as to solve existing problems as well as open up and explore new areas of research. We also welcomed the presence of model theorists working on the 'purer' side of the subject (although the work of many leading figures typically straddles the pure/applied divide, and in fact each aspect reinforces and feeds into the other).

Structure of the Programme

The programme had three workshops, two at the Newton Institute (both funded by Marie Curie Actions through the EU) and a satellite conference at the University of East Anglia. There was also a one-day Spitalfields Meeting.

Throughout the programme there was regular seminar activity, typically with 6–8 hours of seminars per week. Some of these were part of extended series (for example a series by Wilkie on *o*-minimal diophantine applications of a theorem of Gromov, a series by Macintyre on the model theory of elliptic functions, and several coordinated lectures on compact complex spaces). Other seminars were single talks on current research, in some cases reporting results obtained during the programme.

In total, the programme had 68 long-stay and 41 short-stay visitors. At any given time there were some 20–25 visitors present. The organisers encouraged groups of participants with a specific common interest to come around the same time; thus there was emphasis on groups of finite Morley rank in March, and on *o*-minimality in May.

There were visits, both for workshops and at other times, from specialists in other fields who had previously shown interest in model theory. These included, among others, D Bertrand, Bost, Fesenko, Gabrielov, Khovanskii, M Kim, Pink,

Poonen, Y Raynaud, Roessler, Rolin, MF Singer, Timmesfeld, JS Wilson and Yomdin. PhD students came frequently for seminars, for example from Oxford and Leeds.

Workshops

Groups of Finite Morley Rank

Spitalfields Day, 16 March 2005

The theme was an intensive and coordinated programme, instigated around 1988, to prove the 'Algebraicity Conjecture', that every simple group of finite Morley rank is an algebraic group over an algebraically closed field. Many ideas from the classification of finite simple groups have been used. Altinel (Lyon 1) gave an overview of the programme. Cherlin (Rutgers) and Jaligot (Lyon 1) reported on recent progress. Zilber (Oxford) discussed a possible strategy for refuting the conjecture, and Borovik (Manchester) described interactions between groups of finite Morley rank and finite groups, via 'Black Box' groups. These lectures, beautifully presented, were for the non-specialist. More detailed expositions were given in other seminars during March.

An Introduction to Recent Applications of Model Theory

Workshop, 29 March–8 April 2005

This workshop had some 120 participants, many of them PhD students and postdoctoral researchers (some of whom gave talks or presented posters). The workshop had a strong training component. It featured six tutorial series of up to five lectures each, sometimes linked to more advanced lectures, on recent research. These series were reinforced by lecture notes provided by the lecturers, as well as evening discussion sessions.

The tutorial series were somewhat ambitious and covered key areas of current research on the applied side of model theory: *Stability, differential fields and compact complex manifolds*; *Model theory of algebraically closed valued fields*; *Model theory for metric structures*; *Analogues of Hilbert's Tenth Problem*; *Operations on constructible functions*; and *Zariski-type structures*. We were fortunate in attracting the most prominent researchers for both the tutorials and other lectures. There were also several contributions from people outside model theory. Among the high points were fascinating talks by Fesenko on possible new interactions between model theory and number theory, and by Roessler on the use of model-theoretic results in diophantine and algebraic geometry.

Pure Model Theory

Satellite Workshop at the University of East Anglia, 4–8 July 2005

This satellite meeting was sponsored by EPSRC and the London Mathematical Society. There were three tutorials, given by Ben-Yaacov (on continuous model theory), Poizat (on Hrushovski constructions) and Newelski (on topological methods in model theory). Additional talks covered the state-of-the-art in stable and 'simple' theories, but also covered exciting new developments around *o*-minimality, the independence property, and continuous model theory.

Model Theory, Algebraic and Analytic Geometry

Workshop, 11–15 July 2005

This workshop, coming at the end of the programme, consisted of 24 one-hour lectures by leading experts who presented the latest results in model theory and its applications, many of which had been obtained at the Newton Institute during the preceding 6 months. There were 110 participants, plus a reserve list of 8 disappointed applicants.

