Institution: Newcastle University

Unit of Assessment: UOA10 Mathematics and Statistics

a. Overview

Newcastle is one of 20 institutions that submitted to each of the three mathematics UOAs in RAE 2008. Since 2008 we have continued to build on strengths throughout the mathematical sciences, with three new junior appointments (**Bocklandt, Kolb** and **Parker**) and two senior part-time appointments (**Soward** and **Young**). Staff returned for UOA 10 are all members of the School of Mathematics and Statistics within which there are three themed research groups.

Applied mathematics: The principal research areas in applied mathematics are astrophysical fluids (**Shukurov**, **Soward**, **Campbell**, **Sarson**, **Fletcher** and **Bushby**), cosmology (**Moss** and **Toms**) and quantum fluids (**Barenghi**, **Proukakis**, **Parker** and **White**). The research consists of the innovative design of mathematical models for physical processes guided by data from observations and experiments.

Pure mathematics: The research areas of the pure mathematics group are wide-ranging, covering homological algebra and representation theory (**Jorgensen**, **Bocklandt, Kolb**), group theory, geometry and analysis (**Young**, **Rees**, **Lykova, Duncan, Dritschel, King, White, Vdovina**).

Statistics: The research of the statistics group lies predominantly at the interface between theory and practice, with focus on generic methodology motivated by substantive problems. The main themes are biostatistics (**Henderson, Matthews**, **Shi**) and statistical bioinformatics and stochastic systems biology (**Wilkinson**, **Boys, Avery, Farrow, Gillespie, Golightly, Nye).**

Each group maintains a strong collegiate culture and research across the group structures is also actively encouraged. Many publications are multidisciplinary, with authorships spread between different groups. This commitment to multidisciplinary research extends beyond the School and the University, with links to areas of biology, computing science, physics, chemistry and medicine.

b. Research strategy

The long-standing vision driving the research strategy of UoA 10 at Newcastle University has been to pursue fundamental and rigorous mathematical and statistical research which is informed, stimulated, and extended through its application in a wide range of scientific disciplines and practical applications.

Current strategic plans

Our strategy in applied mathematics is to maintain the focus of the group on astrophysical and quantum fluids whilst building up research capability and capacity by making at least two new staff appointments. We plan to follow up on our successful investment in the LOFAR radio-telescope project with participation in the €1.5bn Square Kilometre Array. This instrument will dominate the world of radio astronomy, providing data that will enable our group to make new advances in theoretical astrophysics. In quantum fluids, we will develop the strength and reputation of our new *Joint Quantum Centre*, established with theoreticians and experimentalists in physics and chemistry at Durham University. The *Joint Quantum Centre* is a major initiative, with 60 staff and PhD students working in a key field of fundamental science with the potential for practical applications to metrology and information technology. We will continue to work on ultra-cold gases and other areas of quantum science by building up theoretical models with a view to applications such as next-generation interferometric sensors.

In pure mathematics our strategy involves a combination of continued development of core research in algebra and analysis, together with an increased focus on the application of rigorous

mathematics in other areas. For example, we will build on work in quantum computing and cryptography alongside colleagues in computer science. We will also ensure increased collaboration between pure mathematicians and our applied and statistical colleagues, an example here being our current work on the algebra of phylogenetic trees. Our aim is to break down traditional fragmentation and increase the prominence of trans-disciplinary research making best use of the modern pure mathematical methodology. A research Chair in pure mathematics is being advertised at the time of writing.

Our strategy for statistics involves concentrating on the established strength and standing of statistical bioinformatics research at Newcastle and collaborating with computing colleagues on methodology for the analysis of big data. This research aligns well with Newcastle University's research priorities, and the School already has strong research links with the University's Digital Institute, the Institute for Ageing and Health, and the Environmental Engineering research group. We will continue growing our leading Centre for Bioinfomatics and Stochastic Systems Biology and at the same time manage an increased contribution to research activities elsewhere in the University. We will give equal recognition to research-active staff whether focused on disciplinary research or contributing energetically to University-aligned themes. A new professorial post was agreed by the University in 2013 and pro-active recruitment is underway.

The Industrial Statistics Research Unit, ISRU, which is based in the School, offers an external consultancy service based on applied statistical research. We plan to increase the links between ISRU and our academic research whilst maintaining ISRU's predominantly outward-looking focus. We will make more use of ISRU as a vehicle to ensure that our research has impact beyond academia.

