Institution: University of Sheffield

Unit of Assessment: 10 - Mathematical Sciences

a. Overview

The School of Mathematics and Statistics (SoMaS), consists of 46 Category A staff, of whom 17 are professors, 8 are readers, 8 are senior lecturers and 13 are lecturers. It was formed in 2009-10 from three departments (Applied Mathematics, Pure Mathematics, Probability & Statistics), to form a coherent unit across the mathematical sciences, and to encourage greater interaction. Since 2010 SoMaS has had a single Research Committee chaired by a Director of Research (DoR) with roles in both strategic planning and more immediate support and oversight of research in the School. Other members of Research Committee include a Postgraduate Research (PGR) Director and at least six other members of academic staff to ensure that there is a good overview of broad research areas within the School. External visitors are placed in and looked after through the Mathematics and Statistics Research Centre (MSRC), which is overseen by Research Committee.

Activity is organized into eleven research groups. The research groups are flexible and overlapping. The environment is enriched by several whose papers are not returned to Subpanel. The list refers to active members of the group on the census date; research associates are indicated with an asterisk.

- *Algebra and Algebraic Geometry* [Bridgeland, Bavula, Greenlees, Henriques*, D.Jordan, Katzman],
- *Category Theory* [Cheng, Gurski, Moerdijk, Strickland, Willerton]
- *Differential Geometry* [Jotz, Mackenzie, Moerdijk],
- *Fluid Dynamics* [Kim, Li, Mole, Ohkitani, Rees, Willis],
- *Mathematical Biology and Environment* [Best, Cannings, Haslegrave*, Juarez, Kantzas*, Monk, Quegan, Walters],
- *Number Theory* [Berger, Dummigan, Jarvis, Manoharmayum]
- *Particle Astrophysics and Gravitation* [Dolan, Millington*, van de Bruck, Winstanley],
- *Probability* [Applebaum, Biggins, J.Jordan, Joseph],
- *Solar Physics* [Ballai, Gascoyne*, Gent*, Jain, Key*, Kim, Ruderman, Verth, von Fay Siebenburgen, Willis, Zheng*],
- *Statistics* [Blackwell, Buck, Harris*, Heaton, Juarez, Stillman, Triantafyllopoulos, Walters]
- *Topology* [P.Cheung*, Greenlees, Gurski, Mitchener, Moerdijk, Roukema, Strickland, Whitehouse, Willerton, Wruck*].

The leading groups in SoMaS, from the point of view of both size and international prominence are Solar Physics, Statistics and Topology.

b. Research strategy

Since the formation of SoMaS in 2009-10 we have reviewed the strategies outlined in the three departmental submissions for RAE2008 and integrated these into a coherent School vision. We seek to maintain a vibrant research culture that promotes the traditional subject areas and also strongly encourages interdisciplinary work which cuts across these areas and interacts with other subjects including physics and astronomy, biological sciences and engineering. This gives us a sound basis for impact in the academic community, and more broadly in the economic and cultural spheres.

As a result of the strategic review that followed the formation of the new school, we made the decisions to maintain our research strength in Solar Physics, Statistics and Topology, to develop the existing groups in Probability, Fluid Dynamics and Number Theory and to build two completely new groups in Mathematical Biology and Algebraic Geometry to broaden our research base. In the event we had excellent opportunities to strengthen our groups in Particle Astrophysics and Gravitation, Differential Geometry and Category Theory, which we grasped with enthusiasm. On Zinober's retirement in 2013 as the last member of the non-linear control theory group, it was decided to reinvest in other areas.

We describe the developments and plans by research group, starting with the major new

developments.

The *Mathematical Biology* group was created during the current assessment period. Its members use a range of mathematical and statistical approaches to tackle problems in the life sciences and medicine. The group collaborates widely with leading biologists and medics within the University and across the UK, and is leading current activities aimed at enhancing the coordination and activity of researchers in the broad area of quantitative biology, placing mathematics and statistics at the heart of this rapidly growing research field. Developing mathematical biology to build links across the Science Faculty was a strategic decision for SoMaS since 2008 and we have made four appointments to this area in the past five years: **Monk** to a chair, and **Best, Juarez** and **Walters. Blackwell** also interacts strongly with this group through his work in statistical ecology. We intend to develop this group and its outside links further in the future.

