Contents

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/0102/appendices.html**

1   Long-Stay Participants
2   Chart of Visits of Long-Stay Participants
3   Junior Members of the Newton Institute
4   Nationality and Country of Residence of Participants
5   Cumulative Frequency Graph of Ages
6   Preprints Produced by Participants
7   Papers Produced or in Preparation by Participants
8   Seminars and Lectures
9   Seminars Given Outside the Institute

Director's Report

This report covers the last three months of Keith Moffatt's Directorship as well as the first nine months of mine, and it therefore gives the opportunity to put on record how successful Keith's stewardship has been over the eventful five years of his reign. He has guided the choice of exciting and successful research programmes, ensured that the Institute provided a hospitable and stimulating environment for the scientists who came from all over the world, and secured benefactions of remarkable generosity including the endowment of the N.M. Rothschild & Sons Professorship which future Directors will hold.

Coming from outside Cambridge to succeed him, I am very conscious of the high standards he has set, and of the contribution that the Newton Institute can and must make to the whole UK mathematical community. I have started a series of visits as Director to the important centres of mathematical research throughout the land, to get feedback on the strategy and programmes of the Institute. So far I have had stimulating discussions in London (Queen Mary), Oxford and York, and I hope in time to cover the whole UK.

On 2 July 2002 we will celebrate the tenth anniversary of the formal inauguration of the Institute, with a day of mathematical presentations including my inaugural lecture on *Mathematics for the Twenty-First Century*. We will be delighted to welcome on that occasion Sir Evelyn and Lady de Rothschild, as well as our Honorary Fellow Dill Faulkes, whose generous gift of the Faulkes Gatehouse was recorded last year. The Institute could not have achieved what it has without the help of individuals and organisations, inside and outside Cambridge, who have given us a degree of independence and long term stability on which to base forward-looking scientific plans.
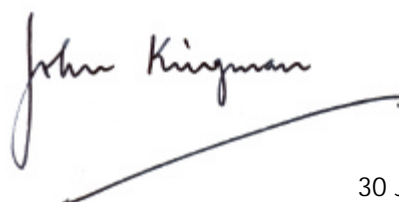
It would not however be realistic to expect such generosity to render unnecessary the support we rely on from the research councils, especially the Engineering and Physical Sciences Research Council. The EPSRC has assured us of continuing backing, so long as we maintain the very high scientific quality of our programmes, and has exercised a wise and light touch on the way we spend their money.

The resulting programmes, up to mid-2002, are described in the pages that follow. But we have to plan about three years ahead, and the programmes into early 2005 have already been arranged. We have a very promising mixture of mathematics and applications, both traditional and novel. The Institute relies on the proposals that are put to it by potential organisers, and I have been impressed with the thought and care that goes into the best of these. The Scientific Steering Committee is always on the lookout for new ideas, and if the reader is inspired by this report to put in a new suggestion, this will be welcome.

The key to a successful programme is to attract the key workers in the field to spend a substantial period in Cambridge taking an active part in the programme. Fortunately there are now enough people who have enjoyed a visit to the Institute, and who encourage their friends and colleagues to respond positively to an invitation to do likewise. Satisfied customers bring in new business.

One reason they are pleased with their stay with us is the warm welcome they receive from the support staff of the Institute. I have inherited from my predecessor a group of staff who are deeply committed to making the place work, by meeting with quiet efficiency the diverse needs of the visitors. It is a pleasure to place on record my gratitude to them all for the work they do, their tolerance of mathematical eccentricity, and the friendly atmosphere they create.

John Kingman

30 June 2002

Brief Scientific Report on Programmes

For full scientific reports see pages 17 to 47.

Programme 41: Managing Uncertainty - New Analysis Tools for Insurance, Economics and Finance

Corporations and governments are making risk decisions based on perceptions of extreme values. Frequently these decisions are taken with an inadequate framework for handling low probability, high severity events drawn from nonstationary time series. This short programme brought together mathematicians, statisticians, economists and environmental scientists who specialise in the analysis of financial and environmental data. Particular attention was paid to mathematical models and statistical prediction tools for extreme events, and for handling nonstationarity.

A series of open one-day workshops, concentrating on new techniques and their applications, provided interactions with the wider academic, financial, insurance and governmental communities. The programme as a whole was a follow-up to two workshops on extreme events held during the *Nonlinear and Nonstationary Signal Processing* programme held at the Newton Institute from July to December 1998. One particular success of the programme was the adoption by Railway Safety of a new method for analysing Signals Passed At Danger (SPADs).

Programme 42: Surface Water Waves

For this programme, the organisers identified two main areas of fundamental importance to water waves that build on results of the twentieth century and pose great theoretical challenges into the next century. The topics are nonlinear three-dimensional waves, and interactions of wind, waves and turbulence. Firstly, with multi-scale resolution now possible using the latest computers, there is potential for significant advances in the semi-analytical and numerical aspects of 3D waves, including both prediction and study of qualitative aspects that heretofore have not even been predicted. Secondly, recent developments in the mathematical theory of nonlinear and breaking waves and of the unsteady critical layer effects when the wind drives waves have pointed the way to a new body of theory for wind–wave interaction. Experimental data is beginning to be available to discriminate between and contribute to the conflicting theories.

One of the most interesting outcomes of the programme was the enthusiastic interaction between researchers working primarily on physical aspects of water wave theory and those working on strictly theoretical constructs. Another disciplinary divide which was opened up is the statistical viewpoint versus the deterministic viewpoint. The bipolar – three-dimensionality and wave-interaction – starting point of the programme rapidly developed into a list of five areas identified for future emphasis.

Programme 43: Integrable Systems

Relatively sizable classes of nonlinear systems posess the property of integrability. Integrable systems have a rich mathematical structure, which means that many interesting exact solutions to PDEs can be found. Now that the properties of most of the "standard" physical models (KdV, sine-Gordon, nonlinear Schrödinger, etc.) exhibiting integrable behaviour are known, interest has shifted to more abstract mathematical questions, and to the remarkable connections between integrable system theory and many other core areas of mathematics: for example algebraic geometry, differential geometry, group theory, invariant theory, spectral theory, etc. For a given PDE or discrete system, there is a variety of partially understood methods to determine the integrability or otherwise of the system. We would like to understand these methods better, to understand the deep links that must lie between them, and to fully classify all integrable systems in some sense.

Although it would be false to claim that the field has now been completely unified and clarified after the meeting, much progress was made during the programme, and a large number of new collaborations were started which will bear fruit over the next few years.

Programme 44: From Individual to Collective Behaviour in Biological Systems

In the last thirty years there has been an enormous increase in our knowledge of biological processes, especially at the molecular and cellular level, but understanding the behaviour of individual enzymes, cells or organisms in isolation is only a first step towards understanding the collective behaviour of a population of such individuals. Incorporating individual aspects of behaviour into macroscopic descriptions of population behaviour is a challenging problem, even if only deterministic aspects are considered.

The first half of the programme focussed on developmental biology and physiology. A notable aspect of this component of the programme was the strong and deep interaction between theoreticians and experimentalists on the fundamental questions from both perspectives. The work here also highlighted many questions relating to stromal cell development and organisation and the aggregation and pattern formation behaviour of *Dictyostelium*.

The second half of the programme was devoted to spatial ecology, immunology and epidemiology. One significant outcome of discussions in these areas was the realisation that the mathematical models developed in one area are often similar to those in another area (e.g., compare immunology and epidemiology). Ideas on stochastic modelling and reinforced random walks opened up a number of novel ways in which phenomena at the cell level may be scaled up to the population level.

Programme 45: Higher Dimensional Complex Geometry

Algebraic geometry is the geometrical study of solutions of systems of polynomial equations. This programme was centred around 3-folds, that is, solution sets of 3 dimensions. The subject of 3-folds has received much attention in the past 20 years because of significant progress in the classification program. The aim is to classify solution sets into three broad classes of geometry: positive, zero and negative curvature. It is only in the past 20 years that a general picture has emerged in the context of higher-dimensional algebraic geometry. The main features of this picture have been established for 3-folds but remain conjectural for higher dimensional algebraic varieties.

In 1999, Shokurov announced a proof of 4-fold flips, one of the main steps in the extension of classification to 4-folds. During the programme, this document was studied in detail. An immediate outcome has been Corti's simplified proof of 3-fold flips following Shokurov's ideas. One of the most active areas at present is the study of derived categories on Calabi–Yau manifolds. This has received a great deal of impetus from physics.

It seems likely that new ideas on stability conditions on derived categories will provide some exciting new methods in mirrow symmetry and the study of derived categories.

Programme 46: M-Theory

To find a quantum theory of gravity and to find a unified theory of all the forces and particles of nature are the two main goals of current work in fundamental physics, and it is remarkable that string theory has the possibility of solving both problems simultaneously. There are five distinct superstring theories, all giving quantum theories of gravity. Discoveries in the mid-90's led to the conclusion that all five arise as different limits of a single theory, which has come to be known as M-theory.

However, much of M-theory remains a mystery. The principal aim of this programme was to investigate its structure, seeking clues as to its fundamental formulation and unravelling its physical consequences.

The programme, and in particular the month-long workshop sponsored by the Clay Mathematics Institute, was an international event of high significance for the field. For the duration of the programme, Cambridge was the international focal point for string theory.

Programme Participation

A total of 1154 visitors was recorded for 2001/2002. This includes 320 long-stay participants, each staying between two weeks and six months (6 weeks on average), and 297 short-stay participants who stayed for two weeks or less. Within the six completed programmes there was a total of 26 workshops (periods of intense activity on specialised topics) which attracted a further 419 visitors to the Institute. There were many others who attended informally at lectures, workshops, Institute Seminars or other events. Within all the programmes, workshops and other activities, around 884 seminars were given in total at the Institute during the year.

In addition to workshops, which serve to widen UK participation in programmes, programme organisers are encouraged to organise more informal special days, short meetings or intensive lecture series which can attract daily or short-term visitors, so further opening the activities of the Institute to the UK mathematical community.

The Institute also funds visits by programme participants to other UK institutions to give seminars, and 154 such seminars took place last year.

Programme	Long-stay participants	Mean stay (days)	Short-stay participants	Mean stay (days)
Managing Uncertainty	23	15	68	2
Surface Water Waves	20	21	46	6
Integrable Systems	55	59	72	9
From Individual to Collective Behaviour in Biological Systems	40	55	65	6
Higher Dimensional Complex Geometry	74	81	29	10
M-Theory	108	32	17	23
Totals 2001/2002	**320**	**49**	**297**	**7**

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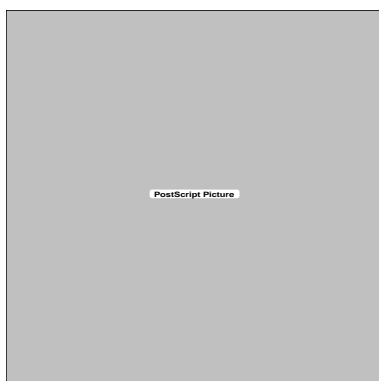
Long-stay participants
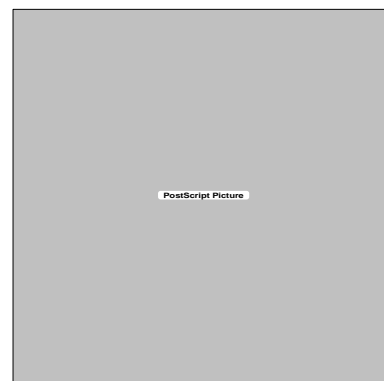
Short-stay and workshop participants

The following chart summarises the total figures for long- and short-stay participation since the Institute began:
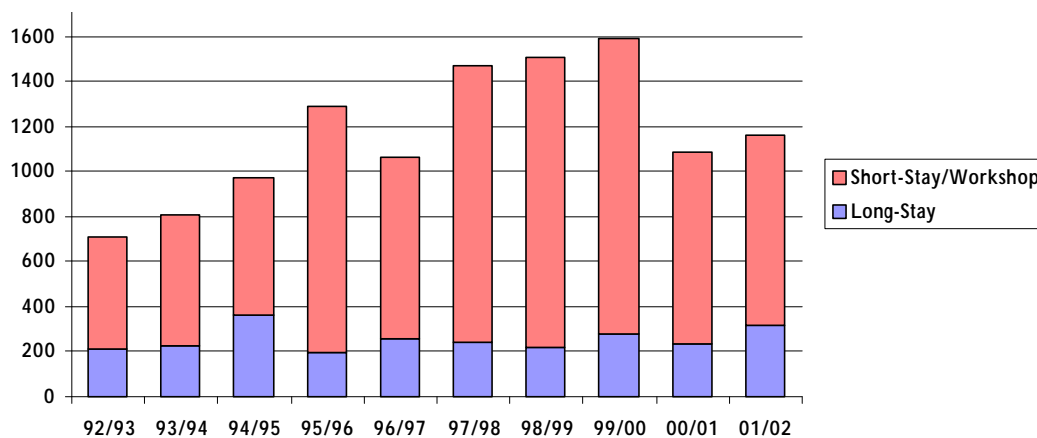
The following chart summarises the total number of person-days for long- and short-stay participants combined:
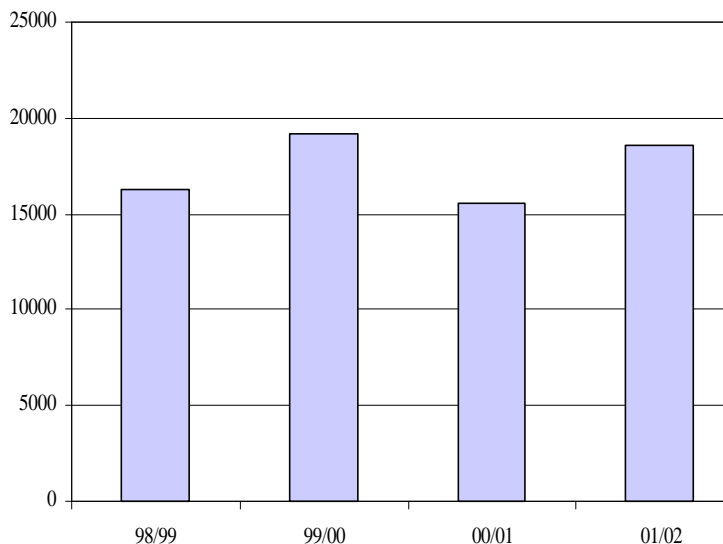
The median age for long- and short-stay participants combined in 2001/2002 is 36 years, with an interquartile range of 29–47 years. The following chart shows the cumulative frequency of participant ages.
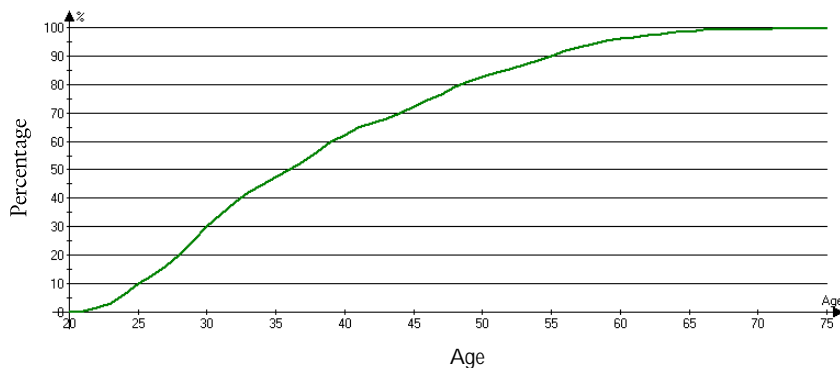
More detailed statistics, including visit dates and home institutions of participants, and a complete list of seminars and papers, are given in the Appendices, available separately from the Institute or at

http://www.newton.cam.ac.uk/reports/0102/appendices.html

National Advisory Board and UK Mathematics

Membership of the National Advisory Board as at 30 June 2002:

Professor AFM Smith FRS (Chair)	Queen Mary, University of London
Professor Sir John Kingman FRS	Director, Newton Institute
Dr RE Hunt	Deputy Director, Newton Institute
Professor Sir Michael Berry FRS	University of Bristol
Professor J Brindley	University of Leeds
Professor KA Brown	University of Glasgow
Professor EB Davies FRS	Kings College London
Professor PJ Diggle	University of Lancaster
Professor CM Elliott	University of Sussex
Professor EG Rees	University of Edinburgh
Dr M Sheppard	Schlumberger Cambridge Research Ltd
Professor JR Whiteman	Brunel University

National Advisory Board

Following discussions with EPSRC, a National Advisory Board (NAB) for the Institute was established during 1999, and has now met four times.

