**Institution: University of Cambridge**

**Unit of Assessment: B10**

## a. Overview

Cambridge mathematics research is exceptionally broad, covering Algebra, Analysis (Pure, Applied and Computational aspects), Categories and Logic, Combinatorics, Geometry and Topology, Number Theory, Probability and Statistics, Astrophysics, Geophysics, Fluid and Solid Mechanics, Mathematical Biology, Quantum Information, High Energy Physics and General Relativity and Cosmology. Research approaches range from analytical to computational to experimental in our large and well-equipped laboratory. All research areas have an active programme involving academic staff, postdocs and research students in regular seminars and working groups and in all areas there have been significant developments over the REF period.

The Cambridge Unit of Assessment consists of two departments, the Department of Applied Mathematics and Theoretical Physics (DAMTP) and the Department of Pure Mathematics and Mathematical Statistics (DPMMS); the latter includes the Statistical Laboratory as a sub-Department. The UoA comprises 110 academic staff together with 105 research staff and 240 PhD students. (Numbers include academic and research staff employed by the Colleges, who play an important part in Departmental research activities.) The UoA staff are housed in the Centre for Mathematical Sciences (CMS) alongside the Isaac Newton Institute for Mathematical Sciences (INI) and the Betty and Gordon Moore Library (BGML). The INI is an international visitor research institute and a separate institution within the University from the Departments. It runs programmes on selected themes in mathematics and its applications across science and technology and contributes to the vibrant mathematics environment on the CMS site. The BGML is an exceptional research resource containing the University Library's holdings in mathematical sciences.

The two Departments make up the Faculty of Mathematics which is the body responsible to the University for the organization of teaching and research in mathematics. The Faculty provides an effective mechanism for cooperation serving to integrate the UoA. The UoA is part of the School of Physical Sciences (one of six Schools in the University of Cambridge), along with the Departments of Chemistry, Geography, Earth Sciences, Materials Science and Physics, and the Institute of Astronomy. It has many research links within the School and elsewhere in the University.

## b. Research strategy

The UoA seeks actively to sustain breadth in research across a wide range of pure and applied mathematics, in theoretical physics and in probability and statistics. We aim to contribute to the most compelling areas of research for its own sake, but also have a strong tradition in applications. We regard it as essential to engage with the wider world and the support of collaborative research is a key component of our strategy. Our priority is to maintain and reinforce major areas of existing expertise and to identify and develop new areas of applications and fresh theoretical directions. The two departmental research strategy committees identify research areas that are likely to remain active and significant in the long term and we build or maintain strength accordingly. As part of this we promote at CMS an exceptionally stimulating research environment where academic and research staff and research students benefit from and contribute to a busy and broad programme of lectures and seminars and in which informal interaction naturally arises. We aim to appoint individuals of the highest quality to academic and research posts. We mentor them and provide them encouragement and support so that through their career their own research evolves to follow, and indeed define, profitable new areas of enquiry.

In RAE 2008 there were three separate submissions from Cambridge Mathematics, DAMTP to UoA21 and DPMMS to UoA20 (Pure Mathematics) and UoA22 (Statistics and Operational

Research). The way in which plans for the future were presented in each was different but a common theme was the need to refresh or redirect research by new appointments. Specific areas highlighted were algebra, analysis, geometry/topology and statistics as well as broad areas of applied mathematics and theoretical physics. New research fields emerge in an unpredictable fashion and as a result strategy has to be flexible. Some specific aims of 2008 have been achieved while others will be reconsidered. But since RAE 2008 there have been appointments across the whole of Cambridge mathematics with the focus on building for the future and with significant impact on research directions.

One critical component of strategy is the leadership provided by appointments at the Professorial level. Three important Professorships were highlighted in the DAMTP RAE 2008 submission and excellent appointments have been made in all three cases. Richard Josza, one of the founders of Quantum Information Sciences, was recruited from Bristol to be Leigh Trapnell Professor of Quantum Physics. Paul Linden FRS, a leader in both experimental and theoretical analysis of fluid flows, was recruited from UCSD to the G.I. Taylor Professorship of Fluid Dynamics. The appointment of Michael Green, a pioneer of String Theory, to the Lucasian Chair maintains the exceptional tradition of that Professorship. Additionally Anne Davis, a leader in Theoretical Cosmology has been appointed to the Professorship of Mathematical Physics (1967). In DPMMS there have been further significant Professorial appointments. Vladimir Markovic, who has solved important outstanding problems in 3-manifolds, has been appointed to the Sadleirian chair. Mark Gross, a geometer with a major programme in Mirror Symmetry, has been appointed to the Professorship of Pure Mathematics. Finally, though he joins us after the REF, John Aston, a leading applied statistician, has been appointed to the Professorship of Statistics.

Perhaps the most far reaching new development since RAE 2008 has been our establishment of a Cambridge Centre for Analysis (CCA), following a successful application for funding to the EPSRC. for a Centre for Doctoral Training (CDT) in Analysis, The CDT stems from a joint recognition by the two Departments of the importance of a strong grounding in a range of modern techniques in analysis both for core mathematics and for applications. The CCA has enlivened existing research areas (Probability, Applied and Computational Analysis) and has driven the expansion of a cross-Departmental group in PDEs. The success of the CCA encourages us to plan an extension of its range into Mathematics of Information and into Statistics. In establishing the CCA we specifically recruited two new members of academic staff, Dr Carola Schoenlieb (applied analysis with applications to image processing and signal processing) and Dr (now Professor) Clement Mouhot (kinetic theory). More than 20 staff in the two Departments are contributing to the activities of the CCA, through supervision of student projects and of thesis research. This has the complementary effect of stimulating and enriching traditional areas of strength (e.g. in fluid dynamics).

Our RAE 2008 objective to strengthen the precise mathematical study of PDEs has been addressed within the CCA by the appointment of Professor Mouhot and we look to appoint further in that area. We have also chosen to grow applied and computational analysis and Dr Schonlieb has been joined by Dr Anders Hansen, an expert in compressed sensing. There is increased research activity (funded in particular by a KAUST grant) and new collaborations, with medical departments and with the Magnetic Resonance Research Centre, have been established. We have recruited a strong and active cohort of postdoctoral researchers in modern analysis, linked to our academic appointments within the CCA. Analysis is further strengthened by the appointment of Dr Paul Bourgade in Probability (see below).

Theoretical Physics is an important component of the UoA and we have significantly reoriented research through new appointments.

*High Energy Physics*: Dr David Skinner has been appointed to a University Lectureship. Dr Skinner, previously at the Perimeter Institute, Waterloo, is a leading figure in new mathematical approaches, e.g. using twistors, to calculate scattering amplitudes. Dr Christopher Thomas has

been appointed to a University Lectureship: his expertise combines particle phenomenology and lattice gauge theory and his appointment is important in sustaining the breadth of research activity beyond the expected retirement of Professor Ron Horgan in 2015.