Algebra and Algebraic Geometry. Following the recruitment of **Bridgeland** from Oxford to a chair, we have appointed **Mozgovoy** to a lectureship in algebraic geometry (he will take up the post after the census date). The traditional strengths of the *Algebra* Group in commutative algebra and ring theory complement those in algebraic geometry and representation theory. The two new appointees will form the nucleus of a new research group, and it is a priority to develop this group around **Bridgeland** in ways that will also have a significant impact on the development of algebra and topology.

In *Statistics*, Sheffield was the lead institution of a consortium of five universities working on the RCUK-funded project “Managing Uncertainty in Complex Models” (MUCM). The project led by **Oakley** and **O’Hagan** ran from 2006 to 2012, and provided employment and training for 12 post-doctoral research associates and 4 postgraduate research students. The project consolidated the UK's standing as world-leading in research in statistical methods for analysing uncertainty in complex computer models. Development of this theme, in the context of our overall strength in applied statistics, is one of our ongoing strategic priorities. There have been three new appointments in statistics (**Heaton, Juarez** and **Walters**) in the assessment period, which have strengthened our activity in Bayesian modelling and biological statistical modelling.

Meanwhile, the existence of the School has permitted us to develop *Probability* as a separate group, seen as a bridge between the pure and statistics areas. To expand the existing group, we have made two appointments in the assessment period: **Luczak** (who has since moved on) to a chair and **Joseph**, who contributes expertise in the important area of stochastic PDEs.

In *Solar Physics*, Sheffield has one of the leading mathematical groups in the UK, well-funded through an STFC consolidated grant, recently renewed. Alongside recruitment of research staff, **Ruderman** and **Verth** have had Leverhulme Fellowships, and we have appointed **Verth** to a permanent position.

We continued to build the *Fluid Dynamics Group* around **Ohkitani**. It was created in the 2001-7 period, with the appointment of **Willis** further strengthening the group. Links with solar physics and engineering aspects (wind and rheology) are strong and ongoing.

The *Particle Astrophysics and Gravitation Group* has strong links to the physics department, and is supported by an STFC consolidated grant linking it with Manchester and Lancaster. It has received a significant impetus through the appointment of **Dolan** and the promotion of **van de Bruck** to a chair.

The *Topology Group* has a strong international profile and has been closely involved in major developments in equivariant topology and homotopy invariant structures. There are strong links with the *category theory* group, deeply embedded in both groups, and we have developed this further through the appointment of **Gurski** in 2009. The Postdoctoral Fellows **Hepworth**, **Barnes** and **Wruck** and the EPSRC Career Development Fellowship for **Gurski** have further stimulated activity. The LMS Funded Transpennine Topology Triangle gives strong links with the groups in Leicester and Manchester. The Topology Group also has close links to both commutative algebra and representation theory through the derived category and to analysis through K-theory.

The flourishing *Number Theory Group*, which focuses on elliptic curves, modular forms and Galois representations, has maintained strong connections with the Heilbronn Institute through **Jarvis** and **Snaith** (now emeritus). The group was further strengthened with the arrival of **Berger** in 2010. *Differential Geometry* has been strengthened by the appointment of **Jotz** to a UoS Vice-

Chancellor's Fellowship in 2013 (following 3 years as a research fellow she will transfer to a lectureship).

Research strategy is influenced by discussions at research group level that feed via the Group convenors into Research Committee. New ideas are disseminated in weekly seminars and study groups run by suitable combinations of the research groups. Funding for research activity is administered through three funds. External visitors are funded through the MSRC, and research visits are paid for through the Research Fund; there is inevitably an element of competition amongst applications and decisions about funding are taken by small subcommittees of Research Committee. The third fund is for smaller amounts and academic staff can automatically obtain funding for all reasonable requests up to £500. The MSRC also organises and funds short conferences to be held in Sheffield. For example meetings on homotopy theory, magnetohydrodynamics and probability, statistics, and analysis on groups have been held under its auspices since 2010. In March 2013 the School successfully hosted the 65th British Mathematical Colloquium, with an array of distinguished plenary and morning speakers covering a wide range of subjects. Specialist workshops in six disciplines were organised by members of the School and several of the LMS Scheme 3 groups to which we are affiliated held satellite meetings in advance.