The remit of the NAB is "To advise the Director in all matters relating to the role of the Newton Institute as a National Institute for the Mathematical Sciences."

The membership, as at 30 June 2002, 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 have been:

- The attendance of young UK scientists
- The Institute's strategy vis-à-vis its national role, interdisciplinarity and outreach
- Flexibility in the scientific programming to respond to new developments
- The interests of the EPSRC programmes which contribute to the Institute
- A focus on the Institute's databases to enable it to produce information on subject coverage, the geographical distribution of participants and the status of participants
- The Institute's mode of interface with industry

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

Symposia Activities

The Institute continues to maintain a list of forthcoming UK symposia, workshops, etc., in the Mathematical Sciences. This list is maintained in consultation with representatives of LMS, IMA, RSS, ICMS (Edinburgh) and the Warwick Mathematics Research Centre. For details, see **http://www.newton.cam.ac.uk/symposia.html**

UK correspondents

During 2000/01, at the suggestion of the National Advisory Board, the Newton Institute established a list of UK University correspondents who act as a channel of communication between the Newton Institute and the mathematical sciences community of the Universities concerned. Correspondents are regularly informed about activities of the Institute, and it is their responsibility to ensure that the information is disseminated to the relevant University Departments, and also to provide any feedback to the Institute. The names of the correspondents so far established can be found on the Institute website at

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

Universities not yet represented on this list are encouraged to provide a suitable nominee.

Satellite Workshops

The Institute encourages organisers of longer (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-term 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.

Costs for satellite workshops are typically approximately £10,000 (excluding the overseas travel costs of Institute participants) and are shared approximately 50/50 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). We are grateful that LMS in particular has expressed a willingness to half-fund up to two such workshops a year.

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

Seminars

Long-term participants in Newton Institute programmes are strongly encouraged to visit other UK institutions during their stay at the Institute, and many did so during 2001/2002 (see p 4). To promote this activity, the Institute covers on request the travel costs within the UK for any overseas participant.

The Institute has recently 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 find this useful when planning their schedule of speakers. The register can be found at

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

Institute Seminars

The regular series of Institute Seminars, held on Mondays during term-time, is intended to be of general interest and to attract a wide range of mathematical scientists. Audio files of Institute Seminars, with accompanying transparencies and stills, are published on the web at

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

This year's seminars were

- M Kruskal (Rutgers), *An Elementary Perspective on Axiom Systems, in General and for Euclid in Particular*

- H Othmer (Minnesota), *Mathematical and Computational Challenges Posed by Models of Biological Systems*

- D Rand (Warwick), *How the Immune System Uses Mathematics to Recognise Invading Pathogens*

- V Zakharov (Landau), *The Theory of Integrable Systems Applied to the Classical Problems of Differential Geometry: N-Orthogonal Co-ordinate Systems and Spaces of Diagonal Curvature*

- M Mustata (Clay), *An Introduction to Spaces of Arcs in the Study of Singularities*

- S Mukai (Kyoto), *Invariant Theory and Moduli: from Cayley, Nagata to the Verlinde Formula*

- G Gibbons (Cambridge), *Geometry, Gravity and M-Theory*

- R Dijkgraaf (Amsterdam), *Complex Geometry and String Theory*

- M Reid (Warwick), *Update on 3-Folds*

- K Wendland (North Carolina), *A Hiker's View of K3: Geometric Aspects of Conformal Field Theory*

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 EMS acts as an intermediary between mathematicians and those in charge of politics and funds in Brussels; the membership consists of about 50 mathematical societies throughout Europe and around 2000 individual members who have joined through their national societies.

The current Director of the Newton Institute, Sir John Kingman, became President-Elect of the EMS in May 2002. His term of office as President will run from January 2003 to December 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 which have a substantial visitor research programme in the mathematical sciences. ERCOM was founded in 1997 and meets annually. The current chair is Prof M Castellet of the Centre de Recerca Matemàtica in Barcelona. 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 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 contribute to the visibility of the EMS
- to cultivate contacts with similar research centres within and outside Europe

ERCOM is particularly concerned at present with the EC's Framework programme 6, and is making representations to ensure that the underpinning importance of mathematics to every one of the seven thematic priorities of the Programme is recognised. It is also addressing the general problem of raising the profile of mathematics with MEPs in individual countries.

The most recent meeting of ERCOM was held at the Stefan Banach International Mathematical Center in Warsaw, Poland, in March 2002; the next will be held in Vienna in March 2003.

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 at least 18 months in a foreign country and between 6 and 18 months at one of the EPDI institutes. Competition is strong and the scientific quality is high. British applicants, who are currently under-represented, are particularly encouraged.

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

Other Institute News

Fellowship of the Institute

Dr Dill Faulkes was elected an Honorary Fellow of the Newton Institute on 20 September 2001. A programme of talks in Dr Faulkes' honour on the topic of Geometry and Fluid Flow was followed by the official opening of the Faulkes Gatehouse. (See last year's *Annual Report* for more information about the Gatehouse, which was generously funded by a donation from the Dill Faulkes Foundation.) Professor John Brindley of the Institute's Management Committee conducted the formal presentation of the Fellowship Scroll.

N Luckhurst

Dr D Faulkes (left) receiving his Scroll of Fellowship from Prof J Brindley

Awards

Professor Sir Martin Rees, Astronomer Royal and a long-standing member of the Institute's Management Committee, was awarded the Peter Gruber Cosmology Prize 2001. The Prize recognises individuals who have contributed to fundamental advances in the field of cosmology, and was awarded on 2 November 2001 in Bern.

Dr Robert Hunt, Deputy Director of the Institute, received a "Webby" award from the International Academy of Digital Arts and Sciences at its fifth annual Webby Awards ceremony in San Francisco in July 2001. Dr Hunt is the editor of *Plus*, an online magazine about mathematics and its applications aimed at the general public, which was named by a distinguished panel of judges as the best Science site on the web. The magazine can be found at **http://plus.maths.org/** and is run by the Millennium Mathematics Project, a national initiative based in Cambridge involving a collaboration between the University's Department of Applied Mathematics and Theoretical Physics and its Faculty of Education. Other winners included the BBC World Service online, Google and Yahoo! Finance.

Dr Hunt was also awarded in July 2001 a Pilkington Teaching Prize by the University of Cambridge, in recognition of excellence in University teaching.

National Science Week

Professor Michael Green gave a public lecture on Saturday 23 March 2002 as part of National Science Week. In the lecture, entitled *String Theory – Tying it all up*, Professor Green described the way in which string theory unifies the laws of physics and radically alters our ideas about the nature of the universe at the smallest and largest distance scales. The lecture was well attended by over 140 visitors, including many teenagers.

Posters in the London Underground

The "Maths in the Underground" project, which ran during 2000 in the trains of the London Underground, was described in the Institute's *Annual Reports* for 1999–2000 and 2000–2001. A reprinting, kindly funded by EPSRC, has resulted in free sets of the posters being distributed to UK schools courtesy of the OCR Examinations Board. The posters were seen on Channel 4 Television during classroom scenes in the programme *Dawson's Creek*, and have now been used in the MGM film *Agent Cody Banks* due to be released in early 2003.

All available copies of the posters have now been distributed, but they are still displayed on the web at **http://www.newton.cam.ac.uk/wmy2kposters/** A booklet featuring all 12 posters is currently in preparation.

Newton Institute Publications

Papers and Preprints

Over 100 papers were produced or in preparation by participants at the Institute during 2001/2002 (a complete list is given in Appendix 7). Many of these are included in the Newton Institute's Preprint Series to which participants are encouraged to submit papers. A web page giving details of Newton Institute preprints is available at

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

Books arising from Newton Institute Programmes

The following titles were published during 2001/2002:

CF Barenghi, RJ Donnelly and WF Vinen (Eds.)
Quantized Vortex Dynamics and Superfluid Turbulence
Springer, 2001
455pp, ISBN: 3540422269 (Hbk) £57.00

RG Crittenden and NG Turok (Eds.)
Structure Formation in the Universe
NATO Science Series, Kluwer, 2001
384pp, ISBN: 140200155X (Hbk) £95.00

MAH Dempster (Ed.)
Risk Management: Value at Risk and Beyond
Cambridge University Press, 2002
288pp, ISBN: 0521781809 (Hbk) £45.00

P Donnelly and RA Foley (Eds.)
Genes, Fossils and Behaviour: An Integrated Approach to Human Evolution
NATO Science Series, Kluwer, 2001
246pp, ISBN: 905199449 4 (Hbk) £61.00

RL Ricca (Ed.)
An Introduction to the Geometry and Topology of Fluid Flows
NATO Science Series, Kluwer, 2001
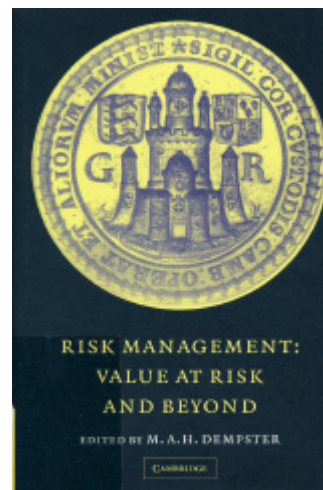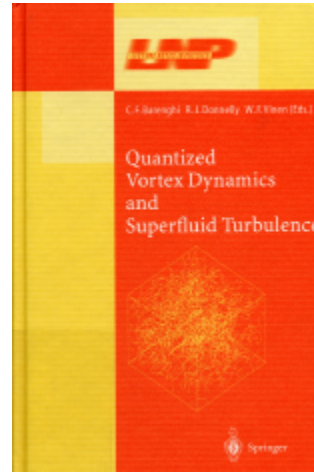215pp, ISBN: 0792369769 (Hbk) £61.00

D Siersma, CTC Wall and V Zakalyukin
New Developments in Singularity Theory
NATO Science Series, Kluwer, 2001
480pp, ISBN: 0792369963 (Hbk) £105.00

A complete list of books published as a result of Newton Institute programmes is available at

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

Young Scientists

The Institute holds a number of events each year which are specifically targeted at young scientists. In 2001/2002 these events included:

- EuroConference on *Nonlinear Evolution Equations and Dynamical Systems* (NEEDS)
- EC Summer School on *What is Integrability?*
- EuroWorkshop on *Discrete Systems and Integrability*
- Workshop on *Algebraic Aspects of Integrability*
- Satellite workshop: *Warwick Teach-in on 3-folds*
- Clay Mathematics Institute School on *Geometry and String Theory*
- EuroConference on *Higher Dimensional Complex Geometry*
- Workshop on *M-Theory, Gravity and Geometry*

The following young scientists were recipients of bursaries from the Cambridge Philosophical Society in 2001/2002:

Integrable Systems
- V Novikov (Landau)
- A Zotov (Institute for Theoretical and Experimental Physics)

From Individual to Collective Behaviour in Biological Systems
- E Crampin (Oxford)
- K Painter (Heriot-Watt)

Higher Dimensional Complex Geometry
- C Maclean (ENS, Paris)
- T Logvinenko (Bath)
- C Avanjo (Princeton)

M-Theory
- P de Medeiros (Queen Mary)
- S Pakis (Queen Mary)

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, we introduced in 1997 a category of Junior Membership of the Newton Institute. To be eligible for membership you must be a Research Student or within 5 years of having received a PhD (with appropriate allowance for career breaks) and you must work or study in a UK University or a related research institution.

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 or support for 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-term participants in the Institute's programmes. Those wishing to become Junior Members should consult the Institute's web site at

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

N Luckhurst

Participants at the Clay Mathematics Institute School on Geometry and String Theory

Hewlett-Packard

## Report from the Hewlett-Packard Senior Research Fellow, Professor Kostya Khanin

In the past year my research has been concentrated around two topics: rigidity theory in one-dimensional dynamics, and Burgers turbulence. Rigidity theory studies universal metrical properties of dynamical systems which have similar topological structure of trajectories. In the case of one-dimensional dynamics the topological structure is determined by the combinatorial types of trajectories. Analysis of the celebrated Feigenbaum universality led to realizing that the combinatorics associated with a one-dimensional dynamical system, in fact, uniquely determines the asymptotic geometry or, in other words, the asymptotic scalings of trajectories. This brings us to the rigidity principle, which seems to be valid in a very general situation. Roughly speaking, it can be formulated in the following way. If two one-dimensional mappings have the same structure of singularities and the same combinatorial type, then they are, in a certain sense, metrically equivalent. In other words, if two maps are homeomorphically conjugate to each other and the types of their singular points are the same, then, in fact, the conjugation is smooth. At present, there exist only a few examples where this general statement has been proven, and renormalisation is the most powerful tool in existing approaches.

In a joint research project with D Khmelev and A Teplinskiy we studied the case of circle homeomorphisms with a singularity of the break type, that is circle homeomorphisms which are smooth everywhere except at one point where they have a jump of the first derivative. It is important to mention that such homeomorphisms can be viewed as a natural one-parameter deformation of the class of circle diffeomorphisms. They can also be obtained with the help of a simple geometrical construction. In the case of circle homeomorphisms with a break singularity we managed to prove the global hyperbolicity of the renormalisations. In other words, there exists a global hyperbolic horseshoe structure corresponding to the renormalisation transformation (see figure). This

structure has remarkable symmetries and its analysis allows us to prove the rigidity conjecture for a rather wide class of rotation numbers. At the same time we expect that in this case one can construct the full rigidity theory, that is to prove certain rigidity for all irrational rotations. Notice that in the diffeomorphism case the global rigidity conjecture is known to be incorrect. However, quite surprisingly the presence of a singularity makes dynamics more rigid.

In a different line of research, together with Jeremie Bec (Observatoire de la Côte d'Azur, Nice) we have studied Burgers turbulence for spatially extended systems. The main aim of this research project is to analyse large scale properties of the stationary distribution for shocks. This work is connected with our previous work on topological shocks in Burgers turbulence. In the case of spatially extended systems the global topological shocks disappear. However, one can introduce a notion of T-global shocks, that is shocks which behave like global ones on a time scale of order T. Our numerical and theoretical results suggest that the density of the T-global shocks scales like $T^{-2/3}$.