*General Relativity and Cosmology*: Dr Daniel Baumann, Dr Jorge Santos and Dr Ulrich Sperhake have been appointed as University Lecturers. Dr Baumann, previously at Princeton, is an influential researcher in early-universe cosmology. Dr Santos, previously at Santa Barbara, has broad interests from general relativity and related areas, including the AdS/CFT correspondence and its possible applications to condensed matter and fluid systems. Dr Sperhake, previously at Caltech and Barcelona, is a leader in numerical relativity: his work has given insight into high-energy collisions of black holes and black holes as sources of gravitational waves.

*Quantum Information*: Since Professor Jozsa's arrival the former Centre for Quantum Computation has evolved into the Centre of Quantum Information and Fundamentals, with participation from DAMTP, DPMMS and the Department of Philosophy.

There have also been significant developments in applied mathematics (beyond the CCA). *Astrophysics:* Dr Henrik Latter has been recruited as a University Lecturer. His research in protoplanetary disks, planetary rings and magnetorotational instability complements existing activity in astrophysics and assures the continuing strength of the group beyond the expected retirement of Professor John Papaloizou FRS in 2014.

*Geophysics:* Dr John Taylor has been recruited as a University Lecturer. Dr Taylor studies the fluid dynamics of the ocean, with a particular interest in ocean turbulence and mixing, ocean fronts and the surface boundary layer, and the impact of turbulence on micro-organisms, primarily using computational methods. Addition of oceanographic processes is a significant broadening of previous activity, with new collaboration with the British Antarctic Survey, the National Oceanography Centre and the University of Plymouth. The appointment of Dr Neufeld (see below) sustains our strong connection to Earth Sciences.

*Fluid and Solid Mechanics:* Additionally to Linden's appointment, Dr Jerome Neufeld has been appointed to a University Lectureship jointly between DAMTP and the Department of Earth Sciences within the BP Institute (BPI). The BPI is the focus for highly interdisciplinary research in multiphase flow. The UoA is heavily involved in the BPI and the Lectureship arises from increased support by BP. Fluid and Solid Mechanics is also strengthened by the appointment of Dr John Taylor (see Geophysics) and Dr Eric Lauga (see Mathematical Biology). In particular Dr Taylor significantly strengthens our computational research in fluid mechanics.

*Mathematical Biology*: Dr Eric Lauga, previously an Associate Professor at UCSD, has been recruited to a University Senior Lectureship. Dr Lauga's research concerns the physics of solids and fluids and their application to biological systems, e.g. to biological locomotion. In this subject area there is greatly increased and broader research activity particularly through grants to Professor Goldstein and a wide range of collaboration with other Cambridge Departments. Professor Richard Durbin FRS has been appointed to an Honorary Professorship in DAMTP to strengthen links with the Sanger Institute. Professor Simon Tavare (Professor of Oncology with secondary appointment in DAMTP) remains strongly connected to us and has recently become Director of the CRUK Cambridge Laboratory.

In *Pure Mathematics*, the two professorial appointments realise major aims from the RAE 2008 submission. The appointment of Professor Markovic complements existing expertise in low-dimensional topology and consolidates strength in analysis linked to geometry. Our desire to promote mathematics stemming from Theoretical Physics is met by the appointment of Professor Gross whose focus on the algebraic geometric role of Mirror Symmetry complements existing strength on the symplectic side. We have further branched out in Topology with the appointment of

Dr Oscar Randal-Williams who works on mapping class groups, moduli spaces and more generally applications of homotopy theory to geometry. We have decided to build in Number Theory from below and our first step is the recent appointment of Dr Jack Thorne, who is responsible for ground breaking work in two distinct areas: automorphy lifting theorems (which contribute to the Langlands Programme) and arithmetic invariant theory.

The primary goal of the Statistical Laboratory in RAE 2008 was growth in staffing and research in Statistics. We have also sought to respond to significant new developments in Probability. *Probability:* The group is very active, running a major Programme Grant in Random Geometry and with a blossoming relationship with AIMR Tohoku. As a result there is increased activity in areas of traditional strength. Fields Medallist Wendelin Werner is a regular visitor to the group. Further we have taken a conscious decision to extend our range of interests with the appointment of Dr Paul Bourgade, an expert in random matrices. Bourgade's work on the local spectral statistics of random matrices has applications on the one hand to the zeros of the zeta function and on the other to mathematical physics.

*Statistics:* We have made considerable progress with our RAE 2008 aim to build expertise in core and methodological statistics. Early in the assessment period we appointed Dr Richard Nickl, a mathematical statistician with interests at the interface of statistics with probability theory, functional analysis, and approximation theory. More recently we have appointed Dr Rajen Shah whose work focuses on the design and theoretical properties of statistical algorithms. These complementary appointments increase our strength in higher dimensional statistical inference. By investing heavily in postdocs we have now established a lively research group in statistics with strong commitment to their subject. That is exemplified by the Statistics Clinic (http://www.statslab.cam.ac.uk/clinic) set up by Professor Richard Samworth. This provides free statistical advice throughout the University on a drop-in basis. Typically 10 people turn up to each of the 20 sessions in a year and from a wide range of University departments. The Clinic and also the example of Professor Philip Dawid and Professor David Spiegelhalter connecting theory with real-world applications has led to a strategic decision also to seek growth in applied statistics. The recent appointment of Professor John Aston to a Chair is the first step in that direction.

Achieving a higher profile in fund-raising and increasing resources from Colleges were both mentioned as priorities in RAE 2008. A very recent success is the Avery donation for a Stephen Hawking Professorship of Cosmology. This presents an opportunity to develop strength in one of our major interests and we will want to make a distinguished appointment. New joint funded posts with Colleges have been set up in the assessment period and there are ongoing discussions about further posts of this type. These posts typically offer early career researchers an opportunity to move on the next career stage and have been helpful in augmenting and diversifying our research strength.

*Future Directions 2013 onwards:* There are a number of areas which are currently a priority. We are pleased with the strength we have been building in Mathematical Biology and hope to complement that further, we intend as soon as possible to make further appointments in Statistics, both in theory and applications. We look to extend existing expertise in PDEs and Geometric Analysis by making further appointments in Analysis broadly conceived, certainly at the junior and possible at the senior level. Rebuilding Number Theory is an essentially new strategic objective and alongside that the future shape of algebra at Cambridge needs to be addressed. We are keen to involve our strong recent appointments in strategic decision making. Finally we are currently seeking candidates for two important Professorships, the Herchel Smith Professorship of Pure Mathematics which has fallen vacant with the move of Ben Green to Oxford and the Lucasian Chair which will become vacant early in the next REF assessment period. These vacancies present important opportunities for high-level appointments and hence reinforcement and broadening of our research activity.