RAE2008 Objectives

A number of strategic objectives were identified in RAE2008 for each of the units making up the present UOA: Applied Mathematics UOA21; Pure Mathematics UOA20; Statistics UOA22. Our progress against these objectives is described below:

Objective 1: to integrate our mathematical modeling with experiment or observations (UOA21)

Astrophysical fluids models MHD processes in planets, stars and galaxies. Highlights during the REF period include new models of the solar dynamo, new models of the origin and structure of magnetic fields in the interstellar medium and the exploration of magnetic fields in galaxies through radio-telescope observations (**Shukurov**, **Sarson**, **Fletcher**, **Bushby**). Advances made by **Moss** on observational predictions of early universe cosmology have contributed to STFC funding a Newcastle-Durham (mathematics) consortium to work on Particle, Fields and Spacetime.

The mathematical modeling of quantum fluids, based in our new *Joint Quantum Centre*, is used to interpret experiments on Bose–Einstein condensates and superfluidity at laboratories located in major Universities, including Durham, Manchester, Lancaster, Paris, Amsterdam, Chicago and Vienna. **Barenghi** is an international leader in the applications of fluid dynamics in low temperature physics. His work has been recognised through his election to a Fellowship of the American Physical Society. **Proukakis** has made substantial advances in modeling non-equilibrium phenomena in degenerate atomic Bose gases, working alongside **Parker,** who was appointed during the REF period to strengthen research in this area and **White,** who was awarded a personal EPSRC Fellowship.

Objective 2: to build up strengths in numerical modeling (UOA21)

We have been awarded substantial computing resources on the CSC Espoo (Finland) for Galactic dynamo simulations (**Shukurov**, **Fletcher**, **Sarson**), on HECToR for state-of-the-art solar MHD simulations (**Bushby**) and for vortex simulations (**White**). **Sarson** is a CI on the UKMHD High Performance Computing consortium which received a Royal Astronomical Society achievement award in 2013.

Objective 3: to make an appointment in homological algebra and representation theory (UOA20)

Newcastle has made a significant investment in pure mathematics through the appointment of lecturers **Bocklandt** and **Kolb** to work alongside **Jorgensen** on homological algebra and representation theory. The International Review of Mathematical Sciences 2010 recognised this on page 16: "In addition to already established research groups in algebra, strong groups have grown recently (for example, at Aberdeen, East Anglia, Kent and Newcastle)".

Objective 4: to improve grant income (UOA20)

Our strategic focus on applying mathematics to other areas can be seen in our approach to research funding. The £500K EPSRC grant (**Rees**, **Duncan**, **Vdovina**) funded interdisciplinary research into the Foundations of Quantum Computation, linking pure mathematicians and computer scientists in Newcastle, Edinburgh, Glasgow, Manchester, York, and New Jersey. **Vdovina** is part of a joint Newcastle-Durham team with £500K funding from EPSRC working on the geometry of simplicial complexes. New appointee **Kolb** has obtained £100K EPSRC funding for a project on representation theory and integrability.

Objective 5: to concentrate on statistical bioinformatics and applied statistics (UOA22)

The £350K BBSRC-funded CaliBayes project (**Wilkinson**, **Boys**) has led to the development of a range of computationally intensive Bayesian statistical methods for estimating and calibrating intractable stochastic models of dynamical biological systems. **Wilkinson** was awarded a BBSRC fellowship for three years to work on stochastic models of biological systems and his pioneering work on robotic genetics approaches to yeast biology has been funded by the BBSRC, MRC and Wellcome trust. **Boys** and **Nye** have been participating in a €2m ERC project to study eukaryotic genomic origins and **Nye** has also developed a novel method for performing principal components analysis within the geometrical space of phylogenetic trees.

Objective 6: to contribute to methodological research motivated by applied problems (UOA22)

Applied statistics at Newcastle is predominantly related to biological or medical applications. Research takes place at the interface of theory and practice and we have made significant contributions to both statistical methodology and clinical understanding. For example, **Shi** and **Henderson** have proposed methods to analyse marginal model bias and model uncertainty bias simultaneously for nonlinear models with missing data. This can be applied to solve many different types of model misspecification problems. **Boys, Wilkinson** and colleagues devised a method for estimation of parameters for a stochastic model for mitochondrial DNA population dynamics using experimental data on deletion mutation accumulation.

c. People

i. Staffing strategy and staff development

Staffing strategy Three new lecturers have been appointed since RAE2008. Recruitment for these posts has followed the research strategy by focusing on astrophysical and quantum fluids in applied mathematics and appointing in the areas of homological algebra and representation theory in pure mathematics. The appointees were selected from a strong list of international applicants for each post. We have also recruited the applied mathematician and Fellow of the Royal Society **Soward** to rejoin the applied group on a part-time basis as well as the experienced analyst **Young** to join the pure group. These leading figures bring a wealth of experience and enthusiasm which has invigorated our research culture.