The main themes were *o*-minimality, from model theoretic, real analytic and computational viewpoints, the interaction of model theory with diophantine geometry in the spirit of Hrushovski's famous work, rigid analytic geometry and 'definable groups'. The latter cropped up as a unifying element in several talks: groups defined over valued fields, in *o*-minimal structures, in the theory of compact complex spaces, as well as in their own right in the theory of small profinite groups and groups of finite Morley rank. A further theme, unexpected by the organisers at the time the programme was drawn up but a good example of work done during the period itself, concerned first-order definability questions over the class of finitely generated (rather than all) fields.

Even though, as requested by the organisers, most of the talks reported on up-to-the-minute research, the presentations were of such a high standard that they could all be appreciated by the large number of students and young researchers attending the meeting. The replies to the Institute's questionnaires provided ample evidence for this.

Outcome and Achievements

The overall consensus of participants and organisers was that the programme was an overwhelming success. The Newton Institute provided a very supportive environment both for quiet contemplation and intense collaborations. We will describe below some of the more explicit and tangible advances and breakthroughs that were achieved during the programme. There were, of course, other less tangible benefits which were frequently indicated in participants' reports, including inspiring conversations, often with specialists from other fields, possibly leading to later collaborations; greater understanding of adjacent fields of research, through the seminars and workshops; the opportunity for young researchers to broaden their knowledge and build contacts; and the completion or revision of earlier work, often assisted by the presence of collaborators.

Continuous Model Theory

Through excellent tutorials in two of the workshops, some current foundational work by Ben-Yaacov, Henson and their collaborators was successfully disseminated and picked up by other researchers. This was partly the aim of the organisers of the March–April workshop in asking Henson and Berenstein to prepare a tutorial on Henson's 'logic for metric structures'. Henson's logic and various related generalisations of classical first order model theory have now been unified in an attractive framework: continuous logic for metric structures. New research projects were initiated, including connections between the continuous model theory of probability spaces and the Macpherson–Steinhorn 'measurable' supersimple structures.

o-minimality

The broad topic of *o*-minimality, namely ordered structures with good topological behaviour of definable sets, was in evidence throughout the programme. A striking success was that a conjecture of Pillay relating groups definable in saturated *o*-minimal structures to compact Lie groups via an intrinsic 'standard part map' was proved by Hrushovski, Peterzil and Pillay early in the programme, and further conjectures and results around a new notion of 'compact domination' were developed later. Early in the programme Wilkie obtained an important representation theorem for definable sets in arbitrary *o*-minimal expansions of real closed fields, generalising work of Yomdin and Gromov, and, with Pila, applied his theorem to *o*-minimal diophantine questions. The theorem was also used in parts of the Hrushovski–Peterzil–Pillay work mentioned above. Lipshitz and Robinson presented a new *o*-minimal structure in the second July workshop, and their construction was almost immediately used by Hrushovski and Peterzil to solve negatively an outstanding open question of van den Dries in the general theory of *o*-minimality. Moosa, Speissegger and Starchenko made new connections between *o*-minimality and compact complex manifolds, by characterising the compactness of an irreducible component of the space of cycles of a compact complex space in terms of uniform definability in *o*-minimal expansions of $\mathbb{R}_{\text{an}}$. The presence of the real geometer Jean-Philippe Rolin for various periods of time, and his collaborations with Salma Kuhlmann, Speissegger and others, were also very important for this aspect of our programme.

Motivic Integration

Some of the main players in motivic integration, such as Loeser and Cluckers, were present during various parts of the programme. While at the Newton Institute, Hrushovski completed the writing of a major paper (with Kazhdan) on the topic. This paper gives an alternative 'geometric' approach to that of Denef–Loeser, and is likely to have a big impact.