We list a selection of research highlights for the period 2008-13. **Bridgeland** has provided a solution to the twenty-year old problem of constructing quantum groups via Hall algebras of quiver representations and has proved the conjecture equating reduced Donaldson-Thomas invariants with stable pair invariants. **Bavula** has established an analogue of the Dixmier conjecture for certain algebras of polynomial integro-differential operators**. van de Bruck** has analysed the cosmological consequences of dark energy models with screening mechanisms (such as the runaway dilaton model and chameleon field theories) and made predictions for local experiments.

Monk has developed a mathematical model for the regulation of root hair formation. A key prediction about a gene controlling hair/non-hair loss in the epidermis was verified by experiment, and this has revised conventional biological thinking about the phenomenon. **Applebaum** (with Riedle, Manchester, now KCL) has developed a general theory of cylindrical Levy processes in Banach spaces, and begun to explore applications to stochastic PDEs. **Jarvis** (with Buzzard, Imperial and Diamond, KCL) has completed the prediction of optimal weights for modular mod p Galois representations for totally real fields. **Ruderman**, **von Fay-Siebenburgen** (publishing as **Erdelyi**) and **Verth** have derived the equation describing kink waves in a magnetic tube with variable radius of cross-section. This equation is important because of its application to a new and fast emerging branch of solar physics called coronal seismology and it is being used to estimate the atmospheric scale height in the solar corona related to the plasma temperature. With **Dowker** (Sheffield), **Ohkitani** has established a novel characterisation of intermittency in 3D Navier-Stokes turbulence, on the basis of a cutting-edge theorem of Caffarelli-Kohn-Nirenberg. Also they have shown numerically that 3D Navier-Stokes flows are less singular than (globally regular) 3D Burgers flows. **Oakley** (with **Chilcott** and **Strong**, both Sheffield) has developed an innovative approach for tackling arguably the hardest problem in quantifying uncertainty in a computer model prediction, namely quantifying uncertainty due to an imperfect model, without using real world observations. This involved decomposition into sub-models and use of variance-based sensitivity analysis. **Greenlees** (with Shipley, Illinois) gave a complete algebraic model for rational torus-equivariant cohomology theories. **Moerdijk** has constructed the category of dendroidal sets and a model category structure on it, thereby giving a new model for infinity categories.

c. People, including:

i. Staffing strategy and staff development

When recruiting new staff we sometimes target specific research areas that we aim to build, as described above for Mathematical Biology and Algebraic Geometry. On other occasions we cast the net more widely to extend and complement our existing strengths. Our general strategy is to recruit talented staff who show promise and achievement early in their career. Chairs of all University interview panels are required to undertake training, which includes the issues of equality and diversity. The University is an active supporter of the two tick initiative which guarantees an interview for individuals who disclose a disability and meet the essential criteria for the role.

All academic staff have an annual review, either a Probationary Review or as part of the Staff

Review and Development Scheme. In either case this has both a retrospective and a prospective element, and is implemented so as to provide support and guidance to the reviewee. These processes also feed into decisions about reward. The reviews cover all aspects of academic duties, including specifically a research plan and a report on progress towards publication, impact and grants. Each postdoctoral researcher has a mentor, who provides support and guidance. In addition they have an annual SRDS review conducted by another senior member of staff.

With Faculty and University support, SoMaS maintains a series of measures designed to protect research time including a Study Leave policy in which members of staff are entitled to request a semester of leave after six semesters of standard duties. Recommendations on granting this leave are made by a School panel and approved by Faculty, with the aim of supporting research excellence; typically 3 or 4 members of staff are on Study Leave at any one time. Grant funded research time is represented in the School's workload allocation model. "Red-lining weeks" in January and July are cross-faculty initiatives which encourage researchers to put red lines through their diaries for two weeks per year to focus solely on research, and to consider interdisciplinary collaboration and grant writing. Where possible, the School attempts to accommodate research travel by leave and reallocation of duties.