**c. People, including:**

**i. Staffing strategy and staff development**

*Staffing strategy:* Our staffing strategy aims to enhance and sustain our research capability, maintaining breadth while being at the forefront of new developments. Research strategy committees consider the areas to which staff resources should be allocated. For permanent academic staff, decisions have to be agreed by the School of Physical Sciences in accord with its overall research strategy. We advertise internationally, generally in a specific strategically important research area though the pure mathematics strategy puts more emphasis on seeking outstanding individuals from a range of possible fields. We always succeed in attracting a very strong international field. Measures of the success of our staffing strategy include our ability to attract top class individuals in the face of competition from other internationally leading institutions (Chicago, Harvard, Princeton), the career progressions of permanent staff through the rigorous Cambridge academic promotions system and the recognition of individuals by their role in the international research community and by fellowships and honours.

The maintenance of a large postdoc community is an important component of our staffing strategy. Details are given later but here we note that while postdocs are for the most part funded by external research grants or fellowships we have increasingly been using University funding to build up the community, especially in pure mathematics but also in statistics. The postdocs are themselves significant contributors to research and also to the quality of the research environment. They play a major role in our ability to recruit on the international stage. Alongside our early career researchers, we encourage retiring academic staff distinguished in research to maintain their involvement in our research activities. Some supervise PhD students; some have grant-funded research projects. About 12 are still very active and this participation adds significantly to our research environment.

*Career Development and Support:* Appointments of all junior academic and research staff are subject to satisfactory completion of a period of probation. Early Career staff have a mentor with the responsibility to provide advice and support. Progress is monitored through the probationary period and if there is any doubt about satisfactory completion then a raft of support measures is introduced. The University requires that all academic and research staff are subject to an appraisal system, annually if requested and otherwise at least every two years. For contract research staff there is an additional requirement for a biennial Career Management Review meeting.

On starting employment all academic and research staff go through a formal induction procedure in which they are made aware of the broader structure and mission of the University, the various University policies and procedures, and, in particular, the career development opportunities that will be available to them during their employment. These opportunities include, for both academic and research staff, a wide range of courses offered by the University's Personal and Professional Development (PPD) scheme. Courses range from teaching, supervision and administration skills to data security, managing stress and leadership. Within the PPD scheme a Researcher Development programme has been established to meet the particular needs of research staff and PhD students. An individual consultant within this programme focuses on the needs of staff within the School of Physical Sciences. All newly appointed lecturers attend the Pathways in Higher Education Practice Programme (PHEP) which offers personal, flexible orientation and professional development both on appointment and throughout the probationary period. For academic staff considering applying for promotion a CV Mentoring Scheme is now offered by the University to help such staff prepare the strongest possible applications (see below for promotions during the REF period). Our strong outreach activities are described in our Impact statement, but we note here that academic and research staff and research students are offered opportunities for outreach, plus appropriate training, as a natural complement to their research.

Academic staff are entitled to one term of fully paid sabbatical leave, dedicated exclusively to

research, for every six terms served. This important aspect of the long-term careers of academic staff allows them periodically to refresh and renew their research activity. Over the REF period 62 individual members of staff took sabbatical leave.

The University Careers Service offers specialist advice to academic and research staff at all levels. Staff in the School of Physical Sciences have access to a bespoke programme for Physical Sciences and Technology. Resources available include one-to-one careers discussion with a specialist adviser, guidance on particular aspects of job applications, a wide range of careers workshops and events covering different themes and topics relevant to building a successful career in academia or outside, and access to a range of information on specific opportunities including vacancies, contactable alumni in relevant careers and so on. The UoA seeks to enhance this University-level provision through cooperation, discussion and feedback. In each Department a member of academic staff has oversight of research staff and PhD student career development activities, supported by University funds. Additionally the UoA regularly hosts University Careers Service events to enhance take-up by our own staff and students.

Evidence of successful career development support is given by the career paths of those who leave the Departments (see 'Research Fellowships' later) and by the promotion record of long-term academic staff, who have the opportunity to apply for promotion in annual rounds. Promotion to Reader and then Professor is on the basis of a significant international research reputation assessed by a rigorous process. The case for promotion of individuals in mathematics is measured against and is in competition with other internationally leading Departments in the School of Physical Sciences and within the University as a whole. Over half our submitted academic staff are Professors. During the REF period there were 14 promotions to Reader and 11 promotions to Professor in the UoA (compared to 16 academic staff recruited at Lecturer level and 2 to Readerships during that period). (There were 19 Reader applications and 18 Professor applications) We are particularly pleased that all our female members of staff applying for promotion during the REF period have been successful.

*Research Staff:* Our research is greatly enhanced by many Research Fellows who have individually won funding on the basis of their demonstrated research potential and their research plans. Funding for these Research Fellows comes from a wide variety of sources, some external and some internal to the University. We also employ a large number of postdocs attached to individual projects. We regard the two groups as contributing equally to the research environment. We recognise that nurturing postdocs is an important responsibility. All postdocs are mentored. As well as providing scientific guidance we provide practical support (help with CVs, interview practice) through the Careers Service (see above). The University is a signatory to the UK Concordat to support the Career Development of Researchers and in recognition of its work in fostering good working conditions and career development for researchers has received the European Commission's 'HR Excellence in Research' award. The University Human Resources Division formulates policy and procedures on appointment and support of research staff (in accordance with the Concordat) which govern practice in the UoA.

In 2012 postdoctoral research workers became the largest staff group in the University (now over 37%). In response to this growth the University has embarked on a major property development in North West Cambridge. In the first £300M phase, due to open in 2016, high-quality and sustainable housing will be provided for over 500 postdocs and their families, together with retail and social facilities. In addition, the University has created the new role of Director of Postdoctoral Affairs: the first Director, Professor Chris Abell (Chemistry) will coordinate and develop strategy for the entire postdoctoral community, spearhead fund-raising for further NWC facilities, and act as an advocate for postdocs in the governance machinery of the University. The University supports Postdocs Of Cambridge (PdOC) as the University Society for postdoctoral research staff including research fellows. PdOC represents postdocs in career development, contract research conditions, college affiliation, and social and sporting issues. Many postdoctoral staff within the UoA are active

members of PdOC.

We aim to attract and encourage high-quality applicants for external Fellowship schemes and to provide administrative and academic support to ensure their applications are as strong as possible. Over 70 such fellowships have been held in the UoA over the REF period. National and international schemes which have supported Research Fellows in the REF assessment period are the Royal Society University Research Fellowships, EPSRC Research Fellowships, STFC Research Fellowships, NERC Research Fellowships, EU Marie Curie Fellowships, Newton International Fellowships, AXA Research Fellowships (the AXA Research Fund supports research into risk), the Lloyds Tercentenary Foundation and the Leverhulme Trust. We have hosted several Research Fellows funded through competitive schemes in their home countries. In the REF period these have included Swedish Research Council, CONACYT (Mexico), NSF and Leopoldina (Germany) Fellows.