Groups of Finite Morley Rank

The tightly-knit group of researchers working on the conjecture that simple groups of finite Morley rank are algebraic groups made tremendous advances during their time at the Institute. So-called 'degenerate type' groups, those with no infinite 2-Sylow subgroups, present a potential

source of counterexamples. A collaborative effort involving Borovik, Burdges and Cherlin led to a proof that degenerate-type groups of finite Morley rank have no involutions, a result with substantial impact on the overall project.

In a somewhat separate development, Hrushovski and Wagner proved a striking model-theoretic result on counting and dimensions with applications to counting the number of points in intersections of subvarieties of simple algebraic groups with finite subgroups, as well as counting the number of 'rational' points of definable subsets of 'bad fields'.

Number Theory and Geometry

Long- and short-stay visits by D Bertrand, Bost, M Kim, Pink, Poonen, Roessler and MF Singer had a big impact on the programme. Bertrand and Pink discovered the connections between Zilber's conjecture on intersections in tori (related to his study of the complex exponential function), recent conjectures and work of Bombieri–Masser–Zannier, and generalisations of the André–Oort conjecture. In fact, Pink reported on these connections in his talk in the second July workshop. Influenced by discussions with Bertrand and Bost, Pillay proved that the nonlinear version of the Grothendieck–Katz conjecture can be reduced to the linear version modulo a conjecture around 'nonorthogonality to the constants' in the model theory of differential fields. The 'elliptic Schanuel conjecture' emerged as another common theme, and discussions with Bertrand impacted upon the work of Jonathan Kirby, a graduate student from Oxford who is now extending his Ax-theorems for the Weierstrass function to the case of elliptic curves with non-constant j-invariant. Through discussions with Singer, Chatzidakis found a unification of the two different treatments of difference Galois theory.

Model Theory and Noncommutative Geometry

There were considerable discussions around the connections between model-theoretic constructions and examples on the one hand, and noncommutative geometry on the other. These speculations, fuelled originally by Zilber, grabbed the imagination of many participants and visitors. David Evans was able to answer some of Zilber's

S Wilkinson

Participants at the workshop on 'Pure Model Theory'

concrete questions related to definability in some of these 'noncommutative geometric objects' such as the Heisenberg group and Hrushovski's non-algebraic 2-cover of the projective line. Zilber himself completed a long paper on noncommutative geometry and new stable structures.

Other Results

We would like to mention a couple of additional beautiful and surprising results which were proved during the programme. Both relate to studying the expressive power of first order logic when ranging over objects with some finite nature (finitely generated fields and finite groups respectively). Bjorn Poonen proved that (i) there is a first order sentence separating the class of finitely generated fields of characteristic zero from the class of all fields of positive characteristic, and (ii) for each n the property that n elements are algebraically independent over the prime field is first order definable within the class of all finitely generated fields.

JS Wilson proved that there is a first order sentence σ in the language of groups such that, for any finite group G, σ holds of G if and only if G is soluble.

Publications

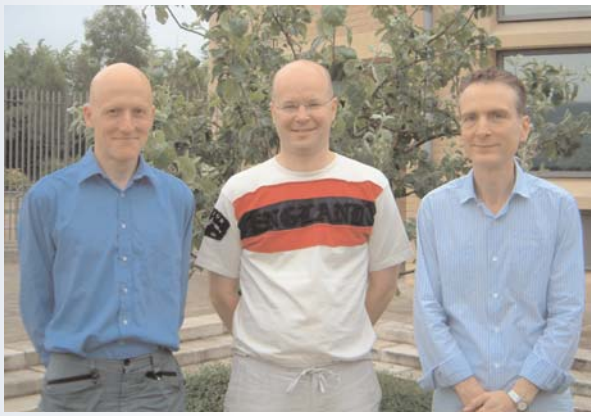
The four organisers will be the editors of a volume (probably, in fact, two volumes, and probably published by Cambridge University Press) based on the programme. This will not be a Proceedings volume, but rather an attempt to reflect the most important current activity in the field through about 20–25 commissioned articles by participants. Most of these will be related to seminars given at the Newton Institute, and some will be survey articles.