We are in the process of appointing new professors in both statistics and pure mathematics. In the very near future, at least three additional lectureships will be used to strengthen our position in the areas mentioned in our research strategy: astrophysical and quantum fluids, biostatistics and big data. At the same time as taking the planned strategic approach, we value flexibility and will remain vigilant and proactive to opportunities in new areas of research related to those already mentioned.

Staff development The School promotes an active research culture and provides generous support for individual researchers. For academic staff, the School allocates workload hours for personal research to account nominally for 50% of time in the School workload model. As well as core research, additional workload hours are allocated for postgraduate and postdoctoral supervision, and for the development of major grant applications. New members of staff are given extra research hours in the School workload model over their first four years and hence reduced teaching and administration as they build independent research profiles. A formal mentoring system is used for advice and guidance of new appointees.

Annual personal development reviews are used to determine measures to facilitate staff in their research, for example by making adjustments to workload, and to discuss career progression. Since RAE2008, two members of staff have been promoted to Senior Lectureships, three to Personal Readerships and two to Personal Chairs. An exemplar of rapid career development for exceptional individuals is provided by **Proukakis,** who was instrumental in setting up the *Joint Quantum Centre*, and was promoted to Reader in 2009 and Professor in 2013.

The School invests a substantial amount of its income from all sources into supporting research. All research active members of staff are entitled to regular sabbaticals on full pay for one semester, historically every nine or ten semesters but imminently every seven semesters following a change in School policy. This was in recognition of their important contribution to the School's research culture. Principal Investigators receive grant-earned overheads without any RCUK reductions, and 15% of overheads are paid directly into investigators' personal research support accounts, for use for academic purposes at their discretion. Each member of academic staff has a personal research support allocation from School funds.

Research Assistants Responsibility for supporting the career development of research assistants lies with the Director for Research, who works in conjunction with the Principal Investigator when the researcher is employed on a research grant. Research assistants are fully integrated into our research groups and share the same facilities. They are given the opportunity to teach or support, one module per year on behalf of their supervisor. Research staff also have access to the Career Pathways Framework programme run by the Faculty. The success of our approach is evidenced by the fact that 76% of RAs finishing their contracts during the REF period remain in academia. An additional two RAs who finished in 2007 also have full-time academic positions.

The Career Pathways Framework for Research Staff is a programme to assist research staff in planning their career development activities, inside or outside academia. Specific Career Development Workshops have been designed to complement our Career Pathways Scheme for staff at key points in the first two years of their research career. Researchers can request a Career Pathways Review with an independent trained adviser. The review looks specifically at the researcher's previous progress, outputs, skills and aptitude for research and explores their future career trajectory, advising on the most appropriate pathway for the researcher and their actions needed to follow this.

Concordat to Support the Career Development of Researchers In September 2010, Newcastle University secured its place as one of the first Universities in the UK and Europe to be awarded the HR Excellence in Research Award. This award was the result of the University's early work to champion the Concordat to support the career development of researchers by conducting a review of policies and practices against the principles of the Concordat in 2009, followed by their redesign to ensure they were concordat compatible, and later the institution-wide implementation of new policies and Performance Development Review processes. Following a recent review, the University has retained the award for a further two years until 2014.

Personal Research Fellowships During the evaluation period **Wilkinson** had a three-year full-time BBSRC Research Development Fellowship and **White** was awarded a three-year EPSRC Personal Fellowship, both held in Newcastle.

International staff and visiting scholars The School of Mathematics and Statistics currently has 11 international members of academic staff and 5 research assistants whose country of origin lies outside the UK. During the REF period, one international member of staff retired and two new international staff members were appointed, one each from Belgium and Germany.