The resources and perceived international strength of the University of Cambridge allow us further important Fellowship possibilities. Cambridge College Research Fellowships are highly competitive, attracting international fields of applicants. On average five such Fellowships are awarded across the UoA each year. The significant Herchel Smith bequest ($90M) to the University of Cambridge funds on average two postdoctoral fellowships each year in the UoA. The University Oppenheimer Fund has funded two Research Fellowships to the UoA in the REF period. The Centre for Theoretical Cosmology (established in DAMTP in 2007 and funded by significant external donations) offers occasional Hawking Research Fellowships (3 in the REF period). As part of its mitigation of the effects of the 2008 financial crisis, the Simons Foundation funded four Fellowships in the UoA. The Isaac Newton Trust supported by Trinity College offers the required institutional co-funding for applications for Leverhulme Trust Early Career Fellowships (with 2 successful applications in the REF period). Finally University-funded Research Fellowships in Mathematics attract strong international interest. Six such Fellows are currently in post. Taking the postdoc population as a whole during the REF period, a total of 168 left posts in the UoA. The current employment of this group is: 46 in long-term academic/research posts in UK, 55 in long-term academic/research posts outside the UK, 18 in fixed-term academic/research posts in the UK, 38 in fixed-term academic/research posts outside the UK, 11 outside academic/research. Examples of destinations for long-term posts include Oxford, Warwick, Edinburgh, Bristol (Professor), UCL (Professor), Durham (Professor), Harvard, Princeton, Caltech, UCLA, MIT, ETH (Professor), Singapore; 3 have academic posts in the UoA (Hansen, Neufeld and Randall-Williams) and 1 in another UoA in Cambridge.

*International appointments and visitors:* As already indicated all academic and postdoc recruitment in the UoA is from an international field. We are successful in attracting leading world figures and top young researchers worldwide to Cambridge. During the REF period about 80% of our academic appointments (and shortlisted applicants) were previously based outside the UK. Appointments recruited directly from non-UK institutions were, Baumann (Princeton), Bourgade (Harvard), Gross (UCSD), Lauga (UCSD), Linden (UCSD), Markowic (Caltech), Mouhot (Paris), Nickl (Connecticutt), Santos (UCSB), Schoenlieb (Goettingen), Skinner (Perimeter), Sperhake (Barcelona), Taylor (MIT), Thomas (Dublin), Thorne (Harvard), Reciprocally our academic staff are sought after internationally. During the REF period Professor Neil Turok moved to become Director of the Perimeter Institute, Dr Benjamin Schlein to a Professorship at Bonn, Dr Peter Friz to a Professorship in Berlin and Dr Robert Gramacy to the Booth School of Business (Chicago). Additionally Professor Fernando Quevedo has taken an extended period of leave to be Director of the International Centre for Theoretical Physics, Trieste and Professor Peter Markowich has spent a period of leave as a Distinguished Professor at the King Abdullah University of Science and Technology, Saudi Arabia.

Across the UoA we regularly welcome research visitors, many of them eminent senior figures in their field. During the REF period Jerry Gollub (Haverford), Howard Berg (Harvard), Doug Arnold

(Minnesota), Dan Freedman (MIT), George Ellis (Cape Town) have all visited for extended periods. Leon Simon (Stanford), Igor Rodnianski (MIT), Wendelin Werner (ETH) and Simon Brendle (Stanford) were brought to Cambridge by the DPMMS Distinguished Visitor Scheme. The University of Cambridge invests heavily in the Isaac Newton Instiute and research in the UoA benefits significantly from the continual stream of visitors to the Institute including the appointment of a Rothschild Visiting Professor (RVP) or Senior Fellow in association with each programme. Recent examples of particularly strong interaction include the Strings programme (Andy Strominger was RVP) and the Dynamics of Discs and Planets programme (Doug Lin was RVP). Our annual invited lectures (Mordell, Dirac, Batchelor) bring distinguished international figures to Cambridge. During the REF period these were: Colding (MIT), Katok (Penn State), Lubotsky (Jerusalem), Seidel (MIT), Wilczek (MIT), Polyakov (Princeton), Kadanoff (Chicago), Fadeev (St Petersburg), Ellis (KCL), Englert (Brussels), Quere (Paris), Hosoi (MIT), Guazzelli (Marseille). The David Crighton Fellowship Scheme brings early career researchers in applied mathematics to DAMTP from elsewhere in the UK and from overseas.

*Equality and Diversity:* The University has in place equal opportunities, disability and employment policies which operate throughout the UoA. There is regular communication with University HR staff about good practice. We require all involved in selection for academic posts to undertake Equality and Diversity Training. The University offers generous arrangements for maternity or paternity leave, has two workplace nurseries and provides a Holiday Playscheme for school-age children. Nursery costs can be paid for by an efficient salary-exchange scheme. This provision is widely advertised within the UoA. In addition the University's Returning Carers' Scheme which is open to both men and women provides grants to individuals returning after periods of parental or carers' leave, to facilitate their return to research.

Gender equality is perceived as a particular challenge in Mathematics. DAMTP has a long-running scheme in which two members of academic staff act as Women's Officers and organise regular events at which women members of the Department meet. The UoA actively promotes events for women in mathematics, for example providing support to the European Girls Mathematical Olympiad held in Cambridge in 2012, support to the LMS Women in Mathematics Day held in 2013 and support to a women's student society – the Emmy Noether Society. The UoA is a supporter of the London Mathematical Society Women in Mathematics Good Practice scheme and is in the process of preparing an application for the Athena SWAN Bronze Award. The two Departments are funding extra staff for this purpose. (The University as a whole already holds the Bronze Award.)

The University's Women in Science, Engineering and Technology Initiative (WiSETI) promotes and supports women, from undergraduate to professorial level in Science, Engineering, Technology and Mathematics, organising activities such as an annual WiSETI lecture, career development seminars and annual talks by women scientists working in policy, industry and academia.

The University Equality and Diversity teams assist with legal matters formally through the recently updated Equal Opportunities Policy (in line with the Equality Act 2010), in all matters relating to staffing, A Dignity@work policy clearly sets out University procedures for dealing with harassment, bullying and other inappropriate behaviours drawing on specialist advisors. In October 2009, the University approved the appointment of 3 Equality champions (around Gender, Disability and Race) to demonstrate leadership and support the University Diversity Networks (which include the BME Network, the Disabled Staff Network, the Faith and Belief in Practice group, the LGB&T Network, the Senior Gender Equality Network and the Women's Staff Network). Representatives from the Diversity Networks form the E&D Consultative Forum to support the development of University policies and practice. The University's Personal and Professional Development team run two gender-specific staff and graduate student training programmes: Springboard for women and Navigator for men.

The School of Physical Sciences has set up an Equality and Diversity Forum; the UoA has two

senior members of academic staff as representatives. Professor Davis currently chairs the Forum and plays a role in the University's new Senior Gender Equality Network to support senior-level staff. The University won the Employee Engagement Award from the Employers Network for Equality and Inclusion in 2012; and in 2012 and 2013 it was ranked 11th on the Stonewall Top 100 Employers workplace equality list, the highest UK HEI.

The Centre for Mathematical Sciences buildings were designed to allow straightforward access to disabled staff and students. We make sure that any staff or students who have a disability know that they can be assessed by the University's Disability Resource Centre (DRC), who then liaise with us to help us to take steps to accommodate any special needs. The DRC also lends specialist equipment to eligible staff and students, and coordinates the University's network of Departmental Disability Liaison Officers, who provide information about disability to staff. We also provide information to students and staff about the University's Occupational Health Service, which promotes and preserves both the physical and mental well-being of all staff and provides a counselling service free to all University staff.