Developments in Quantitative Finance

24 January to 22 July 2005

Report from the Organisers:
D Duffie (Stanford), DG Hobson (Bath), LCG Rogers (Cambridge) and JA Scheinkman (Princeton)

S Wilkinson



Left to right: LCG Rogers, DG Hobson and JA Scheinkman

Scientific Background

Mathematical finance sprang to life in the early 1970s with the development of the now-legendary Black–Scholes–Merton option pricing formula. This formula was quickly extended by Ross, Harrison, Kreps, Pliska and others into a general theory for the pricing of options; these authors showed that the fair price of an option is the expected discounted payoff of the option, where the expectation is taken not with respect to original probability measure, but rather with respect to an equivalent martingale measure under which the discounted price process is a martingale.

Although the theory is based on stochastic models, and there are immediate applications of statistical inference and data analysis, part of the explanation for the rapid growth of financial mathematics is that the field provides fertile grounds for collaboration between researchers with different backgrounds: numerical analysis and computational methods are required to calculate specific answers; functional analysis and the general theory of stochastic process have combined to give exact conditions for the fundamental theorems; and convex analysis is used to investigate difficult constrained investment problems via the dual functions.

In 1995 the Newton Institute hosted a programme entitled *Financial Mathematics*. After a gap of a decade, in which new problems of interest such as securitisation, credit derivatives, risk measures and model uncertainty have come to the fore, the subject was ripe for a further programme, which aimed to give the same impetus to the field as the earlier meeting.

Structure of the Programme

The six-month programme attracted an extremely large number of participants. There were 47 long-stay participants, including 17 from the UK, and a further 154 short-stay participants, including 64 from the UK. In addition there were almost as many further visitors, from both the finance industry and academia, who attended one of the industry days or workshops.

In addition to two large workshops (one in April held as a satellite meeting at the ICMS in Edinburgh, the second a larger event in July) the programme held a series of themed events, often of a week in duration. The purpose of these weeks was to gather in one place a group of researchers with interests in a particular field of financial mathematics, and for those people to engage with the longer-stay participants and other interested parties to hold a mini-workshop. Typically these events were relatively unstructured, which gave them a spontaneous feel and provided the perfect forum for free discussion and the presentation of the most recent but not necessarily most polished results. Organisation of these themes and the decisions over whom to invite were delegated to a distinguished figure in the relevant field.

Between the themed events the programme was quiet, but only in a relative sense. There were still

often 20 scientists in residence and 4 or 5 seminars per week, but talks ranged over a wider range of subjects and there was greater opportunity for prolonged discussions. All long- and short-stay participants were allowed the opportunity to give presentations or seminars on their latest research. In most cases these were organised to take place soon after arrival, so that the seminar could act as an introduction to the other participants.

The programme also combined with interested parties in the Centre for Mathematical Sciences, the Judge Business School and the Faculty of Economics at the University of Cambridge to hold a weekly Tuesday seminar in the late afternoon. Benoit Mandelbrot spoke on *Fractal and Multi-Fractal Finance*. The Tuesday seminar was a prelude to regular informal social events.

The Rothschild Professor, Stan Pliska, gave a seminar entitled *Portfolio Optimisation: The Quest for Useful Mathematics*.

M Kabanova

Anna Pavlova during her seminar

Themed Events and Workshops

Continuous Time Processes based on Infinite Activity Innovations

Themed Week, 31 January–4 February 2005

Organisers: O Barndorff-Nielsen and N Shephard

It has long been recognised that whilst the classical Brownian models for asset prices postulate continuous price processes, in reality market prices exhibit jumps. One of the simplest classes of models that address this phenomenon is the class of Lévy models. This themed week was concerned with recent advances in the field and especially the problems of inference for price processes based on infinite activity Lévy models, and on models in which the underlying process has a mean-reverting volatility with innovations driven by a subordinator.