Finally, I want to mention a work on dynamical systems methods in queueing theory and a connected paper on nonlinear generalizations of the Perron–Frobenius theorem (jointly with D Khmelev, A Rybko and A Vladimirov).
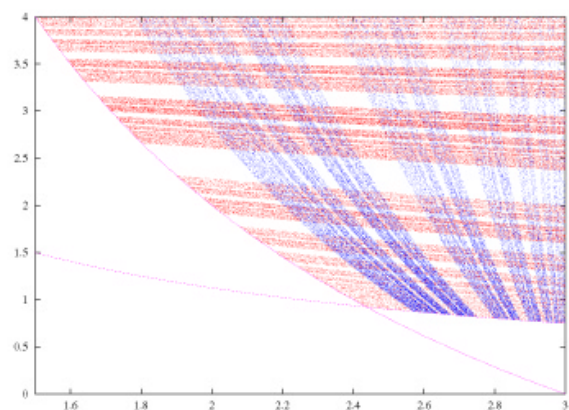
Stable and unstable manifolds for renormalisations of circle homeomorphisms with break singularities

Scientific Steering Committee

Membership of the Scientific Steering Committee at 30 June 2002 was as follows:

Professor JM Ball FRS	University of Oxford
Professor C Bernardi	University of Paris
Professor RH Dijkgraaf	University of Amsterdam
Professor CM Elliott	University of Sussex
Professor WT Gowers FRS	University of Cambridge
Professor Sir John Kingman FRS (Secretary)	Director, Newton Institute
Professor AJ Macintyre FRS	University of Edinburgh
Professor TCB McLeish	University of Leeds
Professor MA Moore FRS	University of Manchester
Professor EG Rees (Chair)	University of Edinburgh
Professor G Ross FRS	University of Oxford
Professor J Stark	University College London
Professor JR Whiteman	Brunel University

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

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 2001:

- Professor S White FRS (Munich)
- Professor N Hitchin FRS (Oxford)
- Professor D Zagier (Bonn)

The following new members were elected:

- Professor G Ross FRS (Oxford)
- Professor JM Ball FRS (Oxford)
- Professor C Bernardi (Paris)
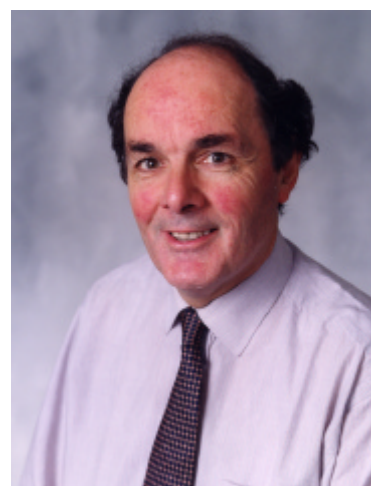
Prof EG Rees,
Chair of the Scientific Steering Committee

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.

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 Institute's 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.

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.

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. 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 will run programmes over a wide range of fields and, over the years, achieve this balance. Such considerations, however, are secondary to the prime objective of having high quality programmes.

Future Programmes

The diagram below shows the forthcoming programmes which have been selected by the Scientific Steering Committee. To participate in a workshop, registration is required. For longer-term participation in a programme, an invitation is usually required, and applications are best made 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, topics and information about workshops which will take place during the programme

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 be found at **http://www.newton.cam.ac.uk/participation.html**

JAN	JUL	SEP	DEC

2002

Higher Dimensional Complex Geometry	Foams and Minimal Surfaces	New Contexts for Stable Homotopy Theory	
M-Theory	Computation, Combinatorics and Probability		

2003

Computational Challenges in Partial Differential Equations	Spaces of Kleinian Groups and Hyperbolic 3-Manifolds	Granular and Particle-Laden Flows	
Nonlinear Hyperbolic Waves in Phase Dynamics and Astrophysics	Interaction and Growth in Complex Stochastic Systems		

2004

Statistical Mechanics of Molecular and Cellular Biological Systems	Magnetic Reconnection Theory	Magnetohydrodynamics of Stellar Interiors	
Random Matrix Approaches in Number Theory	Quantum Information Science		

2005

Model Theory and Applications to Algebra and Analysis			

Management Committee

Membership of the Management Committee at 30 June 2002 was as follows:

Professor J Brindley	Co-opted at the discretion of the Committee
Professor EB Davies FRS	LMS
Dr WJ Fitzgerald	Council of the School of Technology
Dr RE Hunt (Secretary)	Deputy Director, Newton Institute
Dr PT Johnstone	St John's College
Professor Sir John Kingman FRS	Director, Newton Institute
Professor PV Landshoff (Chair)	General Board
Professor WBR Lickorish	Head of Department, DPMMS, Cambridge
Professor TJ Pedley	Head of Department, DAMTP, Cambridge
Professor EG Rees	Chair of Scientific Steering Committee
Professor Sir Martin Rees FRS	Council of the School of Physical Sciences
Dr C Teleman	Faculty of Mathematics
Dr AEA Rose	EPSRC
Dr PMH Wilson	Trinity College

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 staff at the Institute, appointment of organisers of programmes, housing, library and computing facilities, publicity, and general oversight of all the activities of the Institute.

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

Staff of the Institute

The staff of the Institute at 30 June 2002 was as follows:

- Wendy Abbott, Director's Administrative Assistant
- Dr Mustapha Amrani, Computer Systems Manager
- Tracey Andrew, Conference and Programme Secretary
- Elsie Batcheler, Assistant Librarian
- Lynn Berry, Catering Assistant
- Jonathan Chin, Deputy Computer Systems Manager
- Caroline Fallon, Conference and Programme Assistant
- Jackie Gleeson, Housing Officer
- Louise Grainger, Receptionist
- Matt Hodson, Technical Assistant
- Dr Robert Hunt, Deputy Director
- Professor Konstantin Khanin, Hewlett-Packard Senior Research Fellow
- Professor Sir John Kingman FRS, Director
- Doreen Rook, Clerk
- Christine West, Institute Administrator
- Sara Wilkinson, Librarian and Information Officer
- Stephen Williams, Senior Accounts Clerk

Managing Uncertainty - New Analysis Tools for Insurance, Economics and Finance

23 July to 10 August 2001

Report from the Organisers:

P Embrechts (ETH, Zurich), DJ Goodman (Foundation for Science and Technology, London), WJ Fitzgerald (Engineering, Cambridge), RL Smith (University of North Carolina)

Background

Corporations and governments are making risk decisions based on perceptions of extreme values. Frequently these decisions are taken with an inadequate framework for handling low probability, high severity events drawn from nonstationary time series. The situations in which these problems arise are very diverse and range from analysis of the stability of the UK economy and corporate governance issues, to the reinsurance purchase decision of a major insurer. Forecasts of future events must take into account possible changes in the structure of the underlying time series, including the possible impact of global changes in the environment.

This short programme brought together mathematicians, statisticians, economists and environmental scientists who specialise in the analysis of financial and environmental data. Particular attention was paid to mathematical models and statistical prediction tools for extreme events, and for handling nonstationarity. Specific problems include the calculation of Value at Risk in nonstationary time series, the development of alternative "measures of risk", incorporation of model uncertainty into statistical calculations, and the extensions to multivariate time series.

A series of open one-day workshops, concentrating on new techniques and their applications, provided interactions with the wider academic, financial, insurance and governmental communities. The programme as a whole was a follow-up to two workshops on extreme events held during the *Nonlinear and Nonstationary Signal Processing* programme held at the Newton Institute from July to December 1998.

A dinner/discussion was held with the Foundation for Science and Technology on 2 August 2001 with over 100 participants on the theme of managing uncertainty in the corporate context. The three speakers were Professor Myron Scholes (Stanford), Sir Ian Prosser (Chairman, Six Continents plc) and Dr David Allen (Executive Vice-President, BP plc), and the subsequent general discussion was chaired by the Rt Hon Lord Jenkin of Roding.

Core Programme

The nineteen core-programme participants (and three students) collaborated informally on a variety of aspects of extreme value and nonstationary time series analysis methods but also met together for formal seminars. Topics discussed in the seminars were:

- Multivariate high risk scenarios

- Volatility estimation in very high dimensions

- Extreme value theory and internet auctions

- Global asset liability management

- Recent advances in the application of copulae to nonlinear Value-at-Risk

- Managing uncertainty and corporate governance

- Market equilibrium with coherent measures of risk

- General state space modelling and its applications to analysis of financial and economic time series

- Real option games with incomplete information and learning spillovers

- A characterisation of multivariate regular variation

- Nonparametric implied volatility: a single number based on no arbitrage

- Maximum likelihood estimation of non-Gaussian state space models including stochastic volatility models

- Max-stable processes and value at risk

- Nonstationarities in stock returns

- Modelling financial data as a max-stable process

Seated from left to right: P Embrechts, DJ Goodman and WJ Fitzgerald, together with workshop participants

Workshops

Four one-day workshops were held on the estimation of risk, particularly for low probability, high severity events in insurance, finance, economics and environmental problems. One further workshop was organised to discuss corporate governance issues at which executive and non-executive directors met with the core programme participants to discuss how companies and government organisations tackled risky decisions. Around fifteen extra participants joined the core group for each of the workshops.

Core participants gave presentations at the workshops on a range of analysis methods, and workshop participants presented case studies to which these methods might be applied. The case studies ranged very widely from electricity pricing, windstorm loss data, step jumps in the economy and tree ring analysis to Signals Passed At Danger (SPADs) from the Railway Safety organisation.

Outcome and Achievements

All the participants valued the special atmosphere of the Newton Institute and, because of the excellent facilities, the ability to work together during the programme on new problems. Three weeks is, however, only sufficient time to develop ideas rather than complete a study.

For many years, it has been widely recognised that financial time series display a number of characteristic properties, widely known as "stylised facts", which distinguish them from other kinds of time series:

- They tend to be long-tailed, i.e., there is a higher frequency of very extreme events than would be expected with say normally distributed data.

- They tend to show long-range dependence, e.g., the autocorrelation function of the absolute log returns or squared log returns decays to zero at a much slower rate than conventional time series models such as ARMA.

- They exhibit volatility, i.e., the apparent variance of the log returns is not a constant but tends to fluctuate irregularly.

The same phenomena tend to be observed in other contexts as well, e.g., insurance data or internet traffic data (not a theme of this programme, but containing many similar mathematical ideas). Earlier research has developed a number of tools for handling each of these properties on their own, e.g., extreme value theory and threshold methods for long-tailed data; Hurst coefficient and fractional ARIMA models for long-range dependence; GARCH and stochastic volatility models to handle variable volatility. However, the interplay among these different themes is only very imperfectly understood.

New research during the programme helped shed insight on a number of aspects of the links between these three characteristic properties. Study was concentrated on several areas:

- New mathematical techniques, based on the theory of stochastic recurrence equations, are being developed for analysing the asymptotic extreme value behaviour of GARCH and related models for volatile time series. These show, for example, that many of the apparent long-tailed properties of GARCH processes are a natural consequence of the structure of the process.

- Multivariate regular variation is being developed as a broad general tool for understanding dependence in long-tailed time series. It is also relevant in developing a theory of "high-risk scenarios", i.e., what we can say about the values of a multivariate random variable conditional on the information that it lies in an extreme subset. The mathematical analysis of multivariate regularly varying functions continues to develop, and has proved to be a valuable tool in developing statistical models for multivariate extremes.

- New research has shown that apparent "long-range dependence" can arise in time series displaying a standard volatility structure (such as GARCH) but with an additional assumption of "regime changes", which are linked to nonstationarity. This is relevant to the applied themes of the programme because although long-range dependence is widely observed as an empirical phenomenon, there is no satisfactory economic theory to explain it. In contrast, both volatility and the notion of a long-term instability in the basic parameters of the process are phenomena that are widely observed (and which recent research has confirmed, for example in analysis of the S&P 500 Index data) and therefore much easier to explain.

- Alternative models involving multivariate extreme value theory are being developed and are proving successful for explaining the dependence among tail values of financial time series.

- Within the theme of nonstationary time series, further work (since the 1998 Newton Institute programme on *Nonlinear and Nonstationary Signal Processing*) has led to a number of new developments, including much new work on the "particle filters" approach and refinement of Markov Chain Monte Carlo (MCMC) methods. For example, particle filter methods have been applied to the problem of earthquake forecasting in Japan.

- Another way to combine the themes of long-tailed distributions and nonstationarity is through "generalised additive modelling for extremes", which allows for a random process to behave locally (in any short time interval) like a stationary extreme value process, but for the parameters of that process to change over time. New methods for fitting these models were presented and discussed during the programme.

Although the programme was only of three weeks' duration and therefore too short for many new papers to be written during the programme, it is likely that over the next 2–3 years numerous papers will appear which were in some way influenced by the programme. As a specific example, three of the core participants (Mikosch, Smith and Embrechts) subsequently participated in the SEMSTAT (European statistics research group) meeting on extreme values that took place in Gothenburg during December 2001. The proceedings of that meeting are being published as a monograph in the Chapman and Hall statistics series. At least a dozen other research papers were in some way stimulated by discussion during the programme and are likely to acknowledge the Newton Institute.

Conclusion

The gap between theory and application is wide. Many workshop participants found it difficult to see how the theories presented by the core group could be applied in the real world. Nevertheless real progress was made in developing theoretical

aspects of extreme value theory and nonstationary time series analysis. Many new papers were stimulated by the programme. Workshop participants were stimulated to find out more about the methods discussed: one success was the adoption by Railway Safety of a new method for analysing Signals Passed At Danger (SPADs).

For further details of the programme please contact DJ Goodman at dougal.goodman@ foundation.org.uk. Support from the following is gratefully acknowledged: British Antarctic Survey (a NERC Research Institute), the staff of the Newton Institute, and (financially) BP, Benfield Greig, Faraday, McKinsey & Co., Royal & SunAlliance, Schlumberger and TXU Europe Trading.

Surface Water Waves

13 to 31 August 2001

Report from the Organisers: SE Belcher (Reading), TJ Bridges (Surrey), SG Sajjadi (John C Stennis Space Center)

Scientific Background

Of all the various types of fluid wave motion that occur in nature, surface water waves are not only the most easily observed but of great practical importance because of their impact on coastal and offshore structures and ship dynamics, their implications for sediment transport and coastal morphology and their overall effect on the energy and momentum exchange between the atmosphere and oceans. There has been no shortage of motivation for a theoretical description of water waves, and the problem has attracted the attention of mathematicians across the whole spectrum from applied to pure mathematics.

Since the work of Stokes and his contemporaries in the nineteenth century, there has been significant advance in the theoretical understanding of water waves. The end of the twentieth century was a convenient time to assess the accomplishments in the theoretical study of water waves, and to identify key new directions for the twenty-first century.

For this programme, the organisers identified two main areas of fundamental importance to water waves that build on results of the twentieth century and pose great theoretical challenges into the next century. The topics are nonlinear three-dimensional waves, and interactions of wind, waves and turbulence. Firstly, with multi-scale resolution now possible using the latest computers, there is potential for significant advances in the semi-analytical and numerical aspects of 3D waves, including both prediction and study of qualitative aspects that heretofore have not even been predicted. Secondly, recent developments of mathematical theory of nonlinear and breaking waves and of the unsteady critical layer effects when the wind drives waves have pointed the way to a new body of theory for wind–wave interaction. Experimental data is beginning to be available to discriminate between and contribute to the conflicting theories.

Structure of the Programme

The three-week programme was possibly the longest duration focussed academic meeting on water waves in history, and the participation was global with representatives attending from Australia, USA, France, Canada, Germany, Ukraine, Russia, Portugal, Italy, Denmark, Netherlands, Israel, India, Estonia, Greece, Mexico, Sweden and the UK. A complete list of short- and long-stay participants can be found on the programme's web page on the Newton Institute site.

The first two weeks of the programme had a bi-polar structure, with formal talks in a workshop setting blended in with large time gaps for informal discussion groups; and in the third week, the time was structured by Euroconference format.

In the first two weeks there were 6 focussed sessions. Each of these sessions took place in the afternoon, leaving 6 mornings and 4 full-days for discussion groups. The main formal events in the first two weeks are listed below. Each of these events has an individual web page with talk titles, programme and other information, to which links can be found on the programme's web page.

- Opening Day Talks (Monday): The opening day focussed on "Challenges", with talks by leading experts in meteorology, ocean-ography, air–sea interaction and wave breaking discussing major open problems. The speakers were PAEM Janssen (ECMWF), DH Peregrine (Bristol), J Gunson (UK Met. Office), J Wolf (Proudman Oceanographic Laboratory) and SA Thorpe (Southampton), and the session chair was JCR Hunt (UCL).

- BRIMS Day (Tuesday): This event was sponsored by the Hewlett-Packard BRIMS research facility in Bristol. The theme was "New Developments in the

Participants in the LMS Spitalfields Day
"Mathematics of Water Waves"

Study of Water Waves". The speakers were MS Longuet-Higgins (San Diego), JL Bona (Texas), F Dias (Ecole Normale Supérieure), WK Melville (San Diego), H Segur (Colorado) and J-M Vanden-Broeck (East Anglia), and the session chair was SE Belcher (Reading).