***Postdoctoral research staff**:* In 2012 the University was awarded the *HR Excellence in Research* award from the European Commission and we are committed to applying the 7 principles of the *UK Concordat for the Career Development of Researcher*s and supporting the University's action plan. All postdoctoral research staff receive cognate-discipline tailored inductions that highlight researcher professional development (RPD) opportunities available to them. They then access a programme of RPD and career support opportunities that fit their career tracks (content is balanced between provision for those aspiring to be independent researchers and those aspiring to other careers); highlights include *Crucible* and *Spring Board for Women.* Our postdoctoral research staff are exposed to different disciplines as many events facilitate networking across disciplines (events geared to this include *Broadening Horizons; GradSchool* and *Researcher Mentoring*). They also have access to a tailored researcher mentoring programme designed to inculcate independence amongst junior researchers. Equipped with new skills and ways of thinking, we recognise that the RPD opportunities not only help individuals' careers but equally benefit their roles at Sheffield and their ability to contribute more fully to Sheffield's ambitions. At the School level, our Early Career Support Officer has the specific responsibility of overseeing the interests and wellbeing of ECRs.

Research Fellowships: The presence of Fellows within the School boosts the research environment and encourages other visitors. Naturally, the School encourages staff to apply for Fellowships, and others to hold their Fellowships in Sheffield, and it provides full support for fellows during their tenure. During the assessment period the School has hosted **Ruderman** and **Verth** on Leverhulme Fellowships, **Bridgeland** on a Royal Society URF, **Barnes** and **Hepworth** as EPSRC PDRFs and **Wruck** as a DFG PDRF.

International appointments and visiting scholars. We have one member of staff (**Moerdijk**) who has an appointment split between Sheffield and the University of Nijmejgen. A steady stream of visiting scholars spend time in the School; the process is facilitated through the MSRC, and dedicated office space and computer facilities are provided for visitors.

Equality and diversity. The School is made up from staff from a variety of cultures around the world, making SoMaS an exciting and diverse place in which to work. We recruit the best academic and research staff regardless of their race, gender, nationality, sexual orientation, or religion. We recognise that supporting equality and diversity contributes to making the environment healthy and productive. The key diversity challenge for us, and for the profession as a whole, is to attract, retain and develop excellent female staff. With our percentage of female academic staff being almost 30% at Reader and Senior Lecturer level and over 20% at Professorial level, we are considerably above the national average, though there is much work to be done to improve our position.

In partnership with other Faculty of Science Departments, we are taking positive actions and making investments to increase the number of female academics, researchers and students. The

Faculty has a high-level strategic commitment to be a place of choice for women to work and has established a Faculty Equality and Diversity Committee to understand and address any barriers in achieving this aim. All members of this Committee, plus the Faculty Executive Board have received Unconscious Bias training. The University operates a flagship Women Academic Returners Programme which offers funding to women returning to research after a break to ensure that they are able to focus on research for their first semester.

The School is an LMS Good Practice Scheme supporter and we have also formed an Athena Swan Self-Assessment Team to work towards achieving an Athena Swan Award. As part of our November 2013 submission, a comprehensive action plan is supplemented by the following: training for staff in gender awareness, gender equality and workplace bias, monitoring UG student data by gender, monitoring staff appointments, including fellowships and pay award success rates, training managers in flexible working practice, and promoting and agreeing flexible working as an option to all staff, encouraging the take up of the mentoring schemes available to staff and providing further evidence to staff about the potential benefits.

Fostering Good Research Practices. Amongst the Russell Group, the University is a leader in fostering good research practices (GRP), recognising that excellence requires intellect and integrity and that research environments must be underpinned by cultures of integrity. Mathematics contributed to the content of the University's *Good R&I Practices Policy* (which seeks to reflect world-wide best practice). The Policy sets the tone, clarifying that GRP is as much about how people are respected as about the rigour of doing research. Sheffield delivers compulsory GRP training for all its research students and this training is delivered along 5 cognate discipline lines by academics and early career researchers in the disciplines.