Credit

Themed Fortnight, 21 February–4 March 2005

Organiser: M Davis

Following the financial collapse of several major companies, and the downgrading of debt ratings for several others, credit and credit risk remain major problems of interest in both financial markets and academia. This was reflected both in the fact that this themed event on credit extended to two weeks (including an industry workshop: see page 42) and in that a further day of talks was organised by Bielecki, Jeanblanc and Rutkowski later in the programme on 29 June. The literature in credit is roughly divided between structural and reduced form models and the latest research on both these topics was presented. A major issue is how to model joint and correlated defaults, whether via a copula or by introducing a correlation into the stochastic processes that drive the individual securities. The continued growth of the credit market and the introduction of innovative products such as *CDO*s and CDO^2s mean that new challenges involve modelling portfolios of credit-based securities with option-like payoffs. New approaches, including drawing a parallel between sequences of defaults and arrivals in queues, were presented.

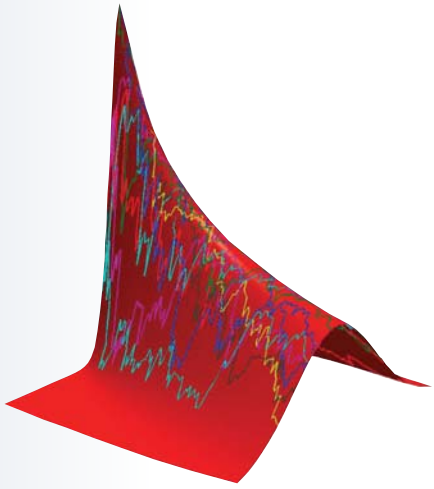
Risk Management

Themed Week, 7–11 March 2005

Organisers: P Artzner and P Embrechts

This themed week was concerned with risk measurement and management, including the problems of model uncertainty. The recently introduced concepts of coherent and convex risk measures played a prominent role in the week, along with good-deal bounds.

On Thursday 10 March, as part of this theme week, the programme held an LMS Spitalfields Day entitled *Risk Management of Hedge Funds*, which covered what they are, how to model them and their risks, and how they behave when they



The transition density of a drifting Brownian motion, superimposed with some typical sample paths

face extreme events. The day attracted a large number of PhD students and other visitors.

International Finance

Themed Days, 14–15 March 2005

Organiser: R Uppal

Most of the participants who were present specifically for this theme were from finance or economics departments. Nonetheless, the most striking difference between this workshop and other parts of the programme was in the type of question that was under consideration rather than in the mathematical technologies and tools that were utilised. Indeed, the approach was generally to attempt to solve problems in full equilibrium, and to use fundamental economic variables to derive the prices of goods and securities in many countries simultaneously, rather than to take the more traditional approach in mathematical finance which is to work in a partial equilibrium model in which prices are modelled exogenously. Many challenging problems on the existence of equilibria were posed for the mathematicians.

The Interface between Quantitative Finance and Insurance

Satellite Workshop at ICMS, 4–8 April 2005

Organiser: A Cairns, with C Kluppelberg, S Pitts and LCG Rogers

This workshop, supported by Watson Wyatt, considered research at the interface between insurance, pensions and quantitative finance. In addition to their insurance risks, insurance companies face economic and financial risks, which have traditionally been the remit of more mainstream finance. One of the tasks facing the actuarial industry is to incorporate the advances in modelling and understanding which have been achieved in financial mathematics. In return, the securitisation of insurance risk throws up new challenges for the financial mathematician. By bringing together researchers from the relevant disciplines this workshop achieved significant progress in opening a dialogue on these issues.

Fundamentals

Themed Week, 25–29 April 2005

Organiser: W Schachermayer

This week was concerned with the fundamental properties of option prices and consumption/investment problems in a general financial market model. The main topics of interest were risk measures, the problems of optimal risk sharing and definition of risk measures in a dynamic context; and marginal utility based pricing, the link with minimal distance martingale measures and the sensitivity and convergence properties of such prices.