- Methodology versus Rigour (Wednesday): In this special session there were only two speakers, K Kirchgaessner (Stuttgart) and CC Mei (MIT). Both methodology and rigour have played important roles in the development of the theory of water waves, and these two talks, by leading proponents of each view, contrasted these two approaches to theory. The session was chaired by JL Bona (Texas).

- LMS Spitalfields Day (Thursday): The London Mathematical Society sponsored a day devoted to "Mathematics of Water Waves". This session included speakers from North America, the Netherlands, France, Germany and the UK. The speakers were W Craig (McMaster), E van Groesen (Twente), G Iooss (Nice), G Schneider (Bayreuth) and JF Toland (Bath). The organiser and chair of the session was TJ Bridges (Surrey).

- Geometry, Oceanography and Overview (Friday): This Friday afternoon session included talks from three different angles. D Holm (Los Alamos) talked about

geometric formulation of shallow water models, M Banner (New South Wales) talked about recent developments in wave breaking and V Shrira (Keele) talked about three-dimensional horseshoe patterns on the ocean surface. The session was chaired by CC Mei (MIT).

- Overview Session (Friday): On Friday afternoon, JCR Hunt (UCL) gave an overview of the accomplishments of the week, and gave some insight into what directions the programme might consider in weeks two and three.

- Wind, Wave and Turbulence Day (Wednesday, 22 August): This session concentrated on interaction issues: wind–wave, wave–wave and wave–turbulence interaction. The main speakers were D Nicholls (Notre Dame), V Shrira (Keele), G Caulliez (Marseille), T Hara (Rhode Island), V Kudryavtsev (Ukraine) and MAC Teixeira (Lisboa). At the end of the session there was a joint lecture between the *Surface Water Waves* programme and the *Integrable Systems* programme given by PJ Olver (Minnesota). The organiser and chair of this session was SE Belcher (Reading).

Theoretical Developments: Two and Three Dimensional Water Waves

Euroconference, 28–31 August 2001

Week three, beginning Tuesday, 28 August (Monday, 27 August was a Bank Holiday), was full conference mode, with over 50 additional participants arriving.

The range and depth of the lectures was extraordinary. Topics included: theory and observation of breaking waves, statistical aspects of the sea surface, remote sensing, interaction of random waves, three-dimensionality of wave breaking, extreme and freak waves, violent waves and impact phenomena, effect of driving and dissipation, sea drag, mechanisms for wind forcing of waves, large scale modelling, standing waves,

stability of solitary waves, solitary waves on deep water, dimension breaking of waves, existence of three-dimensional solitary waves, new developments in Boussinesq models, hexagonal and other surface patterns, three-dimensional patterns, short-crested waves, flow over topography, interface modelling, interaction of waves with longitudinal vortices, wave turbulence, and spectral modelling.

Highlights included the opening talk by VE Zakharov (Landau Institute) who gave an overview of the progress in his group over the past few years on water wave problems, and the special Institute Lecture on Tuesday evening by ADD Craik (St Andrews) on the history of theoretical developments on water waves in the 19th Century during the time of George Stokes. (An expanded version of this talk will appear in the proceedings of the *Wind-over-Water* meeting).

Day two had eleven 30-minute talks in two sessions, with the morning session on wind–wave interaction and the afternoon session on solitary waves. On day three, there were again eleven 30-minute talks in two sessions, with the morning session on "Three-dimensional water wave patterns" and the afternoon session on "Wave– wind– vortex– and turbulence–wave interaction". The conference dinner, on Thursday evening, was held in Christ's College Hall, where MS Longuet-Higgins read out a poem written by Keith Moffatt in honour of "Theoretical and Applied Mechanics Day" (see the Annual Report of the Newton Institute, 2000 – 2001).

Wind-over-Waves

Meeting at Churchill College, Cambridge, 3- 5 September 2001
Organisers: SE Belcher, TJ Bridges, JCR Hunt and SG Sajjadi

This conference was held immediately after the Newton Institute programme and was sponsored by the IMA. It is the second conference on wind-over-waves, following the successful first meeting held at the University of Salford in 1997. Sessions addressed air–sea interaction, ocean wave dynamics and forecasting, breaking waves, wave turbulence interactions and Langmuir circulations. The list of invited speakers was J Battjes (Delft), TJ Bridges (Surrey), MS Longuet-Higgins (San Diego), V Makin (KNMI, Netherlands) and WK Melville (San Diego). The complete programme can be found on the web at

http://www.maths.surrey.ac.uk/personal/st/ T.Bridges/WOW.html

In addition to the plenary lectures, there were over 20 contributed lectures on a wide range of topics. On Tuesday evening, a dinner was held in Churchill College Hall in honour of the 60th birthday of Julian Hunt.

Outcomes, Achievements and Publications

One of the most interesting outcomes of the programme was the enthusiastic interaction between researchers working primarily on physical aspects of water wave theory and those working on strictly theoretical constructs. Another disciplinary divide which was opened up is the statistical viewpoint versus the deterministic viewpoint. The bipolar – three-dimensionality and wave-interaction – starting point of the programme rapidly developed into a list of five areas identified for future emphasis.

An excellent indication of the volume of activity at the programme is the "wrap-up session".This discussion session, chaired by M Banner (New

S Wilkinson

Participants in the Euroconference on "Theoretical Developments: Two and Three Dimensional Water Waves"

Figure 4. Later stages of an eddy when it becomes an elongated vortex tube interacting with and distorting the surrounding incoherent turbulence. This may lead to the eventual breakdown of the vortex, in some cases via the generation of waves on the vortex.
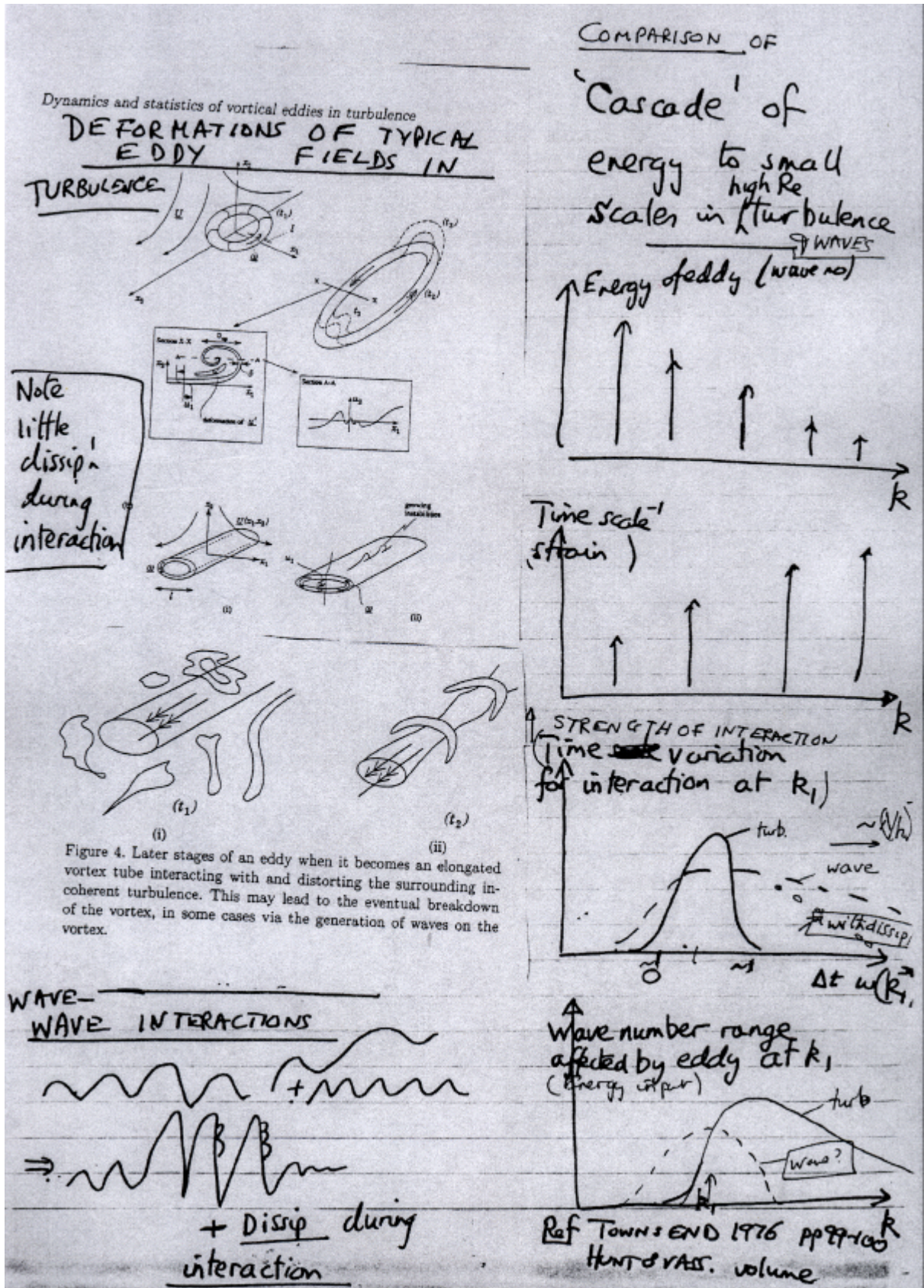
Julian Hunt's overview of the waves–turbulence interaction problem

South Wales), engaged the audience with a concentrated discussion lasting more than 3 hours – although only 90 minutes had been planned! The five main themes which emerged from the programme and an overview of some of the future issues raised in the discussion are highlighted below.

- Statistical wave evolution models: planning for the next generation SWE model; extending the current range of validity; modelling nonlinear spectral transfer mechanisms; modelling wind input forcing, and dissipation.

- Fundamental mathematical questions: development of new model equations with three-dimensionality; testing of model equations using dynamical systems and functional analysis; methods for the initial value problem; role of "spatial dynamics"; new theories for large amplitude determistic or statistical representations.

- 3D patterns and coherent structures: the level of detail of ocean waves that can be represented mathematically; role of solitary waves and envelopes for 3D waves; role of vorticity; horseshoe patterns as coherent structures; role of nonlinearity in wave group dynamics; Langmuir cells; mathematics of inhomogeneity.

- Wave breaking in deep water: role of directionality; influence of underlying shear; models for predicting onset and strength of breaking; relating statistics to dissipation; development of model equations for 3D wave breaking; deterministic breaking versus statistical analysis; need a model or paradigm for post-breaking of waves. See the figure for Julian Hunt's overview of the wave–turbulence interaction problem.

- Extreme waves in oceanography: identification of the underlying mechanisms; role of refraction by sub-mesoscale currents; methods for prediction; cause of occurrence rate; role of nonlinearity; spatio-temporal statistics of extremes; acceptable definition for freak waves.

The two main sources of publication are the *Wind-over-Wave* proceedings and a scientific overview by the organisers. The WOW meeting will have a traditional conference proceedings volume, and manuscripts from the Newton Institute programme participants have been invited as well. The volume is edited by SG Sajjadi and JCR Hunt, and is expected to be published soon. An article on the WOW meeting has appeared in the Spring 2002 issue of *Mathematics Today*, published by the IMA.

Integrable Systems

23 July to 19 December 2001

Report from the Organisers: JC Eilbeck (Heriot-Watt), AV Mikhailov (Leeds), PM Santini (Rome), VE Zakharov (Moscow)

S Wilkinson

*Left to right: PM Santini, VE Zakharov,
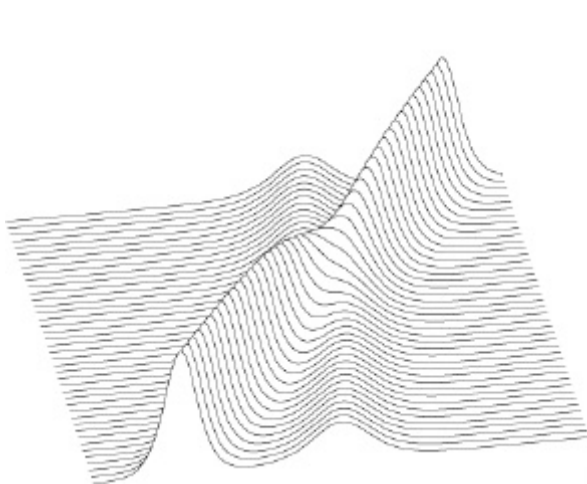AV Mikhailov, JC Eilbeck*

Scientific Background

Many natural systems can be modelled by partial differential equations (PDEs), especially systems exhibiting wave-like phenomena. Such systems often have quantities that are conserved in time, common examples being energy or momentum. Often such systems are nonlinear; small changes in input can produce large changes in output, or vice versa. Mathematically, such nonlinearities make such systems difficult to study except using computer simulations.

Rather surprisingly, relatively sizable classes of nonlinear systems are found to have an extra property, integrability, which changes the picture completely. Integrable systems have a rich mathematical structure, which means that many interesting exact solutions to the PDEs can be found. Although important in their own right, these systems form an archipelago of solvable models in a sea of unknown, and can be used as stepping stones to investigate properties of "nearby" non-integrable systems.

A typical feature of integrable nonlinear wave equation is the existence of multi-soliton solutions, where a soliton is a stable solitary wave. The velocity of the soliton depends on its amplitude, so a bigger soliton can overtake a smaller one: the surprise is that after the collision the two waves separate with unchanged form, except for a phase shift.

Now that the properties of most of the "standard" physical models (KdV, sine-Gordon, nonlinear Schrödinger, etc.) exhibiting integrable behaviour are known, interest has shifted to more abstract mathematical questions, and to the remarkable connections between integrable system theory and many other core areas of mathematics: for example algebraic geometry, differential geometry, group theory, invariant theory, spectral theory, etc. For a given PDE or discrete system, there is a variety of partially understood methods to determine the integrability or otherwise of the system. We would like to understand these methods better, to understand the deep links that must lie between them, and to fully classify all integrable systems in some sense. Although it would be false to claim that the field has now been completely unified and clarified after the meeting, much progress was made during the programme, and a large number of new collaborations were started which will bear fruit over the next few years.

A two soliton collision in the KdV equation
$$u_t + uu_x + u_{xxx} = 0.$$

Organisation and Participation

Throughout the programme there was a regular series of seminars, at least two per week on Mondays and Wednesdays. In addition there were a number of workshops and conferences, with up to a hundred participants for the major meetings.

Several visitors to the programme also travelled to other UK Universities to give seminars (Bogdanov, Boiti, Buchstaber, Calogero, Degasperis, Enolskii, Krichever, Kruskal, Matinez Alonso, Tamizhmani, Tsarev, Zakharov).

A total of 53 long-stay visitors attended the programme, 14 of whom were from the UK. There were in addition 57 short-stay visitors, 19 of whom were from the UK. Many more attended specific workshops and conferences.

Meetings and Workshops

Nonlinear Evolution Equations and Dynamical Systems (NEEDS) XVth Meeting

Euroconference, 25-31 July 2001
Organisers: M Bruschi, F Calogero, AV Mikhailov and PM Santini

In the tradition of the NEEDS meetings, there was an eclectic mix of 78 half-hour talks plus a poster session in a very crowded but enjoyable schedule. The meeting covered a range of theory for integrable and near-integrable systems, with examples drawn from fluid mechanics, plasma physics, nonlinear optics, general relativity and Bose-Einstein condensation. Techniques considered included spectral methods, direct methods (dbar dressing, finite gap method, bilinear methods), integrability criteria and tests, bi-Hamiltonian systems and separation of variables, integrable quantizations, and integrable functional equations.