### ii. Research students

Our aim is to recruit gifted and motivated PhD students and provide them with their first experience of cutting-edge research in the exceptionally broad and stimulating mathematical environment in Cambridge. Through this we aim to provide the students with skills necessary for a successful career whether in academia, government, industry or business.

Opportunities for PhD research and funding are well advertised and individual subject groups seek actively to attract applicants. Over the assessment period we have admitted on average about 60 PhD students per year with 44% from the UK, 30% from the EU and 26% from outside the EU. Currently about a fifth of the intake is admitted to our Centre for Doctoral Training (the CCA). About half our PhD students are recruited from Part III, our Masters level course taken by about 240 students each year including 4th year undergraduates and graduates from elsewhere, with the vast majority of the latter coming from outside the UK. The other PhD students are recruited from elsewhere usually with Masters equivalent qualifications.

Funding for PhD students is a major consideration. It comes from a diverse range of sources including UK Research Councils (principally EPSRC and STFC), research grants (e.g. ERC), University funding including the Cambridge Trusts (primarily for non-UK students) and, on an individual basis, national funding schemes. Timing of offers depends on individual and funding circumstances. Some offers are made in June after the Part III examinations but many others are made earlier in the academic year. Whatever the timing we look not only for high academic attainment (as evidenced by degree results and references) but also for a good match with the supervisor and proposed topic. For applicants from Part III the potential supervisor may already have had considerable contact with the student. For others we typically interview during a visit or remotely.

Our PhD training accords with the Code of Practice of Cambridge's Board of Graduate Studies and is overseen in each department by a Graduate Education Committee. Details are given in our Graduate Handbooks. At our Induction Day we make clear our expectation of how, through their PhD, students will develop as mathematicians and acquire additional skills needed for a successful career inside or outside academia.

In addition to the 80 Masters-level courses in Part III, we provide some 20 graduate courses (some on a developing research topic, some focused on computational techniques, e.g. in fluid dynamics or statistics) aimed specifically at PhD students. These are regarded as an essential part of graduate education and there is a strong culture of engagement with them. The establishment of

the CCA has broadened the range of courses available and also provided increased opportunities for interaction outside academia. Regular attendance at relevant seminar series is expected and all students are given the opportunity to present their work formally at least twice during the PhD. Students run their own seminars and this provides further experience of mathematics presentation in a less formal setting. Summer schools and conferences are an important part of training and considerable resources (typically £1.5K per student from Departments and additional funds from Colleges) are devoted to supporting students to attend them. Participation in broader academic and transferable skills training is considered formally in our assessment procedures. Original research is a challenge and we actively support our students. Each Department has a Graduate Education Officer, responsible for transferable skills training and also for monitoring overall progress of the students. In addition to their PhD supervisor each student has a mentor (a further member of staff or a postdoc) who gives advice and encouragement about the general research experience. The research groups themselves provide a context for individual research. Finally we want all students across the CMS site to feel part of a lively community. To that end we support a Graduate Mathematics Society and through it encourage students to take full advantage of research and training opportunities.

Transferable skills training is supported by the University post-Roberts via its Researcher Development Programme with an annual spend of £1.1m. Central provision includes the Office of External Affairs and Communication (the 'Rising Stars' public engagement programme), the Centre for Entrepreneurial Learning (business skills) and the Careers Service (CV-writing and interview techniques). Some of the spend is devolved to the School and Departments. There is specific training in scientific writing, publishing research and preparing grant applications. Activities specific to mathematics include training in supervision and other teaching and experience of public engagement via the Millennium Mathematics Project which is run from the CMS. Our expectation is that PhD students spend the equivalent of two weeks over a year in transferable skills activities.

There are two key aspects of early assessment of the progress of PhD students. A decision on registration for the PhD is required at the end of the first year and is based on a short report written by the student and considered by two assessors from outside the supervisory team. A second major progress assessment is made in the fourth or fifth term. A substantial written report is expected and the student will be interviewed by the two assessors. Participation in broader academic activities and in transferable skills training is considered as part of the assessment. Students report on courses attended and keep a log of transferable skills activities.

Regular formal feedback about progress is provided by supervisor's reports submitted termly: these can be read by the student. At the end of the PhD the dissertation is assessed by two examiners, at least one external to the University. The requirement for the PhD is that the dissertation must be clearly written, take due account of previously published work and represent a significant contribution to learning. We expect publishable work: almost all theses result in publications, often before submission. Our PhD students regularly win competitive Fellowships (e.g. EPSRC PDRFs) and Prizes (Lighthill-Thwaites Prize, Wellcome Science Writing Prize, RAS Prizes). They are well placed for employment. Over the last 4 years, 54% have taken up research posts, 38% non-research positions, including finance, industry, IT and teaching and 3% began further study).

We continue to respond to the changing funding landscape for PhD training. We are building relationships with other Departments and industrial partners to expand PhD possibilities in statistics, mathematics of information, fluid mechanics and physical biology and expect to secure significant external resources to support PhD students in these areas. We are participants in a successful Cambridge-wide (University of Cambridge plus British Antarctic Survey) application to the NERC DTP competition. Alongside that we have set funding for PhD students as one of our main fund-raising priorities taking the view that we are currently disadvantaged in the international competition for top PhD students by our lack of funding opportunities for non-UK students.

**d. Income, infrastructure and facilities**

Several different funding sources are important for the UoA in maintaining a supportive, evolving research environment, with adequate administrative and other support for research activities. Salaries of long-term academic, administrative and support staff, plus some infrastructure costs, are paid from central University funds via the School of Physical Sciences. These funds meet year-on-year salary increases associated with promotion. External grant income is committed to specific costs, including salaries and equipment. Non-committed income, largely research grant overheads plus savings resulting from research leave for academic staff, is generally retained in central Departmental reserves, an important resource which is used for infrastructure costs, enhanced levels of administrative or computing support for research and for strategic purposes (e.g. support of new research initiatives, start-up packages for new staff, etc. often in conjunction with strategic funds from the School).