The School has a substantial visitor programme funded by grants and School funds. These visits vary from a few days to several months. Distinguished visitors during the assessment period have included Rainer Beck (Max Plank Institute, Germany), Paul Davies (Arizona State, USA), Mihai Putinar (California, USA) and Jim Agler (California, USA). Over 60 leading scientists from outside the UK have made visits from institutions including Moscow State University, Lebedev Institute, Russian, Polish and Czech Academies of Science, Ecole Normal Paris, Heidelberg, Potsdam, Niels Bohr Institute, Toronto, Nanjing, MIT, UCSB, Georgia Tech and Texas Tech. Many of the visits lead to publications in highly ranked journals.

Equalities and diversity The policies adopted by Newcastle University on equality and diversity are described in *Single Equality Scheme and Action Plan*, available on the Equality and Diversity University web site. This document sets out how Newcastle University plans to meet its duties under diversity legislation and to follow best practice in all areas. Equality impact assessments are made on academic staff promotions and REF submissions. The School's responsibilities for equality and diversity are monitored by our Athena Swan Committee. Key members of staff in the School of Mathematics and Statistics, including the Director of Research and Head of School, have received formal training in equality and diversity.

In January 2009, the University signed up to the Athena Swan Charter and was granted an institutional Bronze award in September 2009. The University has set itself an institutional objective to achieve Silver award status by 2015 and individual units are also now supported in achieving these awards. The School of Mathematics and Statistics submitted an application for the bronze award in November 2013.

ii. Research students

Recruitment Our recruitment strategy is to accept only the best students, with the minimum of a first class honours degree in a mathematical science at MMath level or its equivalent, to work in the areas described by our research strategy. UK student numbers are limited primarily by the number of funded studentships we have available. School funds are used to increase the number of funded places by an extra one or two per year, and to boost recruitment through undergraduate vacation studentships (25 in four years). We are close to completing plans to expand international student numbers by offering an integrated PhD programme which has more academic courses and a longer duration than the traditional programme.

Training and support mechanisms Postgraduate training is jointly planned and delivered by the School and the SAgE Faculty Researcher Development Programme. The first of a student's two supervisors has previous experience of successful doctoral supervision and takes primary responsibility, meeting the student at least weekly. Both supervisors have regular meetings with the student. The University ensures that all supervisors are appropriately qualified, research active and well-trained. New staff study for a Certificate of Advanced Studies in Academic Practice.

Students participate in weekly research seminars, the student-run Postgraduate Forum, regional seminars and conferences. Statisticians attend annual week-long intensive courses held jointly with Durham, plus two Academy for Postgraduate Training in Statistics courses in year one, and the EPSRC/RSS-sponsored Graduate Training Programme (GTP) courses in years two and three. Pure and applied mathematicians take 100 hours of remote-access EPSRC MAGIC courses, assessed centrally by take-home examination. Newcastle set up and hosts the EPSRC/RSS GTP courses (a new, advanced, national programme, extending the more basic courses offered by Taught Course Centres TCCs), was involved in MAGIC from the outset, and has members on the

advisory boards of the Scottish and London TCCs.

The School attracts overseas research students on short visits ranging from several weeks to several months, allowing us to share our ideas and research culture with other groups. Students have visited from Calgary, Leiden and the Max Planck Institute for Radio-astronomy to work on galactic magnetic fields; from Queensland to work on cold atoms and condensed matter; from Lausanne and Leiden to work on longitudinal data methodology.

Progress monitoring Progress of all students is reviewed annually, using an independent panel to review evidence submitted via an online system by students and supervisors. A potentially failing student faces transfer to MPhil status or termination, but may be allowed to prepare for a reassessment. In order that this exercise should support student development, all students receive detailed feedback.

d. Income, infrastructure and facilities

Newcastle has undertaken a significant capital investment programme during the REF period. This has involved the construction of new buildings (9 have been added since 2005/ 2006) as well as a large scale refurbishment and reconditioning of existing buildings in order to ensure they continue to provide the best possible working environment for staff and students. The digital institute, where the big data theme of our research strategy will be based, is about to be relocated to Newcastle Science Central Campus, a 24 acre site located in the heart of Newcastle's city centre. The School is housed in a building that was completely refurbished in 2007.

National and international supercomputing resources are essential for our work. We have been awarded 2 million CPU hours on the CSC Espoo (Finland) and 4m HECToR allocation units during the REF period. More generic MHD work is done on three national supercomputer centres accessible via the UKMHD High Performance Computing consortium. Research computing support within the School is provided by two specialist technical staff who are experts in fast numerical and distributed processing. They are named as joint authors of 11 research publications, including 2 published in Physical Review Letters.