Particular highlights included the development of a Painlevé test for difference equations (Costin), the discovery of a new class of nonlinear evolution equations possessing many periodic trajectories (Calogero), a new theory of separation of variables for bi-Hamiltonian systems (Pedroni and Falqui), a dbar approach for the dispersionless KP hierarchy (Matinez Alonso), and a spectral approach to boundary value problems for linear and nonlinear PDEs (Pelloni).

The proceedings of this meeting will be published in two special issues of the *Journal of Theoretical and Mathematical Physics*, edited by AV Mikhailov and PM Santini.

What is Integrability?

EC Summer School, 13-24 August 2001
Organisers: A Degasperis, A Hone, AV Mikhailov and A Shabat

One of the main themes of this School was how to test for integrability in ordinary and partial differential equations. One type of test involves perturbative or asymptotic methods; these were represented in the lectures of Degasperis on multiscale expansions, Zakharov on multi-dimensional perturbation theory, and Kodama on normal forms. A second approach is algebraic, involving the classification of symmetries, described by Sokolov and Mikhailov, with connections to number theory as discussed by Saunders. Yet another method is based on the analytic behaviour of solutions in the complex domain: the technique of Painlevé analysis was covered in the lectures by Kruskal.

Other major aspects of integrability were also treated. Olver lectured on multi-Hamiltonian structures, Shabat described Bäcklund transformations within the framework of dressing chains for linear operators, and Hietarinta described the Hirota bilinear method and the connection with tau-functions. The relationship between integrability and geometry was explored in Mason's lectures on twistors and self-dual Yang-Mills equations, while Novikov discussed discrete symmetries and discrete systems on planar graphs. Miwa also gave an introductory course on quantum integrable systems. Other lecturers (Ablowitz, Clarkson, Flashka, Hone and

A discrete breather pseudospherical surface

Winternitz) gave shorter courses and tutorials describing more recent developments in this field.

Selected lecture courses will be published by Princeton University Press in the book *Integrability,* edited by AV Mikhailov.

Discrete Systems and Integrability

Euroworkshop, 3-14 September 2001
Organisers: FW Nijhoff, J Hietarinta and
PM Santini

There were 36 talks, almost all one hour long, organised in thematic sessions (most of which lasted a full working day), linked by an organised discussion. The themes of the sessions could be roughly divided by the following headings:

- Discrete Painlevé equations and affine Weyl groups

- Integrable lattices (partial difference equations)

- Discrete and difference geometry

- Algebraic integrability and computational aspects

- Integrable mappings

- Discrete Painlevé property

- Quantum many-body systems and special functions

- Inverse problems and solutions

- Symmetries of difference equations

- Cellular automata and applications

The talks were all of a very high level, and a large number of new results and ideas were put in front of the audience. In particular we mention the following contributions:

- M Noumi (Kobe): *q-Painlevé Equations Arising from a q-Version of the Modified KP Hierarchy* (on the similarity reduction of the KP hierarchy and the emergence of discrete Painlevé equations from it)

- A Veselov (Loughborough): *Discrete Hydrodynamics and Monge–Ampère Equations*

- C Viallet (Paris VI): *Complexity, Singularity and Integrability of Maps* (on the algebra geometric analysis of singularities in birational mappings and their resolution through the blowing-up procedure)

- MD Kruskal (Rutgers): *Equivalent of the Painlevé Property for Difference Equations and Study of their Solvability* (on a new class of "analysable" functions and their role in the definition of integrability in the discrete domain)

Geometrical Aspects of Integrability

Workshop, 17-18 September 2001
Organisers: N Manton, L Mason and R Ward

A total of 53 participants registered for this workshop and several more attended many of the lectures. There were nine one-hour lectures over the two days including a selection from the leaders in the field and from younger up-and-coming researchers.

One of the main foci was the interaction with equations from particle physics. Hitchin gave a new overview of various integrable geometric structures on the moduli space of Calabi–Yau manifolds that have been discovered in the context of string theory. Manton reviewed the theory of gauged vortices (not, strictly speaking, integrable, but there are nevertheless many exact analytic results). Bielawski reviewed the theory of

hyperkahler structures as an integrable system, providing new methods for their study. Both Mason and Calderbank reviewed different aspects of reductions of anti-self-dual conformal structures, the former from the point of view of the intrinsic equations and the latter from the point of view of the integrable equations that the background geometry can support. Ward's lecture concerned the analysis of a case of this, being the Bogomolny equations on a space of constant curvature, and focussed on some of the new features to which the background curvature leads.

On more traditional topics, there were two lectures on Painlevé equations, Mazzocco's investigating when solutions can be obtained in terms of "classical functions", and Woodhouse's studying the isomonodromy problem using methods from twistor theory. Zakharov's lecture concerned the integrability of a classical problem in geometry: finding metrics with "diagonal" curvature.

The meeting brought together people on the programme whose interest was from more of a traditional applied maths background with those whose primary interest was in geometry and physics, and this led to significant cross-fertilisation.

Computer Algebra in Applications to the Problems of Integrability

Workshop, 16-17 November 2001
Organiser: T Wolf

This workshop brought together users of computer algebra programs related to integrable systems (mainly among the audience), people involved more with the design of algorithms and others with more emphasis on the implementation of algorithms. The scope of talks reflected this wide range and a number of people were happy to have personal contact for the first time with others they knew only through their published papers. A novel aspect was that many computer packages in this area were made available during the meeting for participants to experiment with. The organisers also encouraged participants to suggest suitable computational challenges which could be

addressed during and after the meeting.

Algebraic Aspects of Integrability

Workshop, 26-30 November 2001
Organisers: Y Berest and AP Veselov

This special week was one of the highlights of the programme. The principal speakers were Etingof (MIT), Matsuo (Tokyo) and Barannikov (ENS, Paris). They gave a series of review lectures: Etingof on rational Cherednik algebras in relation to quantum Calogero–Moser systems, Matsuo on vertex operator algebras and the moonshine module, and Barannikov on quantum periods and integrable hierarchies. Other speakers included Athorne (Glasgow), Brzezinski (Swansea), Buchstaber (Moscow), Chalykh, Feigin (Loughborough) and Enolski (Kiev).

The week culminated in the LMS Spitalfields Day at Loughborough University (30 November) where the most important recent achievements in the area were presented. Etingof gave a talk on his joint results with Ginzburg on symplectic reflection algebras, Matsuo on parafermion algebras and the Monster group, Wilson on his joint work with Berest in noncommutative projective geometry, and Chalykh on his recent proofs of the Macdonald conjectures. These results demonstrated once again the importance of the fruitful interaction between the theory of integrable systems and other branches of mathematics.

S Wilkinson

AK Pogrebkov and H Braden

Classical and Quantum Integrable Systems

Satellite Workshop at the University of Edinburgh, 2-8 December 2001

Organisers: R Weston, E Corrigan, JC Eilbeck and T Miwa

This was a satellite meeting hosted by the International Centre for Mathematical Sciences, Edinburgh, and took place on the Heriot-Watt University campus, close to the famous Union canal of soliton fame.

A total of 70 participants took part in this lively meeting. There were 34 talks, 24 of these by the main invited speakers. The remaining 10 shorter talks were specifically from younger participants. This mix was very effective in bringing new faces and new ideas into the meeting.

In the short talks category, the presentations by Caux, Castro-Alvaredo and Doikou notably inspired many scientific conversations. Many of the main talks presented important new results. The talks by Cardy, McCoy, Smirnov and Shiraishi might perhaps be singled out. Cardy's talk showed that they are still many interesting physical systems for which novel exact results can be obtained via conformal field theory. McCoy presented his recent work in which, remarkably, he has discovered a new fundamental symmetry of our most thoroughly studied solvable lattice model. Smirnov discussed recent important results in his ongoing programme to construct a more algebraic geometrical description of quantum integrable systems. Shiraishi described a recent breakthrough that has enabled him to construct, after 10 years of labour, a free-field realisation of the algebra associated with the 8-vertex model. This construction enables him to compute exact correlation functions in this model.

There was much animated discussion of these and many other results at the meeting. Several collaborations certainly grew out of these discussions; two we know of involve Delius and Nepomechie, and Konno and McCoy.

In recent years, through the work of Sklyanin, Smirnov and others, there have started to be signs of some convergence of the fields of classical and quantum integrability. The coming together of the two communities at this meeting, and the participation of many researchers from the main body of the programme, have certainly helped this trend. The organisers believe that this will have a beneficial and lasting influence on both fields.

Boundary Value Problems

Workshop, 17-18 December 2001

Organisers: T Fokas, B Pelloni and AV Mikhailov

This workshop was planned during the NEEDS meeting, when various short talks had focussed on boundary value problems, notably for the nonlinear Schrödinger equation (NLS), and it was felt that time had not allowed a proper discussion. A total of 30 participants took part in this meeting, with 10 talks and plenty of discussions. Various approaches were discussed and compared, for specific examples as well as in talks surveying old and new results in this area. In particular, the results for NLS on the half line obtained by the approach of Fokas and his collaborators were presented alongside the results of Degasperis, Manakov and Santini; this motivated a lively discussion among all the participants.

The possibility for exposition and discussion among researchers interested in similar problems was very much welcomed by all, coming as it did at the end of five months of concentration on integrable systems in general. It also stimulated the possibility of collaboration among different approaches; at least one such collaboration, between Pelloni and Jerome on the sine-Gordon equation, was a direct result of the meeting. More generally, the workshop took advantage of and fully exploited the opportunity offered by the presence at the Newton Institute of most of the people involved in this area of research.

Outcome and Achievements

The organisers and participants felt that the programme was very successful, in bringing

together a large number of key figures in the area and in attracting a promising number of younger researchers. Apart from the hectic workshop schedule, much progress was made by both the long- and short-stay participants in the invigorating surroundings of the Newton Institute. Some long-standing problems were solved, and other new areas opened up for further investigation.

MD Kruskal and KM Tamizhmani among others made progress towards developing a "simple" proof of the Painlevé property for the six Painlevé equations. Inspired by the close proximity to the haunts of the famous Cambridge mathematician HF Baker, C Athorne, JC Eilbeck and V Enolskii developed a fully $SL(2)$ invariant theory of genus 2 hyperelliptic $\wp$ functions, opening up new areas in this field as well as clarifying some rather obscure steps in Baker's original treatment. C Athorne also worked with Sanders and with J Hietarinta on generalizations of Hirota's bilinear derivative.

T Grava, with V Enolskii, found new explicit solutions for the Riemann–Hilbert problem involving algebro-geometric integration of Fuchsian systems and the Schlesinger equations.

AV Mikhailov, JA Sanders and JP Wang discovered a $O(N)$ invariant integrable generalization of the famous sine-Gordon equation. This equation has important applications in Riemanian geometry.

JP Wang has also found an explicit generalization of the Hasimoto transformation to the N-dimensional case. H Braden made progress on a number of problems, including twistor theories and the Calogero–Moser model (with L Mason), Stäckel systems (with A Fordy), and Toda theory and Nahm monopoles (with H Flaschka and N Ercolani). H Flaschka also worked on combinatorial rules for the decomposition of tensor products of compact Lie groups, and related problems on the distribution of eigenvalues of random matrices.

F Calogero worked on a number of ODEs, and also on "cool" irrational numbers and their approximations. D Holm performed a breakthrough numerical simulation showing that the NS-alpha model stimulates decay of a turbulent shear layer at least as well as highly tuned Large Eddy Simulation models.

Using asymptotic methods and the Inverse Scattering Transform, AV Mikhailov and V Novokshenov found a new approach to the problem of DM solitons in nonlinear optics. The analytically predicted shape of the soliton fits well with the corresponding numerical simulations.

ANW Hone, together with A Degasperis and D Holm, developed the integrability theory for a new equation proposed by A Degasperis at the EC Summer School. AV Mikhailov and SP Novikov formulated a perturbative version of the Symmetry Approach which is suitable for non-evolutionary and non-local equations, including multi-dimensional equations, and proved that the Camassa–Holm equation and a new equation discovered by A Degasperis are the only integrable equations in a certain class. They made a complete classification of integrable Benjabin–Ono type equations.

A Kapeav, with A Its, worked on asymptotics of the second Painlevé transcendent. Y Kodama started a new collaboration on the dispersionless KP equations, and worked with AV Mikhailov on normal forms and the symmetry approach for near integrable systems. B Konopelchenko worked with L Martinez Alonso on integrable dispersionless hierarchies, quaso-conformal maps, and the $\bar{\partial}$-dressing method. D Levi, with P Winternitz and R Heredo, worked on Lie symmetries of difference equations. V Matveev worked on topological results for geodesically equivalent Riemannian metrics. FW Nijhoff and J Hietarinta developed new ideas involving the characterisation of integrable mappings in one and two dimensions through the commutativity of discrete flows. B Pelloni worked on boundary value problems for the sine-Gordon and Schrödinger equations.

AK Pogrebkov and A Fokas studied initial value problems for the KPI equations with initial

S Wilkinson
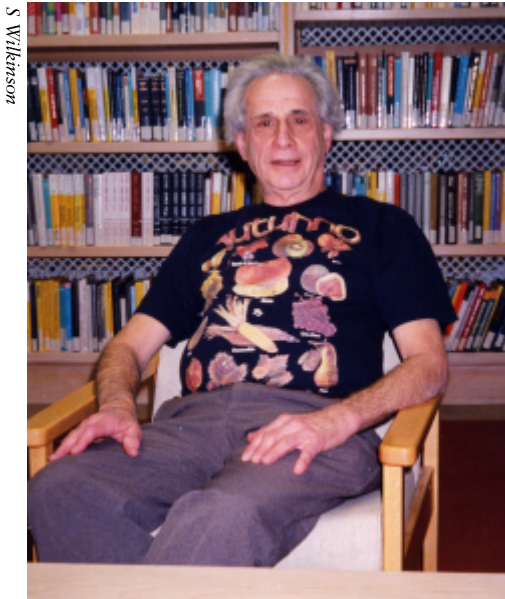
MD Kruskal

addition found time to search for new integrable solutions of the Einstein equations.

conditions given by a single soliton solution plus a rapidly decaying term. Pogrebkov also constructed a hierarchy of quantum explicitly solvable models which can be considered as a quantum version of the dispersionless KdV hierarchy. AB Shabat studied a discrete version of the Schrödinger spectral problem, and the connection between certain isospectral flows and infinite-dimensional hydrodynamic type systems.

V Sokolov, with T Wolf, completed an investigation of vector $(1 + 1)$ dimensional integrable models. With A Tsiganov he developed new integrable polynomial deformations of known integrable models from rigid body dynamics, including a new integrable case for the classical Kirchoff problem of motion of a rigid body.

S Tsarev completed a comprehensive survey of work on integrable exponential systems and a review of algorithmic methods of integration of nonlinear ODEs. VE Zakharov worked with a number of people: with T Bridges on a Hamiltonian description of a "renormalized" fluid; with B Konopelchenko and others on the dispersionless KP hierarchy; with F Diaz on one-dimensional turbulence; with A Fokas on boundary problems for integrable systems; with J Griffiths on diagonal metrics in general relativity; and in

From Individual to Collective Behaviour in Biological Systems

10 September to 19 December 2001

Report from the Organisers: PK Maini (Oxford), H Othmer (Minnesota), TJ Pedley (Cambridge), BD Sleeman (Leeds)

Left to right: PK Maini, N Monk, VAA Jansen, TJ Pedley, BD Sleeman, H Othmer

Brief Programme Overview

In the last thirty years there has been an enormous increase in our knowledge of biological processes, especially at the molecular and cellular level, but understanding the behaviour of individual enzymes, cells or organisms in isolation is only a first step towards understanding the collective behaviour of a population of such individuals. Incorporating individual aspects of behaviour into macroscopic descriptions of population behaviour is a challenging problem, even if only deterministic aspects are considered. This programme was devoted to the question of how microscopic information can be incorporated into macroscopic or population-level descriptions in developmental biology, physiology, ecology, immunology and epidemiology.