In the REF period the total research grants were over £46M resulting in an annual income of greater than £10M per year. The annual income has increased virtually every year during the REF period. (See REF4b). Major external grants are the STFC consolidated grants (formerly rolling grants) to the DAMTP Astrophysics, High Energy Physics and Relativity groups totalling ~£7.8M, EPSRC grants (2 Programme Grants, 'New Frontiers in Random Geometry' to Grimmett and others, 'Mathematical Underpinnings of Stratified Turbulence' to Linden and others, Leadership Fellowship 'New Challenges in Higher-dimensional Statistical Inference' to Samworth) totalling nearly £5M, ERC Advanced Investigator grants (Goldstein, M. Green) and Starting Investigator Award (Baumann, Dafermos, B. Green, Mouhot, Reall, Smith, Tong) totalling nearly £11M and a KAUST Investigator grant (to Markowich) of ~£3.8M. The UoA holds substantial further grants from EPSRC, from the Wellcome Trust (large grant to Goldstein) of £1.3M, NERC, BBSRC, the Royal Society, DSTL, the European Commission and the Leverhulme Trust. We have significant overseas grants; for example from the John Templeton Foundation and the Templeton World Foundation of ~£1.7M and US Navy of about £0.7M. We have also received research funding from Industry which have included Schlumberger, Laing O'Rouke, Ove Arup, AWE, Rolls Royce, Hitachi and Sankhyaa. In addition we have significant funding from the Defence Science and Technology Laboratory of about £0.55M. The UoA also benefits from funding sources unique to Cambridge, particularly the Isaac Newton Trust, which typically provides cofunding and bridging funding. Relative to RAE 2008 the major change is the significant contribution from ERC grants. Whilst constraints on RCUK funding mean that EPSRC fellowship opportunities are restricted, we have had success where they are available and also we have had important successes in significant EPSRC Programme Grants.

Our future plans are based on the need to diversify funding. In particular recently appointed academic staff will receive encouragement and support in making funding applications for ERC Starting and Consolidator Grants. In addition, certain subject areas such as applied and computational analysis and mathematical biology have been significantly strengthened by recent appointments and there are good prospects for raising further substantial research grant income in these areas. STFC science areas continue to be supported by new academic staff appointments thereby strengthening our case for future consolidated grant income. Collaborative research with other Departments (e.g. in climate science with Chemistry and several other departments and in disease dynamics with the Vet School) offers new funding possibilities. Finally new initiatives are planned in Geometry and Statistics that are expected to offer significant funding opportunities.

*Support staff:* The Departments employ about 18 administrative staff, 12 technical and computer staff and 15 facilities staff who play an important role in supporting research and maintaining our excellent working environment. A recent restructure has combined some elements of each Department's administration into shared services and significant benefits are expected from this.

*Accommodation:* The buildings at CMS provide high-standard office accommodation. The offices

are situated in seven pavilions arranged around a central core containing a large common room with cafeteria facilities open to undergraduates as well as research students and staff, plus lecture theatres. Individual pavilions also have common room space, plus one or two further lecture theatres. All common space is regularly used for informal mathematical discussion. CMS therefore provides an exceptionally high-quality physical environment for mathematical research. The major investment required is for gradual refurbishment and redecoration. Some funds are being provided by the central University and these are augmented by funds raised from external users of the facilities for meetings or conferences.

*Computing and IT facilities:* In 2008 DAMTP and DPMMS had separate IT facilities but these are now unified across the UoA: there is a single management structure for IT support of teaching research and administration. The computing environment includes storage, standard and specialist software, computer servers and 1GBit desktop connectivity, plus associated infrastructure and services such as printers, scanners, personal web-pages and backups. A wireless network now covers the CMS site. Over the REF period around £500K has been spent upgrading facilities. The main data network has been upgraded to 1GBit at the edge and 10GBit for the backbone and main compute and storage services. Additionally a set of new central servers has been installed. The UoA has made extensive use of the University of Cambridge High Performance Computing Service throughout the REF period, during which time it has maintained its position as one of the leading facilities in the UK. In June 2012, following an upgrade, the system achieved a sustained Linpack performance of 183.379 TFlops (90.6% of peak) making it the fastest (publicly disclosed) x86_64 cluster in the UK. A new facility was commissioned in August 2013 maintaining this leading position, for which the University will invest £20M to support energy-efficiency with the HPC centre. Specialised high-performance computing is also provided by the COSMOS supercomputer (for cosmology), by grid computing on workstation clusters (provided by the University Computing Service) and by a small number of individual clusters owned by research groups. The UoA has won nearly £5M for high performance computing from STFC in the REF period.

*Library:* The onsite Betty and Gordon Moore Library (BGML), a sub-Department of the University Library, holds a large stock of mathematics, science and engineering periodicals and books. Relations with the Library staff are excellent, we have good representation on Committees and there are effective procedures in place for ordering new and stock on request. Electronic access to journals now exceeds the use of print and the central University Library coordinates University-wide access to a very large number of journals. The University Library is a legal deposit library and its digital library provides access to over 90,000 unique full-text electronic journals and around 400 databases. The provision for mathematics is excellent and we are closely involved in decisions about the use of resources.

*Laboratory:* DAMTP has a long-established international reputation for experimental research in fluid mechanics. At CMS the large 820m$^2$ GK Batchelor Laboratory allows us to carry on this experimental research and the scale and flexibility of the facilities has enabled a significant diversification and expansion. While traditional areas of fluid mechanics are still a key focus, there is now substantial research in biophysics and in granular flows. Since RAE 2008 the level of activity has increased significantly, in part due to two new academic appointments (Linden, Neufeld) and in part to increasing activity of existing staff. This increased level of activity has been backed by substantial investment in research equipment which now allows us to investigate processes with length scales ranging from 10 m to less than 1 micron and with a correspondingly broad range of time scales,

New equipment acquired includes an atomic force microscope, a confocal microscope, an additional five very high-speed cameras, and a high-speed three-dimensional Particle Image Velocimetry system. Existing microscopes have seen substantial upgrades, and two of our precision rotating turntables (for modelling geophysical flows) have been rebuilt. Overall equipment expenditure in the laboratory since RAE 2008 exceeds £1.5m.

Some of our laboratory facilities have attracted users from outside of academic research. For example, our Temperature Controlled Laboratory (-40°C to +30°C) was used for six weeks for filming parts of the BBC Frozen Planet series. Work has also been carried out for DSTL and for Hydroventuri.

DAMTP continues to allocate significant personnel resources to the Laboratory. An academic Director (Dr Stuart Dalziel) takes overall responsibility in all matters of experimental technique and safety. The Director is assisted in this responsibility by a team of five technical officers and workshop technicians. A significant fraction of the funding required has over recent years come from external research grants.

The expanding level of research activity in the Laboratory has been facilitated by a joint investment by School and Department in the workshop through a £60K programme of replacing and upgrading machines (including the acquisition of three new computer-controlled machines) to help meet the increasingly sophisticated demands of the research. While this investment has also increased the efficiency of the workshop, the overall growth in research activity has been such that we are in the process of recruiting an additional technician.

Although research dominates its activities, the Laboratory is also used for teaching fluid dynamics in the undergraduate and postgraduate curriculum and for Summer Schools.

Equipment sharing across departments is also encouraged and facilitated. The University is committed to the Science and Engineering South Equipment Sharing Project, which started in 2011 with EPSRC funding, to develop a database of facilities and equipment and to facilitate shared use of equipment where practical across the University and its partners (UCL, Imperial, Oxford and Southampton). The database holds records of over 1800 items of equipment and facilities.