Staff have also been awarded observing time on radio telescopes including the Effelsberg 100m dish in Germany, the VLA in the USA, Westerbork in the Netherlands, the Parkes telescope in Australia and the LOFAR array in Europe.

Research Funding The annual value of new research awards to the School rose substantially in 2013, reaching a record of £1.4m (100% above the five-year average). This brings us up to a total of £3.5m for new awards in the REF period. The result of this increase at the end of the REF period will be a large increase in research income over the next few years. We aim to maintain this growth through an emphasis on those areas which have generated research income, such as quantum fluids and bioinformatics, as described in our research strategy.

Since RAE 2008, members of the School have contributed as PI's or CI's on large, interdisciplinary projects bringing research income of over £16m to the University. An example of our involvement in large projects is **Wilkinson**'s participation in a £5.5m EPSRC Frontier award. The Frontier Engineering awards are designed to promote multidisciplinary approaches to tackling global grand challenges. The challenge addressed by the Newcastle bid is the provision of cheap, clean water for all. This project will use data from pilot experiments to develop multi-scale stochastic models of the bacterial ecosystem in a water treatment plant. Other large collaborations include **Boys** and **Nye**'s participation in a £1.5m EC project to study eukaryotic genomic origins, parasites, and the essential nature of mitochondria; **Matthews**'s participation in a £2.1m MRC funded project on ways to advance health and wellbeing in later life; and **Shi**'s participation in a £2.1m HICF project on monitoring of upper limb rehabilitation and recovery after stroke, supported by Wellcome trust.

Consultancies Some of the consultancy work at Newcastle is directed through a dedicated

Industrial Statistics Research Unit (ISRU), set up in 1984 as a mechanism for providing concentrated statistical support for the process industries. The unit was awarded a series of European Regional funding grants totaling £1.25m to implement the statistical based Six Sigma management improvement methodology: 125 companies were assisted with 25 receiving at least 25 days consulting. Consultancies during the REF period include National Grid; Northumbria Healthcare; Draeger Safety UK; Parker Dominick Hunter. For example, ISRU have helped Northumbria Healthcare staff to analyse MRSA data and use Statistical Process Control methods to predict the number of MRSA cases. Apart from ISRU, consultancy work by **Henderson** for National Nuclear Laboratories and Sellafield Sites has resulted in improved national security and large financial savings.

e. Collaboration or contribution to the discipline or research base

Collaboration A crucial aspect of our research environment is the extent of collaboration with other centres and disciplines across the University, the UK and internationally. This shows up clearly in our research grant portfolio and in the joint authorship of many of our research outputs. We have joint publications with collaborators in over 50 Universities worldwide including Brown (USA), Johns Hopkins (USA), UCSD (USA), MSU (Russia), McMaster (Canada) and Queensland (Australia).

The interaction between our mathematical modelling of astrophysical systems and observations carried out internationally is exemplified by our membership of the LOFAR project and the Galactic Magneto-Ionic Medium Survey. We help organise and contribute to international LOFAR meetings, and **Fletcher** has carried out observational work using the LOFAR array and other major radio telescopes.

There is evidence that our best research is internationally leading. For example, Nature and Physics World news features covered major advances in quantum gravity made by **Toms** (*Nature*, 2010). The paper by **White**, **Barenghi**, **Proukakis**, Youd and Wacks (*Phys. Rev. Lett.,* 2012) was chosen as an Editor's Suggestion by the leading journal Physical Review Letters. The paper by **Gillespie** (*J. Chem. Phys.,* 2012) was selected by the Virtual Journal of Biological Physics Research, as a top publication in the field. **Shi**'s Gaussian process paper (*J. Nonparametric Statistics* 2011), won the 2011 best paper award by the Journal of Nonparametric Statistics and the American Statistical Association on Nonparametric Statistics and **Henderson**'s paper on optimal dynamic treatment allocation was selected for showcasing by the journal Biometrics at the 2011 Joint Statistical Meetings in Miami.

The inauguration of the *Joint Quantum Centre* in 2013 represents the culmination of 10 years of collaboration between theoreticians in Applied Mathematics in Newcastle and experimentalists in Physics and Chemistry in Durham, including the launch of the Finite Temperature Non-Equilibrium Superfluid workshop series in 2009. Other Durham links include the STFC-funded Newcastle-Durham consortium in *Particles, Fields and Spacetime* and a BBSRC-funded Doctoral Training Grant in Systems and Cells which has supported several PhD studentships in the general area of statistical bioinformatics.