Part I: Developmental Biology and Physiology

The first half of the programme focussed on developmental biology and physiology. The former

was concentrated on pattern formation, gene networks and developmental mechanics, while the latter was devoted to various aspects related to cardiac physiology, including calcium dynamics, analysis of ion channels in excitable systems, muscle mechanics and integrated models of the heart. A notable aspect of this component of the programme was the strong and deep interaction between theoreticians and experimentalists on the fundamental questions from both perspectives. For instance, the detailed presentations by experimentalists such as P Kulesa, K Weijer and R Keller stimulated numerous discussions and several new collaborations between experimentalists and theoreticians.

The work here also highlighted many questions relating to stromal cell development and organisation and the aggregation and pattern formation behaviour of *Dictyostelium*. An important feature of the programme was that in-depth tutorials on both experimental and theoretical aspects were given prior to the workshop and continued throughout the programme. For instance, participants benefited greatly from the tutorials on modelling of the heart given by P Hunter and his associates, since they pointed to the possible use of mathematical techniques developed there in tissue modelling in other areas.

Vertical Integration in Biology: from Molecules to Organisms

Workshop, 24-28 September 2001

The principal theme of this workshop was vertical integration, focussing on specific examples from developmental biology and physiology, viz., gene networks, cell signalling, morphogenesis, neural networks, neurophysiology and cardiology. Three criteria were used to select these particular areas:

- there exist extensive studies of behaviour at both the individual and collective levels;

- well-founded mathematical modelling frameworks are in place for each of these levels;

- there is a pressing need for a directed attempt to combine modelling and experimental investigations to elucidate the mechanisms of vertical integration, bridging the gap between the two levels of understanding.

To foster efforts aimed at providing insight into vertical integration, it is important to

- bring together researchers from different backgrounds who would not normally find the opportunity to meet to discuss this general issue;

- to train truly interdisciplinary researchers.

The workshop has succeeded in this by

- bringing together experimentalists and theoreticians, as well as those who have successfully combined the two approaches;

- inviting researchers whose focus is primarily on either the individual or collective levels, which proved productive because the modelling techniques applicable to the two levels are often quite distinct;

- inviting a significant number of young researchers to expose them to a wide range of presentations in the interactive environment fostered by the Newton Institute, thereby giving them access to some of the most active researchers in these different fields.

Part II: Ecology, Immunology and Epidemiology

The second half of the programme was devoted to spatial ecology, immunology and epidemiology. One significant outcome of discussions in these areas was the realisation that the mathematical models developed in one area are often similar to those in another area (e.g., compare immunology and epidemiology). This cross-fertilisation of ideas may well have important implications for future research. On the more mathematical front the

complementary ideas on stochastic modelling and reinforced random walks discussed by D Drasdo, A Deutch, A Stevens and H Othmer has opened up a number of novel ways in which phenomena at the cell level may be scaled up to the population level. Open problems include how the limiting processes involved should be interpreted and validated. There is also the excluded volume problem relating to taking account of cell size.

Pattern Formation by Swimming Micro-Organisms and Cells

Euromech Satellite Workshop at the University of Leeds, 3–5 December 2001

This workshop was hosted by the Department of Applied Mathematics at the University of Leeds. N Hill (Glasgow) chaired the meeting with M Bees (Surrey) as the co-chairman. It was organised as an international meeting (Euromech Colloquium 422) under the auspices of the European Mechanics Society, and was funded jointly by the Isaac Newton Institute and the London Mathematical Society. The 60 participants contributed a total of 45 presentations including a lively poster session. Prizes for the best student posters were awarded to R Bearon (University of Cambridge) and R Hillary (University of Surrey).

A notable feature of the workshop was bringing together of mathematical modellers in plankton population dynamics, where dispersion is mainly caused by oceanic currents, and those in bioconvection, with theorists in the growth of bacterial

S Wilkinson

D Sumpter

colonies and the behaviour of slime moulds. The standard of the talks was excellent, and there was much energetic discussion enhanced by keynote experimental and biological presentations. The vigorous state of mathematical biology in the UK and worldwide was demonstrated by the wide range of new mathematical models and mathematical results which were presented, e.g., on travelling waves, Taylor dispersion in suspensions of swimming micro-organisms, angiogenesis, and the fluid mechanics of swarming bacterial colonies.

The very successful theme of a workshop devoted to mechanics applied to biology was a timely new venture for Euromech, and points the way forward for future developments of the Society's interests.

From Worker to Colony: Understanding the Organisation of Insect Societies

Workshop, 7-8 December 2001

Preparations

For the two weeks running up to this workshop, we hosted informal discussions outlining the important research questions relating to social insects. Over these two weeks the Institute had short-term visits from nine experimental biologists, two researchers involved in computer tracking and automatic analysis of insect behaviour and two computer scientists involved in ant algorithms (novel methods of solution, inspired by ants, for solving computationally complex problems). These visitors interacted with the mathematicians already resident at the Institute and others who also visited for a short time. For example, M van Baalen and M Beekman worked on a paper on the benefits of genetic diversity for disease resistance, I Couzin and E Despland worked on automated tracking of locusts, and S Martin and D Sumpter began modelling bee colony virus dynamics.

As well as having seminars and informal problem presentations by the visitors, we organised a discussion group on *Robustness in Insect Societies*, taking as inspiration some of the talks earlier in the programme on robustness in other biological systems. M Reuter, D Sumpter, M Beekman, M

Middendorf and R Merkel all gave presentations on this theme, resulting in a great deal of lively discussion. Such discussions also set the scene for the workshop itself.

The Workshop

This was the largest meeting dedicated to the study of insect societies in the UK for at least five years. There were 90 attendees (70 of whom were short-term or "on the day" participants), who heard both extended one hour research talks from leading international researchers and shorter presentations of particular projects. One main theme was construction and digging by ants: in one talk G Theraulaz presented, to the great interest of attendant mathematical biologists, convincing evidence for Turing mechanisms underlying ant cemeteries and other constructions. Another theme was nest choice by ants and bees, with excellent and detailed talks by T Seeley, N Franks and S Pratt. During the breaks between talks there were poster presentations, where younger members got an opportunity to present their work and get some input on possible mathematical modelling. Many new collaborations were formed as biologists found out what mathematics could contribute to the study of insect societies and mathematicians discovered that these societies are a perfect example of individual to collective behaviour in biology. A one-page report on the workshop entitled *Getting the Behavior of Social Insects to Compute* appeared in the March 2002 issue of *Science* **295** p 2357.

Macroscopic Organisation from Microscopic Behaviour in Immunology, Ecology and Epidemiology

Workshop, 10-14 December 2001

The purpose of this workshop was to bring together experimentalists and theoreticians working in immunology, ecology and epidemiology with the aim of fostering interaction and research.

Approaches using classical deterministic mathematical models have had some limited

S Wilkinson

N Monk

success in describing these spatial ecological processes. However, there is a growing realisation, amongst ecologists and theoreticians alike, that stochastic factors, both demographic and environmental, play a fundamental role in determining ecological outcomes.

Because of new technology the quantification of cellular populations is now routine in immunology laboratories. This has led to a steadily increasing stream of kinetic data on the population dynamics of various types of immune cells. With this accumulation of data comes a realisation that a proper understanding of the underlying dynamical systems will only be achieved when the data are considered within the organising framework of a formal theoretical model. Mathematical immunologists have responded energetically to this newly felt need, forming a growing number of close collaborations between theoretical and laboratory immunologists. Some of these collaborations have been rich sources of new insights; not only into biological processes, but also in showing the usefulness of mathematical modelling to large branches of a biological community. Fundamental to such interactions is the question of how one manages the wealth of molecular detail, and where appropriate, how this detail might be incorporated into a macroscopic or population level description. In seeking answers to these questions a major objective was to attempt to identify mathematical and computational methods common to these areas, whether the individuals are molecules, cells or organisms.

Outcome and Achievements

The consensus of those who attended the programme, either as a short-term visitor or a long-term participant, is that it was very successful in achieving its stated objective of bringing together leading theoreticians and experimentalists to discuss major biological problems that may benefit from mathematical modelling and analysis. In addition the programme successfully attracted a very young group of researchers (of 238 participants, 55 were in the 22–30 age group, 99 in the 31–40 range, 52 in the 41–50 range, 26 in the 51–60 range, and 6 in the 61–70 range) of whom 52 were female.

This programme was unusual in that a major objective was to foster constructive engagement between biologists and mathematicians in order to identify some major biological problems amenable to theoretical approaches. This aspect of the programme was a resounding success, as judged by the response of the participants. Several examples of new insights and collaborations are as follows.

A minisymposium on developmental mechanics following the first workshop led to extended discussions between R Keller and H Othmer, amongst others, concerning the feasibility of mathematical modelling and simulation of the process of convergent extension in early embryonic development. This is a major process in early development, and the ability to simulate this process would lead to many new insights into the interplay between mechanics and gene expression. The end result of these discussions is a new collaboration between R Keller, H Othmer and J Dallon, a short-term participant in the programme.

One of the major themes of the second half was immunology, and we were fortunate to have the immunologists R Callard and A Yates in residence for much of the time. Their presence stimulated wide-ranging discussions involving the mathematicians N Burroughs, J Stark and D Rand, and resulted in a one-day focus meeting on current theories of T-cell selection. Stimulated by these discussions, R Callard, J Stark and A Yates have

developed a PDE model of the gene networks that control differentiation of Th1 and Th2 cells.

Many other new collaborations resulted from this meeting. Angiogenesis, which is the growth and migration toward a tumour of new vessels from a pre-existing vasculature, is currently being studied extensively both experimentally and theoretically. B Sleeman, in collaboration with H Levine, and stimulated by discussions with A Stevens, H Othmer, D Horstman, P Kulesa, R Callard and D Drasdo, has developed a new PDE model of this process. The new model predicts not only the initiation of new capillary growth but also the formation of "empty" capillaries recently found experimentally and referred to as "vasculogenic mimicry". Work has also progressed on the fundamental p53 gene, a key player in understanding avascular tumour growth. In a different vein, H Othmer and K Painter (mathematicians) and P Kulesa (developmental biologist) have begun development of a mathematical model for stripe formation in zebrafish. This is a new approach in that the theoretical work will make predictions that can be tested directly in the laboratory.

P Maini, in collaboration with F Sanchez-Garduno, B Sleeman and E Crampin, made significant progress on modelling and analysing growing domains with possible application to pattern formation during early development.

Another goal of the programme was to expose workers in one area to mathematical techniques used in other areas. A number of participants mentioned this as an unexpected benefit of their stay at the Newton Institute. For instance, techniques used in continuum modelling of chemotaxis may prove useful for those studying trail-following behaviour in insects, and similarly, widely-used methods in population dynamics may find application in the analysis of models for cell behaviour in the immune system.

Future Directions

The programme has highlighted a number of important issues and directions for the future

development of research at the interface between biology and mathematics. Some of these are as follows.

- Biological organisation at every level, from molecular to population, is based on complex networks for signal detection, transduction, processing and response, and at present there are few suitable mathematical techniques for analysing and understanding these systems. One conclusion from numerous talks and discussions is that the level of complexity observed may reflect the need for robust performance in the face of fluctuating inputs. Heretofore the mathematical focus has been on how complex the dynamical behaviour of a network can, but from a biological standpoint a better question is how complex the network must be to function robustly in a given environment. A major objective should be to identify canonical structures in networks that produce stereotypical outputs, i.e., to identify the resistors and transistors of biological networks. This requires detailed modelling of well-characterised systems to provide the basis for the development of new mathematical techniques.

- Training issues: Future success in interdisciplinary research can only be realised by increasing the pool of suitably trained young scientists. This will require cross-disciplinary training of students at a much earlier age than is currently done, and retraining of faculty for this purpose. In addition, sustained support at later stages, including postgraduate training and research, is needed.

Higher Dimensional Complex Geometry

4 February to 19 July 2002

Report from the Organisers: A Corti (Cambridge), M Gross (Warwick), M Reid (Warwick)

S Wilkinson

Left to Right: A Corti, M Gross, M Reid

Programme Overview

Algebraic geometry is the geometrical study of solutions of systems of polynomial equations. This programme was centred around 3-folds, that is, solution sets of 3 dimensions. The subject of 3-folds has received much attention in the past 20 years because of significant progress in the classification programme. The aim is to classify solution sets into three broad classes of geometry: positive, zero and negative curvature. This idea goes back to the treatment of conic sections by the Greeks and non-Euclidean geometries in the 19th century, but it is only in the past 20 years that a general picture has emerged in the context of higher-dimensional algebraic geometry. The main features of this picture have been established for 3-folds but remain conjectural for higher dimensional algebraic varieties. Today the field is moving in two main directions. One is to work out explicit consequences of the general theory for special classes of 3-folds. The other direction is to establish the general features of the theory in higher dimensions.

Algebraic geometry is a central subject in mathematics today. A trend has been established over the past 50 years where key ideas of 19th century algebraic geometry, such as moduli spaces, deformations, enumerative problems and motives, have been exported to other styles of geometry (differential, symplectic, analytic, special), PDEs, and mathematical physics, where they have been the basis for the development of major new theories. Algebraic geometry is in turn cross-fertilized by development in all these fields.

Geometry, and especially algebraic geometry, is increasingly the language of theoretical physics and string theory. A recent area of interaction and enormous activity over the past 10 years has been the field of mirror symmetry which, for mathematicians, started with some enumerations by physicists of rationally parametrised curves on Calabi–Yau 3-folds (a special class of 3-folds of zero curvature), and has been studied subsequently from many different points of view. A more recent area of interaction started with the realisation by some physicists, among them Douglas, that D-branes in type IIa string theory form a derived category, a concept first discovered by algebraic geometers in the 1960s. This trend constituted a key area of focus for the programme.

This was not the first major international event to concentrate on 3-folds: it came after symposia and meetings in Warwick (1982), Utah (1988 and 1992), Warwick again (1995) and RIMS Kyoto (1997). We can now see that these events have been instrumental in shaping the field as we know it today, each stimulating progress and anticipating some cultural change. We can hope that our programme will be recognised in the future as having been equally important.

Mathematical Themes

We describe the outcomes of the programme in more detail in the final section below. Here we sketch the main themes and how they fit in to the general advancement of the subject. We see clearly how new ideas and approaches, many significant simplifications in the theory and an increased relevance of explicit methods have arisen right across our spectrum of interests.

The programme had two central themes: the classification of all varieties, in particular the Minimal Model Programme (MMP) in 3 and 4 dimensions; and the detailed study of special classes of varieties such as Fano 3-folds, but especially Calabi–Yau 3-folds and their many relations with physics.

A famous bottleneck in the proof of MMP is the proof that flips exist. A flip is a surgery operation on varieties that occurs in codimension 2: for 3-folds this means cutting out a finite collection of curves and stitching up the variety with new curves in their place. In particular, flips are an ingredient of classification not needed in the surface case. The programme was a platform for understanding new work by Shokurov that has provided far simpler proofs in the case of 3-folds, and furnished the first proof for 4-folds. We worked through these new ideas, revisiting the foundations of the subject in this new light. In a series of lectures given in tandem by members of the programme, we worked through each part of Shokurov's manuscript. Already Corti was able to give a short course, suitable for motivated graduate students, that presented an outline of every part of a proof of 3-fold flips.

There was also a great deal of activity surrounding the study of Calabi–Yau manifolds and mirror symmetry. Calabi–Yau 3-folds occupy one slot in the classification of 3-folds, analogous to that of elliptic curves or K3 surfaces in lower dimensions. Since the late 1980s they have attracted interest because of their deep connections with string theory in physics. This programme ran in parallel with the *M-Theory* programme at the Newton Institute, which was of great benefit to us, and in fact crucial for this point of view. Gross led the work in this area, and gave a number of lectures from the mathematical point of view. There is an array of related fronts, most prominently work on derived categories, equivalences between them and the McKay correspondence, but also work on birational geometry and the Kähler cone, etc. Much of the work done in this area has been inspired by work done by physicists, many of whom attended for some part of the programme.