Computational Finance

Themed Week, 9–13 May 2005

Organisers: M Broadie and P Glasserman

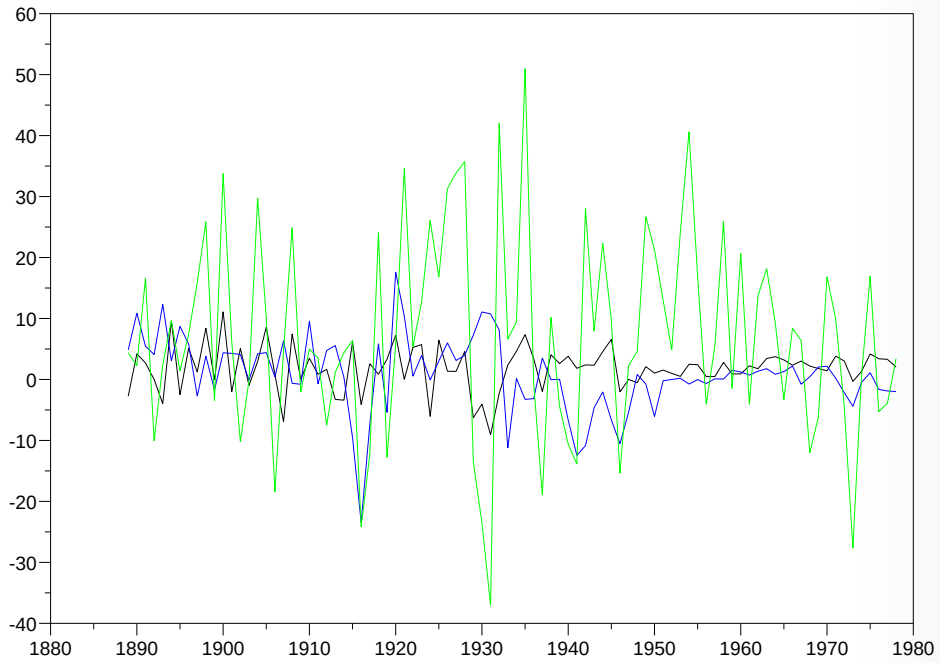
A long-standing problem in financial mathematics is to determine the optimal exercise boundary for an American put option, and this week reported on the latest advances in this style of problem, together with the problems associated with efficient evaluation of option prices under stochastic volatility models and bounds on the prices of volatility options and variance swaps.

Monte Carlo Methods

Themed Week, 16–20 May 2005

Organiser: N Touzi

Monte Carlo methods have undergone a recent renaissance in financial mathematics. This followed both from the discovery that the solution of a dual problem allows the American option pricing problem to be recast in such a way as to be amenable to Monte Carlo methods, and from the recent advances in Malliavan calculus which mean that Monte Carlo techniques can be used as a robust method to determine delta-hedging ratios.



The dataset used by Mehra & Prescott in their celebrated 1985 paper on what has come to be known as the equity premium puzzle, showing consumption growth (black), the return on riskless securities (blue) and the return on the S&P500 (green)

Beauty Contests in Finance

Themed Days, 23–24 May 2005

Organisers: N Kiyotaki and H Shin

Here the use of the phrase 'Beauty Contests' alludes to a quotation from Keynes, and refers to the fact that in deciding on optimal behaviour agents need to consider how their behaviour will influence the actions of others, and how the behaviour of others should influence their own actions. This can continue in an infinite cycle leading to challenging problems relating to the existence and form of equilibria, and more generally to problems involving agent interaction. These two themed days were held in conjunction with the Cambridge Endowment for Research in Finance.

Econometrics

Themed Week, 13–17 June 2005

Organisers: L Hansen and JA Scheinkman

The problems of statistical inference for financial time series can be extremely complicated not least because the data often show non-stationarity. This week reported on some of the latest advances in volatility modelling, the analysis of time series and high-frequency data, and how inference can be improved with the use of moment estimates derived from continuous time models. The week also provided the opportunity for several of the participants to continue their collaborations on eigenvalues and principal components in volatility modelling.