Another indicator of research vitality is the formation of national networks co-organised by members of the School: the EGAN network meetings (Edinburgh, Glasgow and Newcastle), GLEN-meetings (Glasgow, Liverpool, Edinburgh and Newcastle), North British Geometric Group Theory Seminars, North British Functional Analysis Seminars and North British Mathematical Physics Seminars.

An example of cross-disciplinary work within the University, involving mathematics, statistics and archaeology, was the EU NEST Adventure Grant (2006-2010, £260k) project on farming in the Neolithic (**Sarson**, **Shukurov, Boys, Golightly**). This provided a quantitative interpretation of archaeological evidence based on the equations of population dynamics including environmental factors such as rivers and coastlines, soil types and climate changes.

There have been many collaborations with biological sciences. **Wilkinson** was awarded a BBSRC Research Development Fellowship to develop collaborations in stochastic systems biology. This has in turn led to new grants and studentships in this area awarded jointly with researchers in the Institute of Cell and Molecular Biosciences. Other interactions include collaborations on using microbes to clean water (EPSRC funded; **Wilkinson**), on statistical phylogenetics (ESF funded; **Boys**, **Nye**) and on robotic genetics approaches to yeast biology (BBSRC, MRC, Wellcome trust funded; **Wilkinson**).

Academic leadership

Fellowships, awards and prizes Almost all academic staff in the School of Mathematics and Statistics are members of relevant professional bodies. **Soward** is a Fellow of the Royal Society, **Barenghi** is a Fellow of the American Physical Society (a recognition limited to half of 1% of members of the APS) and **Matthews** is incoming president of the British and Irish Region of the International Biometrics Society. The 2009 Royal Statistical Society research prize was awarded to **Golightly**.

Board memberships Research Council involvement includes chairing the BBSRC Tools and Resources Development Fund panel 2012; Grants Committee, Academy of Finland 2011; deputy chair BBSRC Strategy Panel for Integrative Systems Biology 2008 and ordinary memberships of BBSRC, EPSRC and MRC selection panels. **Wilkinson** was BBSRC Research Development Fellow from 2008-2011 and **Matthews** was a member of the MRC Methodology Research Panel and the Quinquennial Review 2012 for the MRC Biostatistics Unit, Cambridge.

Editorial boards Our staff have editorial roles for 20 journals, including Biometrika and the Journal of the Royal Statistical Society. **Soward** is editor in chief on the Journal of Geophysical and Astrophysical Fluid Dynamics and **Henderson** was guest editor of special issues of Biometrical Journal and Statistics in Biosciences. **White** and **Jorgensen** will become main editors of the Bulletin of the LMS in 2014.

Advisory boards Memberships of advisory boards include those of the London and Scottish Taught Course Centres, the German ministry of Education and Research eBio scientific evaluation panel, the Science Advisory Board for the EPSRC-funded MUCM2 project, sub-panel 22 (Statistics and Operations Research) in RAE2008, the International Advisory Board for the FINESS Workshop series and the Royal Statistical Society Research Section Committee. **Henderson** is statistical advisor for the Quality Care Commission.

Conference organisation Newcastle staff have taken the lead in organising a wide range of international conferences. Examples include co-chair of the local organizing committee of the 2012 Pre Olympic Congress in Liverpool (**Shi**); principal organiser of the condensate workshop at the prestigious Lorentz Center in Leiden 2013 (**Proukakis**); co-organiser for conferences on magnetic fields at the Abdus Salam International Centre for Theoretical Physics, Trieste, the International Space Science Institute, Berne 2010, and Kiljavanranta, Finland 2009 (**Shukurov**); co-organiser of statistics workshops at Oberwolfach and Bristol (**Henderson**); workshop organiser for the Fields Institute, Toronto, 2014 (**Lykova**). Many members of staff have served on scientific and local organizing committees for other international meetings.

Conference keynotes We have also delivered over 30 keynote lectures at international meetings, including the British Mathematical Colloquium 2012 and 2013 (**Rees**), the International Union of Geodesy and Geophysics General Assembly 2011 (**Bushby**), Bayesian Statistics 9 in Valencia 2010 (**Wilkinson**) and the International Workshop on Operator Theory and Applications, Sydney 2012 (**Lykova, Young**).