Organisation

The six month period of the programme was marked by three large meetings involving many visitors. Between these focal points, there was much activity among permanent and longer-term participants. We describe each component in detail below, but briefly they are as follows. During 4 weeks of January, a satellite workshop, or 'teach-in', was run by Reid in Warwick. This comprised introductory lecture courses in foundational material, as well as more specialised research talks. It was aimed at younger mathematicians and newcomers to the subject, and hoped to give them a leg-up into the subject and a life belt for use during the rest of the programme. Midway through the programme, the large Clay School focussed attention on activity related to physics, and brought dozens of young researchers to Cambridge. And towards the end, in late June, a week-long Euroconference was the climactic event of the whole programme.

These set-piece events were complemented by a great deal of activity on the main areas of the programme. Throughout the programme, Corti and Reid led efforts to work through Shokurov's proof of 4-fold flips. Gross, Douglas, Szendröi and others drove work on Calabi–Yaus. A meeting of the ABC-KLM network (amazingly, the acronym stands for "algebraic geometry and boundary conformal field theory") in May also coincided with the programme, again with mutual benefit. And, of course, there were weekly seminars – usually six a week and sometimes more, including a number of mini-series of lectures by programme participants on a specific subject.

Meetings and Workshops

Warwick Teach-in on 3-folds

Satellite Workshop at the University of Warwick, 7 January - 1 February 2002

This was a month-long school, with the purpose of helping young geometers get into 3-folds, and to prepare them and others for the programme. It involved about 20 graduate students, most of

whom came from overseas, and a similar number of other young geometers.

Each of the main organisers gave a series of seminars: Reid on classification and birational rigidity; Corti on the X-method, one of the central and much-feared technical tools of the subject; and Gross on mirror symmetry. These were very well attended, attracting both beginners and people familiar with parts of the theory but still needing warming up. The graduate students, perhaps especially the large Polish group, formed independent survival classes.

In addition, Kachi and Takagi, young researchers in the field, gave introductory lectures on birational geometry in general, and on the Shokurov approach to flips in particular. There were also research seminars, and a dozen or so talks by graduate students.

The meeting closed with a football match in which England beat the rest of the world 7–6, a feat not repeated in Japan six months later. Contemporary notes record that Reid was the most highly valued player, followed religiously by his team both on the field and afterwards at the bar.

Clay Mathematics Institute School on Geometry and String Theory

Workshop, 25 March - 19 April 2002

A report on this school appears elsewhere, but since in practice it was an important part of our programme for many of the participants, we say a few words about it here. This school was organised jointly with the *M-Theory* programme. Its subject was geometry and string theory, so it was an essential component of our Calabi–Yau stream.

The school gave intense training in many areas close to current work in string theory. The lectures were given both by mathematicians and physicists, with speakers from the two disciplines working hard to highlight the connections. For many of our participants, this school was a unique opportunity to come face-to-face with the physicists and the physics that they had known only from the mathematical point of view.

Higher Dimensional Complex Geometry

Euroconference, 24 - 28 June 2002

The EAGER-HDG conference at the Newton Institute was a major international event in algebraic geometry. It was attended by more than 100 participants. The scientific schedule centred on the main topics of the 6-month programme. While making an effort to secure a few keynote speakers well in advance, we left a large part of the schedule undecided to make room for recent progress in other areas. For instance, we heard about Voisin's recent major results on long-standing conjectures on the syzygies of canonical curves. As a result, the conference was very successful, with many interesting talks by young speakers on recent advances.

We had coordinated senior lectures surveying progress in 3-folds on birational geometry (Mella, Reid), rational connected varieties and classification (Campana, Kollár) and the flipping problem (Ambro, Kawamata). There were several impressive talks by leading young mathematicians. In particular we note Bridgeland's spectacular work on Π-stability and derived categories on K3s, and Siebert's work with Gross on smoothings of Calabi–Yau varieties. Lectures by Fantechi and graduate talks by Terouanne and Degeratu covered the McKay correspondence. Four plenary talks (and two graduate talks) were by young Romanians, three of them working collaboratively in the USA on a variety of subjects, testifying to the emergence of an outstanding group of researchers.

There was an evening of three graduate talks organised by the students covering all the keynote subjects of the conference. The students (Budur, Degeratu, Terouanne) described their research work in an informal environment that encouraged discussion.

The key aim of the meeting was to encourage Europeans, particularly scientists at the beginning of their careers, to work on 3-folds. And we regard this to mean both fundamental developments internal to the field and outside applications to other parts of mathematics and mathematical physics.

Programme participants at the Clay Mathematics Institute School on Geometry and String Theory dinner

Weekly Seminars and Mini-series

Outside conference times, we ran regular seminars, typically on Thursday and Friday afternoons, although at its height throughout the week. As well as using the Newton Institute's own advertising, we circulated details through the COW seminar series bulletins. COW is an active seminar circuit for algebraic geometry throughout the UK.

There were three mini-series, each of three lectures by a single speaker: Gross on his work with Siebert on degenerations of Calabi–Yau varieties; Ingalls on noncommutative surfaces; and Brown on the computer algebra associated with a database of polarised K3 surfaces.

Outcome and Achievements

At this stage it is too soon to judge many of the outcomes, or to determine which of the sections of the programme had the most impact. The nature of mathematical research, characterised as it is by unforeseen advances and unexpected connections, renders it futile to try to predict its course in advance.

Here we summarise some of the work that took place during the programme and was directly related to one of the main streams of the programme. Of course, there are many omissions. As usual in such meetings, many participants took the opportunity to complete outstanding work and start new collaborations, many of which we will only know about in a few years' time. Here we mention some of the papers that were completed;

for a more complete list see the appendices to this *Annual Report*.

Shokurov's Results on pl-flips

In 1999, Shokurov announced a proof of 4-fold flips, one of the main steps in the extension of classification to 4-folds. Reid edited Shokurov's 250-page manuscript and a number of people began working on it. During the programme, this document was studied in detail. At a series of 23 lectures, and with seven different speakers, each section was dissected, and we met many new ideas. Ambro, Corti, Fujino, Kawakita, McKernan, Takagi and Uehara all gave talks on parts of the proof.

An immediate outcome has been Corti's simplified proof of 3-fold flips following Shokurov's ideas. This is available in abbreviated form from Corti's webpage. Corti gave a graduate course outlining this proof. To many of us, it was amazing to see what has been a long-standing hurdle exposed at this level.

Classification

Looking first at work on flips, Corti's paper *3-fold flips after Shokurov* details a proof of 3-fold flips following Shokurov's ideas. Iskovskikh has written a first version of a paper entitled *B-divisors and functional algebras after Shokurov*. Both Ambro and Takagi have written papers following Shokurov's work and on the classification of Fano 3-folds, and Fujino has written three papers on the subject, one jointly with Takagi. Fujino also wrote a fourth paper *Algebraic fiber spaces whose general fibers are of maximal Albanese dimension.*

We are planning a book, containing our digested version of Shokurov's proof. Its precursors, the Astérisque volumes of Clemens–Kollár–Mori and Kollár *et al.*, came out of the two Utah seminars and have been the central references of the subject for a decade. Our book will follow the style of these, having chapters written by various programme participants, with overall editorial responsibility by Corti.

CL Schoen

Kollár, Smith and Corti (almost) finished a book on *Rational and nearly rational varieties* while two of the authors were together. The subject of rationality, and its close relations, has been a major component of work in classification throughout its history, and even now remains largely a mystery.

In the more explicit vein, several first drafts of papers were written around the subject of Fano 3-folds, especially from the point of view of 'unprojection'. These include a revised version of Papadakis–Reid's *Kustin–Miller unprojection without complexes*, Reid's draft *Quasi-Gorenstein unprojection* and Reid–Suzuki's *Cascades of projections from log del Pezzo surfaces*. In another application, Brown–Zucconi have written the first of a series of planned papers on the pliability of Fano 3-folds.

Many other people did important work at the Institute: Lazarsfeld, McKernan (who finished 4 papers), Mustata, Prokhorov, Shokurov and more.

Calabi–Yaus and Mirror Symmetry

One of the most active areas at present is the study of derived categories on Calabi–Yau manifolds. This has received a great deal of impetus from physics, especially in the work of Douglas, Moore, Aspinwall and others. During his stay Bridgeland carried out research into stability conditions on derived categories as suggested by Douglas. It appears likely that these ideas will provide some very exciting new methods in mirror symmetry and the study of derived categories. He also worked

together with Thomas, working out examples of this notion in symplectic geometry.

There were many other contributors to this subject: Caldararu worked with Bridgeland and Gross on various applications of derived categories to mirror symmetry; Szendröi carried out work with Grojnowski and others on automorphisms of derived categories; Kawamata applied methods of derived categories to study birational geometry in higher dimensions; and Horja worked on automorphisms of derived categories. Nakajima also studied automorphisms of derived categories of moduli of K3 surfaces.

In the general area of mirror symmetry, Barannikov gave several lectures at the Clay School on his approach to higher dimensional mirror symmetry. Batyrev and Matverov continued work on toric aspects of mirror symmetry, in particular writing the paper *Mixed toric residues and Calabi–Yau complete intersections*. Gross and Siebert continued their work on a new approach to mirror symmetry using log geometry which provides an algebro-geometric version of the Strominger–Yau–Zaslow conjecture. An initial version of the resulting huge paper is expected in the next few months, and the programme included four talks on this exciting subject. Kawamata wrote a first version of his paper *D-equivalence is K-equivalence* (available as math.AG/0205287) while at the programme.

In a more physical vein, Wendland and van Enckevort worked on the boundary between string theory and algebraic geometry, and Donagi also participated in the *Strings 2002* conference (see the report on the *M-Theory* programme).

There was also some activity concerning manifolds of special holonomy of a different type: Sawon and O'Grady studied hyperkähler manifolds, while Kovalev developed a new construction of G2 manifolds, resulting in a paper *Coassociative K3 fibrations of compact G2 manifolds*.

In a more arithmetic direction, Yui studied L-functions of Calabi–Yau manifolds, writing four

papers in total. Schoen, in three papers, studied their Brauer groups and associated Tate–Shafarevich groups. Schoen and Thomas started a collaboration based on Thomas' ideas on nodes and algebraic cycles.

Finally, with two of the authors at the programme, a new textbook *Calabi–Yau manifolds and related geometries* by Gross, Huybrechts and Joyce was completed.

Warwick Teach-in on 3-folds

The Warwick satellite workshop brought together many young researchers, and several learned of new problems there that may well become part of their theses. And a number of PhD students were actually able to complete their theses. Warwick students Leng and Ryder were both regular visitors, and both collaborated substantially with other visitors to complete their theses. Leng's work on the McKay correspondence may be seen as the first steps in an ambitious extension of the project. Ryder's work with Corti, Reid and Takagi sets much of Cheltsov's work on elliptic and K3 fibrations on solid footing, working out very substantial examples. Tokyo student Suzuki collaborated with many of the participants on her thesis, especially in her work on classification of Fano 3-folds of higher Fano index.

M-Theory

4 February to 19 July 2002

Report from the Organisers:
RH Dijkgraaf (Amsterdam), M Douglas (Rutgers), JP Gauntlett (Queen Mary), C Hull (Queen Mary)

S Wilkinson

Left to right: JP Gauntlett, M Douglas, C Hull

Scientific Background

Einstein's theory of gravity is not consistent with quantum mechanics – it cannot be quantised – and superstring theory is the only theory we have that provides a consistent quantum description of gravity. Moreover, it unifies gravity with the other forces, and so is a theory that could provide a unified description of all the forces and all the matter in the universe. To find a quantum theory of gravity and to find a unified theory of all the forces and particles of nature are the two main goals of current work in fundamental physics and it is remarkable that string theory has the possibility of solving both problems simultaneously.

There are five distinct superstring theories, all giving quantum theories of gravity. Discoveries in the mid-90's led to the conclusion that all five arise as different limits of a single theory, which has come to be known as M-theory. This conclusion came as a complete surprise, and had a dramatic impact on theoretical physics.

This "second superstring revolution" revealed remarkable connections between the various forms of the theory, leading to solutions of previously intractable problems. The most famous such solution, from 1994, was the Seiberg–Witten solution of $N = 2$ supersymmetric Yang–Mills theory, which produced the first analytic understanding of confinement in a four-dimensional gauge theory. This had important mathematical consequences as well, namely new four-manifold invariants which were comparable to but far simpler than those previously defined by Donaldson. This result was just the tip of an iceberg: it was soon found how to rederive it from string theory and M-theory in several ways, and it now forms part of a rich picture involving many inter-related supersymmetric theories arising from stringy geometry. The new picture goes far beyond strings in that it includes "branes", extended objects like the string but of higher dimension. These branes had been somewhat neglected in the early developments as, unlike the string, they cannot be used as the fundamental defining objects in the theory, but this is directly analogous to the status of instantons and monopoles in gauge theory, which turned out to be extremely important there. Indeed, the branes turn out to be key in all the recent developments. Moreover, it was learned that the non-perturbative structure of string theories is governed by new symmetries, called U-dualities.

Much has been learned about those special sectors of M-theory that can be described by string theories or supergravity theories, and of the remarkable duality symmetries that relate such sectors, but much of M-theory remains a mystery. We have as yet no definition or formulation of the theory, and do not even know what the fundamental degrees of freedom should be. It seems likely that our notions of space and time will have to be modified, bringing in new mathematical structures such as non-commutative geometry, which has recently been shown to play an important role. An important clue has been found in the recent discovery that M-theory, at least in certain backgrounds, has a "holographic" description in

terms of a simple non-gravitational gauge theory or matrix theory.

The principal aim of the programme was to investigate the structure of M-theory, seeking clues as to its fundamental formulation and unravelling its physical consequences.

S Wilkinson

A Ozer

Organisation

The planning was shared between the four organisers, with C Hull the principal organiser. M Douglas, C Hull and JP Gauntlett were present for the entire workshop and shared the running of the programme. RH Dijkgraaf was unfortunately unable to attend as much as he had originally planned but played an active role, especially in the running of the Clay School.

For most of the programme, we had two seminars a week, on Tuesday and Thursday afternoons, which were well-attended. The rest of the time was left free to give participants time to continue their own research and to carry on more informal discussions. We also had two outstanding colloquia, given by RH Dijkgraaf and G Gibbons.

We had three major meetings. The programme started with a workshop on *M-Theory, Gravity and Geometry* held from 11–15 February 2002 which helped ensure that there was full participation in the problematic early period of the programme. The *Clay Mathematics Institute School on Geometry and String Theory*, run jointly with the organisers of the *Higher Dimensional*

Complex Geometry programme, was held from 25 March – 19 April 2002 and was a major focus of the programme, catalysing much fruitful interaction between the participants of the two concurrent programmes. The grand finale was *Strings 2002*, the annual international conference in string theory held at the Cavendish Laboratory, Cambridge, 15–20 July 2002, which attracted nearly 500 people from around the world and was the most important string theory conference of 2002.

Participation and Benefits

The programme was fortunate to have around 105 long-stay participants staying for periods of between three weeks and six months. In addition, there were about twenty short-stay participants. The programme ran at full capacity for almost its entire duration.

The programme proved very popular and there was a large number of people from around the world wanting to participate. Many people wanted to come in the period between the end of the US teaching year in mid-May and the strings conference in July. This made the job of the organisers in choosing whom to invite and for how long rather difficult, but we were pleased that most of the world's leading string theorists were able to attend. Many participants came for less than a month – one common concern was whether the facilities would allow them to work as effectively at the Newton Institute as at their home institution – but many were favourably impressed and said that if they had known how well things worked at the Institute, they would have wanted to come for longer.

Participants were in great demand to give seminars and lectures at other UK universities, and the availability of so many stars of the field was of considerable benefit for the UK community. Indeed, members of the UK community are now much encouraged to apply to hold future M-theory programmes at the Institute.