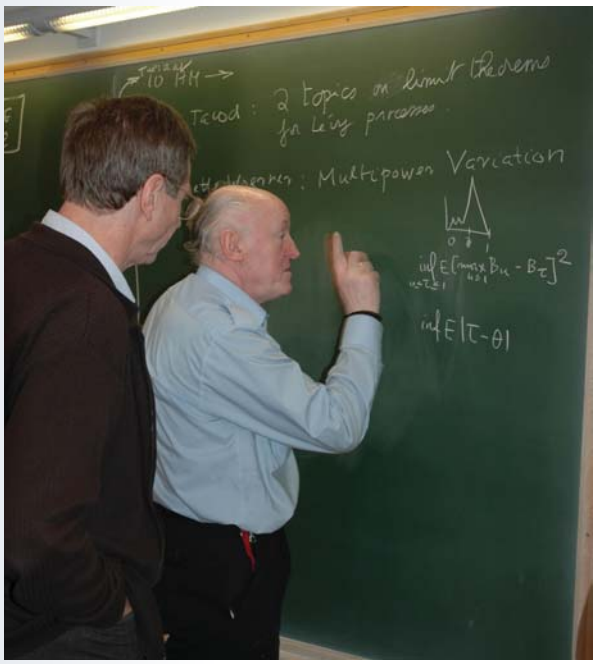
Quantitative Finance: Developments, Applications and Problems

Workshop, 4–8 July 2005

Organiser: V Henderson, with DG Hobson, S Pliska and LCG Rogers

The objective of this conference, which was supported by Nomura International and the EC, was to bring together academics from various fields, including mathematics, economics and finance, as well as City professionals, to discuss the latest developments in the theory of mathematical finance and the application of this theory to current problems facing the industry; and to identify the substantive problems facing academic researchers and practitioners. With 25 speakers and over 100 delegates, the workshop was able to summarise many of the themes and developments of the programme as a whole. Major themes that were well represented included credit and credit derivatives, utility indifference pricing and martingale measures, optimal stopping and hedging, and

M Kabanova



Albert Shiryaev at the board with a colleague during the 'Developments in Quantitative Finance' programme

volatility modelling. The final talk of the meeting was given by Steve Ross, mentioned above as one of the founders of Arbitrage Pricing Theory and mathematical finance, who spoke on behavioural finance and the implications and lessons to be learned from this topic by researchers in other branches of finance.

Industry Events

In addition to the above themed events, and with the support of BNP Paribas, we ran four industry events organised by M Musiela:

- *Credit*, 25–26 February 2005
- *Interest Rates*, 18 March 2005
- *Modelling Philosophy*, 22 April 2005
- *Volatility*, 13–14 May 2005

These 1- or 2-day events, with 5–8 speakers per day divided between industry and academia, had audiences of 60–100 delegates made up of long-stay participants on the programme, practitioners and other interested researchers including large numbers of PhD students. These meetings had a more practical focus than the other themed events. Speakers from the City raised important issues and proposed some solutions, and academics reported some of their research in related areas.

The *Credit* and *Volatility* events were especially successful and well received by the participants.

Outcome and Achievements

Without exception the participants on the programme found that the Isaac Newton Institute provided an excellent environment for research with ideal facilities augmented by efficient and effective administrative support. The thanks of the programme organisers are also given to the theme organisers, each of whom gathered together an outstanding group of senior and younger researchers in order to work on topics in their field.

The chance to visit the Newton Institute provided many researchers with the opportunity both to extend existing collaborations and to develop new ones. Short-stay participants and visitors during themed weeks were able to meet co-workers in the same specialism. Long-stay participants were able to take a more holistic view, and those fortunate enough to be able to spend the entire programme at the Institute saw as full a spectrum of problems and approaches as could be realised in six months.