**e. Collaboration or contribution to the discipline or research base**

*Research collaboration:* Collaboration is one of the forces which drives the research agenda within Cambridge mathematics. Cambridge mathematicians are regularly engaged in collaborations worldwide at an individual level and almost every individual submitted for the REF has active international collaborations. This is evident from a large number of joint publications with colleagues at leading centres such as Caltech, CERN, Ecole Polytechnique, ETH, Hokkaido, IAP, IAS, MIT, Paris VI/VII/Sud, PI, Princeton, Saclay, Santa Barbara, Stanford, UCLA, Uppsala, Weizmann. The Polymath Project initiated by Gowers is a novel form of international collaboration. Members of the UoA are involved in major international collaborations such as Planck (Challinor and Shellard), the EUCLID satellite (Bonvin and Davis), SUSY working group (Allanach) and US science policy White papers (Baumann and Davis). We promote collaboration by accommodating and funding academic visitors and by supporting visits by our own staff. At an institutional level we already have formal links with leading institutions (Texas A&M, Perimeter) and are developing others (Tsinghua).

*Interdisciplinary research:* In accord with our research strategy the UoA participates in many cross-Departmental initiatives within Cambridge. Haynes was one of the founders of the Cambridge Centre for Climate Science in which also Caufield, Linden, McIntyre, Neufeld, Taylor, Wadhams and Worster are active. Linden is Director of the Cambridge Forum for Sustainability and the Environment. Iserles and Samworth are on the Steering Committee of the Cambridge Big Data Initiative. Rogers and Tehranchi are active in Cambridge Finance. Hawking, Kent and Spiegelhalter are advisors in the Cambridge Centre for the Study of Existential Risk. Caulfield and Neufeld are UoA staff at the BP Institute which provides strong links to Earth Sciences, Chemical Engineering, Chemistry, Engineering and Physics,. The following are indicative examples of

collaborative activities. There are close connections with Astronomy and the Kavli Institute for Cosmology (founded in 2008 and housed next to the Institute of Astronomy) where Bonvin is a joint postdoc. Berloff is modelling exciton-polariton condensates in close interaction with Jeremy Baumberg's group in Physics. We share interests with the CRUK Cambridge Institute and have a direct link in Tavare. The expertise of Schoenleib and Hansen in mathematical imaging and compressed sensing has led to collaboration with the Magnetic Resonance Imaging Centre. Berestycki has worked with Murchison (first at the Sanger Institute, now in Veterinary Medicine) on modelling the Tasmanian Red Devil cancer. Goldstein has collaborations with Zoology on the dynamics of the cytoskeleton and with Biochemistry on the biophysics of bacterial flotation. There are significant further collaborations with Archaeology and Anthropology, Chemical Engineering and Biotechnology, Chemistry, Clinical Neuroscience, Engineering, Genetics, the Gurdon Institute, History and Philosophy of Science, Medicine, Plant Sciences, PDN (Physiology, Development and Neuroscience), Philosophy and Zoology. The Statistics Clinic (see above) attracts interest from a wide range of Departments. In 'greater Cambridge' there are collaborations with the British Antarctic Survey, the MRC Cognition and Brain Sciences Unit and the Sanger Institute. The range of non-mathematical Cambridge institutions mentioned here is indicative of analogous collaborations with Universities and other institutions outside Cambridge. Prominent examples include: Oxford-Cambridge Cosmology and Philosophy Project (Barrow), Casimir force experiments at Vrieje University (Netherlands) to search for chameleons (Davis), experimental and observational work on avalanches with Swiss Federal Institute for Snow and Avalanche Research (Vriend), membership of science team for the Hinode/EUV Imaging Spectrometer solar space project (Mason, Del Zanna), Planck Satellite team (Challinor, Shellard), experimental work at University of Geneva and National University of Singapore verifying secure information transmission (Kent),

*Research users:* The UoA has established links with industrial and other non-academic collaborators. These include DSTL, Rolls-Royce, BP (with the BP Institute an important facilitator), Arup, Schlumberger, Met Office, EADS and Microsoft Research Redmond. Our industrial links allow for jointly supervised research students, give opportunities for internships and can lead to joint grant-funded projects. There are many consultancy arrangements between individuals and external organisations, most notably GCHQ via the Heilbronn Institute, with PinPlus, with JLT Re (London) on catastrophe risk management, with BHP Billiton, Frazer-Nash, Thales Underwater Systems, Unilever and Yorkshire Water. Members of the UoA serve on advisory groups and reviews in the area of statistics and are consulted on forensic statistics and DNA interpretation in criminal cases.

*Academic service:* Members of the UoA play leading roles in UK mathematics. Toland is Chair of the Mathematical Sciences REF Panel, Davis is a Panel Member and Norris an Assessor. Kelly was Chair of the Council of the Mathematical Sciences, Peake was Vice-President of the IMA and remains active on its Membership Committee, Totaro served on the LMS Council and Programme Committee, Manton was Chair of the LMS Research Meetings Committee and Hyland was LMS General Secretary. Samworth, Nickl (and Aston) have been members of the Research Section Committee of the Royal Statistical Society. For the Royal Society, Pedley is a Council Member, Proctor and Toland are Sectional Committee and Medals Committee Members, Tong on the Summer Science Exhibition Panel, Gog and Iserles on the Newton International Fellowship Committee, Davis and Toland on the URF Panel. Other significant national roles include Pedley (member of EPSRC Council and Chairman of Steering Committee for EPSRC International Review of Mathematical Sciences, Royal Society/Royal Academy of Engineering Advisory Group for National Physical Laboratory), Iserles (member of Strategic Advisory Team EPSRC Mathematics), Tong (STFC Particle Physics Grants Panel and Ernest Rutherford Fellowships Committee), Challinor (STFC Astronomy Advisory Panel and Far Universe Advisory Panel). Barrow was President British Science Association Physics and Astronomy 2008-9, Mathematics 2011-12.
On the international stage, Grimmett is a member of the Council of the Institute of Mathematical Statistics and Norris is on its Committee on Special Lectures. Norris was also Chair of the

Committee for Conferences on Stochastic Processes of the Bernouilli Society 2009-11. Goldstein is on the Scientific Council of the IHES. Grimmett is on the Advisory Board of the Johan Bernoulli Institute Groningen. The UoA is much involved in IUTAM: Pedley is Vice-President, Linden a delegate on the ISCU Scientific Commission for Problems in the Environment and Peake Chair of the UK panel. Barrow is on the Board of Trustees Templeton Foundation and the Scientific Advisory Board Foundation Questions in Physics and Cosmology Project (FQX). Wadhams is on the US NRC Committee on Responding to Oil Spills in Arctic Environment, a Member of the European Environment Agency Scientific Committee and a Review Editor for Chapter 1 of the 5th Assessment Report (WG1) of the Intergovernmental Panel on Climate Change. Kelly is a member of the RAND Europe Council of Advisors, Linden is Co-chair of the Venice Lagoon Sustainability Management Panel and Gog is an adviser to the WHO. Other examples include: Iserles (Board of Governors of Society for Foundations of Computational Mathematics), Gibbons (Chairman, Fachbereirt, Albert-Einstein Institute Golm), Haynes (member of Norwegian Research Council panel reviewing geophysics in Norway), Caulfield (Woods Hole Oceanographic Institution GFD Program Faculty), Linden (member of Norwegian Research Council panel reviewing mathematics in Norway), Green (International Scientific Committee of the recently founded Institute of Theoretical Sciences, Bangalore). This list consists of illustrative examples and is far from exhaustive.