Meetings and Workshops

M-Theory, Gravity and Geometry

European Superstring Theory Network Meeting, 11-15 February 2002

Organisers: C Hull, JP Gauntlett, M Perry, D Waldram

This was the third network meeting for the European Superstring Theory Network, and was sponsored by the European Union. This was a very successful meeting with around 80 participants and a full programme of research talks. The transparencies from the talks were eventually posted on the meeting's web-page.

Clay Mathematics Institute School on Geometry and String Theory

Workshop, 25 March - 19 April 2002

Organisers: M Douglas, A Corti, R Dijkgraaf, J Gauntlett, M Gross, C Hull, A Jaffe, M Reid

This was run jointly with the organisers of the *Higher Dimensional Complex Geometry* programme, and the organising committee consisted of the organisers of the two programmes, working with A Jaffe of the Clay Institute. M Douglas, as the principal organiser of the school, put in considerable effort to make it so successful. The Clay Mathematics Institute provided generous funding for the school, enabling us to attract excellent students and lecturers.

Formal agreements for the school were finalised in February 2001, and the next few months were spent in planning and lining up speakers. Many top people were already planning to come to one of the workshops, and the prospect seemed sufficiently attractive to enough others to make attracting speakers fairly easy, even without offering any compensation beyond expenses. Indeed, we were able to get many of the leaders in our fields. Almost all of the committed speakers were able to attend, though one was stopped by difficulties related to the US green card procedures.

Nearly sixty students participated, roughly half mathematicians and half physicists. Many local students and academics attended the lectures as well. Attendance was limited to 120 by the size of the lecture hall, a bound we attained a few times, but we did not need to turn people away. Most lectures had 70–80 in attendance.

String theory is a popular subject with two or three major schools devoted to it every year. Comparing this school with others on the interface between mathematics and physics, its main distinguishing feature was that it did not focus on a small area of common interest but rather discussed a broad variety of topics, loosely grouped in the following three categories: manifolds of special holonomy, derived categories and the McKay correspondence, and mirror symmetry. In addition, there were more general lectures introducing the key ideas and background material on both the physics and mathematics sides.

We had four lectures each day (except for March 29 before the Easter holiday), three of 90 minutes and a final late afternoon lecture of 60 minutes. Most of these were lecture series with about 15 seminars on more current research. We also had a poster session to allow students to present their own work.

There was an active social programme which centred around a series of four dinners. In addition we had a punting expedition, bus excursions to London and to East Anglia and football matches involving both students and lecturers. The participants, both students and speakers, were very enthusiastic about the social programme and it was an important contribution to the school's success.

It is planned to publish the contents of the lectures. This will probably be in two volumes, with the AMS publishing a monograph on derived categories, the McKay correspondence, mirror symmetry and related matters, and a separate volume covering the other lectures.

Strings 2002

Conference, 15-20 July 2002

Principal organiser: M Green

The climax of the programme was the annual

international conference in string theory. This attracted nearly 500 people from around the world and was the most important string theory conference of 2002. The number of participants involved led to special problems, as it was hard to find suitable venues for a conference of that size. The conference sessions were in the end held at the Cavendish Laboratory, and the Newton Institute was not in-volved in the organisation of the meeting. However, all of the organisers of the programme were also members of the conference organising committees. Further information, together with transparencies of the talks, is available on the conference website

http://www.damtp.cam.ac.uk/strings2002

Outcome and Achievements

The programme was an international event of high significance for the field, as were the Clay School and the Strings 2002 conference. For the duration of the programme, Cambridge was the international focal point for string theory. UK scientists benefitted strongly through establishing new contacts and collaborations. Many students and researchers attended from across the UK.

Significant work was carried out during the programme on the following inter-related topics:

- Calabi–Yau manifolds and manifolds of special holonomy

- Derived categories of coherent sheaves and the McKay correspondence

- Geometry of M-theory solutions and their modifications due to branes

- D-geometry and conformal field theory

- Supersymmetric geometry and calibrations

- Holography and the correspondence between quantum gravity or string theory in anti-de Sitter space and conformal field theory on the boundary

- Duality symmetries and mirror symmetry

- String theory in plane wave geometries and the implications for gauge theory

- Time-dependent solutions, de Sitter space and cosmology in M-theory

- Topological field theory

- Black holes and the microscopic origin of entropy

10th Anniversary Year 2001-2002

This year the Newton Institute celebrates its tenth anniversary as a national resource for research in the mathematical sciences since it was opened in 1992 by HRH the Duke of Edinburgh. A special day of celebration on 2 July 2002 included four keynote lectures:

- Professor Sir Martin Rees – *Progress and Challenges in Modelling Cosmic Phenomena*

- Professor Charles Elliott – *Interface and Free Boundaries in (and between) Modelling, Analysis and Computation*

- Professor John Coates – *Elliptic Curves*

- Professor Adrian Smith – *Bayes: Little Theorem, Big World*

The day finished with the inaugural lecture of the Director, Sir John Kingman, as the new NM Rothschild & Sons Professor of Mathematical Sciences. This was entitled *Mathematics for the Twenty-First Century* and was held in the Senate House at the University of Cambridge, attended by many friends (old and new) of the Institute.

S Wilkinson
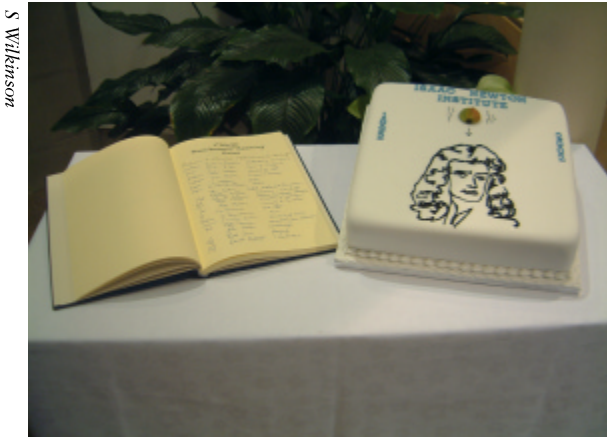
The Visitors Book and 10th Anniversary cake depicting Isaac Newton and a falling apple

Over lunch, a meeting of the Institute's UK Correspondents (see p 6) took place. This was well attended by Correspondents from many institutions, and took the form of a presentation on the work of the Institute and the role of the Correspondents. A very constructive and wide-ranging, two-way discussion focussing particularly on communication with UK universities took place.

Several events for the general public are also planned to take place in 2002 as part of the Anniversary celebrations, but these fall into the Institute year 2002–2003 and will be reported in the next *Annual Report*.

Programmes of the Newton Institute 1992 - 2002

Over the last 10 years the Institute has organised 46 programmes in different areas of mathematics and the mathematical sciences, many of them involving new applications to areas as disparate as genetics and gravity, finance and food. A complete list of past programmes is shown here.

1 Low Dimensional Topology and Quantum Field Theory 01/07/92–31/12/92

2 Dynamo Theory 01/07/92–31/12/92

3 L-functions and Arithmetic 01/01/93–30/06/93

4 Epidemic Models 01/01/93–30/06/93

5 Computer Vision 01/07/93–31/12/93

6 Random Spatial Process 01/07/93–31/12/93

7 Geometry and Gravity 01/01/94–30/06/94

8 Cellular Automata Aggregation and Growth 01/01/94–30/06/94

9 Topological Defects 01/07/94–31/12/94

10 Symplectic Geometry 01/07/94–31/12/94

11 Exponential Asymptotics 01/01/95–30/06/95

12 Financial Mathematics 01/01/95–30/06/95

13 Semantics of Computation 01/07/95–31/12/95

14 From Finite to Infinite Dimensional Dynamical Systems 01/07/95–31/12/95

15 Dynamics of Complex Fluids 01/01/96–30/06/96

16 Computer Security, Cryptology and Coding Theory 01/01/96–30/06/96

17 Mathematics of Atmosphere and Ocean Dynamics 08/07/96–19/12/96

18 Mathematical Modelling of Plankton Population Dynamics 29/07/96–04/09/96

19 Four-Dimensional Geometry and Quantum Field Theory 04/11/96–13/12/96

20 Representation Theory of Algebraic Groups and Related Finite Groups 05/01/97–07/07/97

21 Non-Perturbative Aspects of Quantum Field Theory 05/01/97–07/07/97

22 Disordered Systems and Quantum Chaos 21/07/97–19/12/97

23 Neural Networks and Machine Learning 21/07/97–19/12/97

24 Dynamics of Astrophysical Discs 05/01/98–03/07/98

25 Arithmetic Geometry 05/01/98–03/07/98

26 Nonlinear and Nonstationary Signal Processing 21/07/98–19/12/98

27 Biomolecular Function and Evolution in the Context of the Genome Project 21/07/98–19/12/98

28 Mathematics and Applications of Fractals 06/01/99–23/04/99

29 Turbulence 04/01/99–02/07/99

30 Complexity, Computation and the Physics of Information 10/05/99–20/08/99

31 Structure Formation in the Universe 19/07/99–17/12/99

32 Mathematical Developments in Solid Mechanics and Materials Science 06/09/00–17/12/00

33 Ergodic Theory, Geometric Rigidity and Number Theory 05/01/00–07/07/00

34 Strongly Correlated Electron Systems 05/01/00–07/07/00

35 Free Boundary Problems in Industry 17/07/00–04/08/00

36 Quantized Vortex Dynamics and Superfluid Turbulence 07/08/00–25/08/00

37 Singularity Theory 24/07/00–22/12/00

38 Geometry and Topology of Fluid Flows 04/09/00–17/12/00

39 Symmetric Functions and Macdonald Polynomials 08/01/01–06/07/01

40 Nonlinear Partial Differential Equations 08/01/01–06/07/01

41 Managing Uncertainty – New Analysis Tools for Insurance, Economics and Finance 13/07/01–10/08/01

42 Surface Water Waves 13/08/01–31/08/01

43 Integrable Systems 23/07/01–19/12/01

44 From Individual to Collective Behaviour in Biological Systems 10/09/01–19/12/01

45 Higher Dimensional Complex Geometry 04/02/02–19/07/02

46 M-Theory 04/02/02–19/07/02

Finances

Accounts for July 2001 to June 2002 (Institute Year 10)

Income	2000/2001 Year 9	2001/2002 Year 10
Grant Income – Revenue	1,351,271	1,247,710
Grant Income – Workshop	273,533	377,796
Trust Fund Income	20,097	78,975
Donations – Revenue	9,091	604
Interest on Deposits	86,801	31,901
General Income	5,435	5,066
Housing	18,199	10,938
Total Income	**1,764,427**	**1,752,990**

Expenditure		
Scientific Salaries	326,963	331,912
Scientific Travel and Subsistence	391,170	410,712
Scientific Workshop Expenditure	220,788	288,281
Other Scientific Costs	18,552	16,701
Staff Costs (Payroll)	275,460	290,285
Staff Costs (Contract and Agency)	22,272	18,789
Computing Costs	151,438	57,118
Library Costs	12,973	11,577
Building – Rent	201,572	221,258
Building – Repair and Maintenance	7,447	13,042
University Overheads	30,752	30,597
Consumables	35,710	28,113
Equipment – Capital	4,508	16,819
Equipment – Repair and Maintenance	7,110	4,819
Publicity	16,660	12,253
Recruitment Costs	3,453	3,761
Total Expenditure	**1,726,828**	**1,756,037**
Operating Surplus / (Deficit)	**37,599**	**(3,047)**
Transfer to Building Capital Fund	(41,697)	(4,964)
Transfer (to) / from Reprovision	(62,173)	21,829
Total Surplus / (Deficit)	**(66,271)**	**13,818**

Notes to Accounts

1. Restatement of Accounts
These figures (including last year's) have been restated to present the information in a format based on the Statement of Recommended Practice.

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

	2000/2001 Year 9	2001/2002 Year 10
EPSRC/PPARC Salaries	345,825	344,992
EPSRC/PPARC Travel and Subsistence	268,108	298,112
EPSRC PUS	8,570	0
EPSRC JREI	92,225	0
Trinity College (Isaac Newton Trust)	100,000	100,000
Hewlett-Packard	115,000	115,000
CNRS	37,413	25,668
Leverhulme	78,867	79,513
LMS	20,000	20,000
Cambridge Philosophical Society	2,000	2,250
Daiwa Anglo-Japanese Foundation	6,926	3,074
University of Cambridge (Staff)	74,765	37,843
University of Cambridge (Rent)	201,572	221,258
Total	**1,351,271**	**1,247,710**

3. Trust Fund Income
This breaks down as follows:

	2000/2001 Year 9	2001/2002 Year 10
Rothschild – Visiting Professors	20,097	25,655
Rothschild – Director	0	53,320
Total	**20,097**	**78,975**

4. Donations - Revenue
Funds received from the Cambridge Foundation and Cambridge University Development Office.

5. Housing
This is the net figure of income and expenditure and is lower than the previous year mainly due to reduced income during the closure period in January 2002.

6. Scientific Salaries
This includes EPSRC/PPARC fellowships, Rothschild Professors, the Hewlett-Packard Senior Fellow, the Director and the Deputy Director.

7. Building - Rent
This is the rental for both the main and Gatehouse buildings, and is covered by a grant from the University of Cambridge. The University also pays for all gas, electricity and rates, which have not been included.

8. Consumables

This includes postage, stationery, photocopying, catering, etc., and has reduced as a result of much information now being available on the Institute website.

9. Equipment - Capital

Purchase of two new photocopiers, desk lamps, chairs and security monitoring equipment.

10. Publicity

Costs for the production of the Annual Report, Institute brochures and any other outsourced printing. Year 9's figure includes some costs from the *Posters in the London Underground* campaign.

11. Donations in Kind

Computer equipment has in the past been donated by Hewlett-Packard, Apple UK and Silicon Graphics. Sun Microsystems has made many generous donations in recent years and has also sold equipment to the Institute at a very substantial discount.

Software has been donated by NAG, Claris and Wolfram Research.

Over 4,000 books and journals have been donated by a large number of publishers and individual members of the mathematical community.

Cumulative Financial Grants and Donations

SERC/EPSRC/PPARC	£9,248k	over 16 years
Trinity College (Isaac Newton Trust)	£2,510k	over 12 years
NM Rothschild and Sons	£2,083k	over 10 years
Anonymous Donation	£1,065k	
Hewlett-Packard	£1,065k	over 10 years
Dill Faulkes Foundation	£1,000k	
St John's College	£750k	over 5 years
NATO	£728k	over 10 years
European Union	£728k	over 11 years
Leverhulme Trust	£615k	over 9 years
University of Cambridge	£543k	over 11 years
Le Centre Nationale de la Recherche Scientifique	£435k	over 10 years
Rosenbaum Foundation	£330k	over 7 years
PF Charitable Trust	£240k	over 3 years
London Mathematical Society	£221k	over 12 years
Clay Mathematics Institute	£152k	
Gonville and Caius College	£100k	
Prudential Corporation plc	£100k	over 4 years
Institute of Physics	£68k	over 7 years
British Meteorological Office	£64k	
Nuffield Foundation	£57k	
TSUNAMI	£40k	
Daiwa Anglo-Japanese Foundation	£36k	over 4 years
AFCU (Hamish Maxwell): $50k	£32k	
AFCU (Anonymous Donation): $50k	£32k	
Emmanuel College	£30k	
Jesus College	£30k	over 6 years
British Aerospace	£25k	
Rolls Royce	£25k	
Cambridge Philosophical Society	£25k	over 10 years
Corporate Members (FIN programme)	£22k	
British Gas	£20k	
DERA	£20k	
Magnox Electric	£20k	
Paul Zucherman Trust	£20k	
Thriplow Trust	£18k	
Schlumberger	£17k	
Bank of England	£15k	
Wellcome Trust	£15k	
Benfield Greig	£10k	
NERC	£10k	
Unilever	£10k	
Applied Probability Trust	£10k	over 3 years