The main themes of the programme, and the main achievements in terms of publications, preprints and collaborations, only became apparent as the programme progressed. In the event the topics of greatest interest included option pricing and portfolio optimisation in incomplete markets, real options and endogenous exercise, full equilibrium models and dynamic risk measures. Credit risk modelling was another important theme, and the presence of many of the world's experts at the Institute, both in February and again in June, led to several fruitful interactions.

Finally, thanks are also due to BNP Paribas and Nomura International, who gave unconstrained financial support to the programme over and above that provided by the Institute's regular financial supporters. This extra support was used in part to augment the already distinguished list of speakers at the programme, and in part to support PhD students and other junior visitors.

Finances

Accounts for August 2004 to July 2005 (Institute Year 13)

	2003/2004 Year 12 £'000 (restated[1])	2004/2005 Year 13 £'000
Income		
Grant Income – Revenue[2]	1,003	925
Grant Income – Workshop[3]	254	223
Grant from the University of Cambridge	181	183
NM Rothschild and Sons Trust Funds[4]	132	107
Investment Income	105	118
Donations, Reimbursements and Other Income[5]	24	20
Total Income	**1,699**	**1,576**
Expenditure		
Scientific Salaries[6]	323	375
Scientific Travel and Subsistence[7]	447	410
Scientific Workshop Expenditure[3]	209	163
Other Scientific Costs[8]	16	21
Staff Costs	330	348
Net Housing Costs[9]	63	28
Computing Costs	40	41
Library Costs	9	11
Building – Repair and Maintenance	11	10
Estates and Indirect Costs[1]	250	250
Consumables	22	24
Equipment – Capital[10]	45	18
Equipment – Repair and Maintenance	4	4
Publicity	3	5
Recruitment Costs	4	2
Total Expenditure	**1,776**	**1,710**
Surplus / (Deficit)	**(77)**	**(134)**

Notes to the Accounts

1. Restatement of Accounts
The Institute's estates and other indirect costs have been recalculated following the University's standard costing methodology. The comparative figures for 2003/2004 have been restated accordingly.

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

	2003/2004 Year 12 £'000 (restated)	2004/2005 Year 13 £'000
EPSRC/PPARC Salaries	324	431
EPSRC/PPARC Travel and Subsistence	330	318
Trinity College (Isaac Newton Trust)	100	50
Hewlett-Packard	115	0
PF Charitable Trust	21	22
Le Centre Nationale de la Recherche Scientifique	13	0
Leverhulme Trust	78	77
London Mathematical Society	20	25
Cambridge Philosophical Society	2	2
Total	**1,003**	**925**

3. Grant Income – Workshop
Both income and expenditure on workshops were lower in 2004/2005 than in the previous year owing to reduced workshop activity.

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

Rothschild Visiting Professorships (drawdown)	21	30
Rothschild Mathematical Sciences (income)	111	77
Total	**132**	**107**

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

5. Donations, Reimbursements and Other Income
The figure for 2004/2005 includes additional sponsorship received from the National Science Foundation (USA), Nomura Bank and BNP Paribas, as well as the net income received from publications and the sale of merchandise.

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

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

8. Other Scientific Costs

This includes costs relating to meetings of the Institute's committees, Institute Correspondents' expenses, programme organisers' expenses and entertainment. The figure for 2004/2005 is higher than the previous year's owing to industry events and other non-workshop activities during the programme *Developments in Quantitative Finance*.

9. Net Housing Costs

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

	2003/2004 Year 12 £'000 (restated)	**2004/2005 Year 13 £'000**
Income	202	301
Expenditure	265	329
Total	**(63)**	**(28)**

10. Equipment – Capital

The major costs in 2004/2005 under this heading were for the purchase of a new photocopier, a franking machine and furniture.

Cumulative Financial Grants and Donations

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	
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	£15k	
Wellcome Trust	£15k	
Benfield Greig	£10k	
Unilever	£10k	
Applied Probability Trust	£10k	over 3 years