*Conferences:* Many members of the UoA have played major roles in conference organisation both nationally and internationally. We highlight major conferences that have been organised in Cambridge, e.g. PASCOS 2011 (Particles, Strings and Cosmology), The State of the Universe (Hawking 70$^{th}$ birthday conference), COSMO 2013 (Particle Physics and Cosmology), Geometry and Analysis of Random Processes, Conference on the Birch and Swinnerton-Dyer Conjecture. Other examples are Allanach (principal organizer of 'Collider Phenomenology 2011), Haynes (co-Chair WMO SPARC Assembly 2008), Caulfield (Programme Committee, APS DFD meeting 2009-11), Tong (Founder and co-organiser of 'Fundamental Physics UK conference' 2008-11), Jozsa (steering committee of QIP and AQIS – 2 foremost international conferences in quantum information), Challinor (LOC for 4 international meetings, one at CERN), Markowich (sectional committee for ICM2014), Linden (International Programme Committee ICTAM 2008, 2012, IUTAM symposia/workshops), Kent (lead organizer of 'The Quantum Landscape: Generalizations of Quantum Theory and Experimental Tests' at Perimeter Institute), Skinner (main organizer of "The Geometry of Scattering Amplitudes BIRS Banff"), Green (International Advisory Committees for the main Strings conferences), Wadhams (organizer 'Oil Spills in Sea Ice Past Present and Future' ONR)

Members of the UoA have also played a prominent role (organizers or members of scientific advisory committee) in Isaac Newton Institute Programmes: Jozsa (Mathematical Challenges in Quantum Information), Gog (Infectious Disease Dynamics), Dafermos (Mathematics and Physics of the Holographic Principle), Tong (INI summer school in 'Condensed Matter, Black Holes and Holography'), Goldstein (Topological Dynamics in the Physical and Biological Sciences), Hyland (Semantics and Syntax: A Legacy of Alan Turing), Fokas (Inverse Problems), Markowich(Partial Differential Equations in Kinetic Theories), Kelly (Stochastic Processes in Communication Sciences), Ogilvie (Dynamics of Discs and Planets),

*Invited keynote lectures:* Two members of the UoA (Gibbons and Markowich) were invited speakers at the 2010 International Congress of Mathematicians and four (Dafermos, Grimmett, Gross and Markovic) will be invited speakers at the 2014 Congress. Members of the UoA were plenary speakers at many specialist meetings. Examples include Berestycki and Norris (Stochastic processes and Applications 2011), Berloff and Worster (ICTAM), Figueras (GR20), Green (Solvay Conference commemorating the 100$^{th}$ anniversary of the famous 1911 meeting), Goldstein (SIAM meeting, APS meeting), Mouhot (SIAM Conference, Analysis of PDEs 2011), Samworth (World Congress in Probability and Statistics 2012), Reall and Sperhake (GR20, Marcel

Grossman meeting). Wickramasekera gave the Bochner Lectures in 2009 and both Grimmett and Korner have been Forder Lecturers of the LMS/NZMS and Green, Mason and Wadhams have given lectures at the Royal Institution Evening Discourse. This list is by no means exhaustive.

*Fellowships:* The UoA submission includes 17 Fellows of the Royal Society (Barrow, Gibbons, Goldstein, Gowers, Green, Hawking, Hinch, Kelly, Linden, Manton, Papaloizou, Pedley, Proctor, Spiegelhalter, Toland, Totaro and Townsend) : Goldstein and Totaro were elected during the REF period (together with Tavare submitted through a different UoA). There are also 8 retired FRSs still active in the UoA. In the REF period Hinch and Kelly were elected Foreign Associates of the US National Academy of Engineering. Barrow, Davis, Linden and Pedley were elected to Academia Europaea. Green was awarded an Honorary Fellowship of the IoP. Gowers became an International Member of the American Philosophical Society. Amongst retired staff, all very much active in the UoA, Moffatt was elected a Foreign Associate of the National Academy of Sciences, Willis a Foreign Associate of French Academy of Sciences, McIntyre a Fellow of American Geophysical Union and Huppert and Weiss were both elected to Academia Europaea. (Moffatt was also awarded the 2009 David Crighton Medal by the LMS/IMA and Huppert also gave the 2011 Bakerian Lecture of the Royal Society.)

*Journal editorships:* Members of the UoA act as editors for a wide range of publications. A significant case is the Journal of Fluid Mechanics (Worster is Editor-in-Chief, Linden is Deputy Editor, Caulfield and Peake are Associate Editors). Other major roles are played by Iserles (Managing Editor Acta Numerica), Jozsa (Founding Managing Editor of Quantum Information and Computation; Physical Review Letters), Scholl and Smith (Managing Editors of the Journal of the LMS), Totaro (Editor of Compositio Mathematica). In total members of the UoA have Editorial roles in more than 50 Journals.

*Awards and prizes.* We mention some individual highlights since 2008.

Barrow: RS Michael Faraday Medal 2008, IoP Kelvin Medal 2009, LMS/IMA Christopher Zeeman Medal 2011.
Berestycki: Bernoulli Society Outstanding Expository Paper Prize 2012.
Birkar: Prix de la Fondation Mathematiques de Paris 2010.
Dafermos: IAMP Early Career Award 2009; Whitehead Prize 2009.
Green: Frontiers in Physics Prize 2013.
Goldstein: William Hopkins Prize, Ig Nobel Prize in Physics 2012.
Gowers: KBE 2012, Euler Book Prize 2011 and Stefan Banach Medal 2011.
Hawking: Special Fundamental Physics Prize 2012, Honorary Member Solvay Institute 2013.
Hinch: Euromech Fluid Mechanics Prize 2010, Fluid Dynamics Prize of the APS 2010.
Iserles: LMS/IMA David Crighton Medal 2012.
Kelly: CBE 2013, SIGMETRICS Achievement Award 2009, Gold Medal Association of European Operational Research Societies 2009, Beale Medal of the Operational Research Society 2011, Honorary Doctorate from the Eindhoven University of Technology 2011.
Markovic: Clay Research Award 2012
Mason: UKRC Women of outstanding achievement award 2010. Mason/Del Zanna -- RAS Group Achievement Award 2010.
Pedley: Gold Medal of the IMA 2008, Honorary Degree Imperial College 2013.
Samworth: Guy Medal in Bronze of the Royal Statistical Society.
Smith: Adams Prize 2013.
Tong: Adams Prize 2008.
Toland: Honorary Fellow, UCL 2008; Honorary D.Sc. Essex 2009, Royal Society Sylvester Medal 2012.

We are particularly pleased by the recognition in the above of our younger members of staff: Berestycki, Birkar, Dafermos, Del Zanna, Samworth, Smith and Tong.