ii. Research students

A PGR Director reporting to Research Committee oversees all matters concerning PhD students, and chairs a PGR Committee (which includes 3 student representatives). In addition to having at least one supervisor, all PGR students in SoMaS are allocated an advisor who is well informed about the subject area and involved in the formal and pastoral support of the student. The main element in training and support of PhD students is a regular meeting with the supervisor, and the SoMaS guideline is that students meet their supervisor every week; meetings are logged online. The School has a strong culture of frequent and detailed supervisory meetings, including for part-time or distance-learning students. In the case of recent distance-learning students, supervisors have paid visits to the students' home institution for intensive periods of personal supervision, in addition to regular distance-supervision. The QAA noted that mechanisms to monitor formal meetings with supervisors were effective.

Students all receive a thorough induction with different elements covered at University, Faculty and department level (provision was commended by the QAA). At the start of their studies, students conduct a Training Needs Analysis with their supervisor, and make a plan to ensure suitable support for their studies. The most substantial needs are subject specific knowledge and experience in presentations, but background on research ethics, culture and practices is also included. Professional development opportunities available within the University are accessible via the Doctoral Development Programme – DDP (which was noted positively by the QAA). Guided by EPSRC policy, we require that PGR students should engage in at least 100 hours of taught training for the first two years of their studies. Such study is intended to broaden and deepen the training we offer and so students are encouraged to choose courses from the full range of mathematical science training, including MSc modules, EPSRC Taught Course Centre courses (MAGIC) and external training (e.g. APTS modules and appropriate summer/winter schools). Funding is available to support such training, and decisions are taken in association with the supervisor. In our 2013 PRES survey, 95% of the 42 research students from the School confirmed they had attended an academic research conference (comparing favourably with the sector average of 70%).

Recruitment. Applications in all subjects are sent to potential supervisors, who decide on the academic suitability of candidates. Where possible, suitable candidates are invited for interview and to meet the relevant research group, and successful candidates are offered a place. The

academic members of PGR Committee consider cases for funding competitively on 4 dates; their primary criterion is academic strength, but balance is also taken into account.

Progression. Each student is subject to a full review after 1 year, at which it is decided whether to permit continuation to a PhD or transfer to an MPhil. There is second major review at the end of the second year. In addition there are light touch reports each six months. The target is to ensure students submit a high quality thesis in under four years. Where there is a danger of this not happening, the review and support processes are intensified.

d. Income, infrastructure and facilities

Income: As detailed in the figures in our return, our grant income for academic year 2011/12 comes from EPSRC (16.8%) and STFC (71.7%), with lesser amounts from other sources (11.5%). Our industrial funding (0.8%) for this period included a significant award from Northumbrian Water Ltd. Our intention is to maintain the RCUK income, in broadly similar proportion, but to target ERC and industrial funding.

Plans for income capture are discussed and agreed with individual staff on an annual basis, and reviewed in between. All grant applications are refereed internally by two colleagues from the School, ensuring that standards are high and opportunities for collaboration are maximised. ECRs receive appropriate mentoring and their interests are represented by an Early Career Support Officer. Research Committee plays a key role in the School in ensuring that staff are kept well informed of calls for applications at both national and international level. The University's Research and Innovation Services unit provides us with tailored support for grant and contract negotiations, consultancy arrangements and information about upcoming calls for proposals.

The income figures are somewhat brought to life by a description of just a selection of grants across the School.

Quegan's eminence in the mathematics of Earth observation science has led to a number of key grants coming to SoMaS. These include £636K from NERC's National Centre for Earth Observation for developing the carbon cycle theme (2008-13) which supported two PDRAs and a graduate student, and £150K from the European Space Agency (2009-11) supporting a PDRA to make a background study for the BIOMASS mission to take measurements of forest biomass to assess terrestrial carbon stocks and fluxes. The selection process began in 2005 with 28 groups, and over the next 8 years, BIOMASS won through at each of three competitions to be chosen for the €370M mission, and substantial grant income will come to the School as a result. Another major initiative in which **Quegan** is involved is an EU FP7 grant of £361K for two PDRAs to model forcing and feedback mechanisms within carbon/water fluxes in the Arctic (2009-11).

The solar physics group also has a strong record for grant capture. **von Fay-Siebenburgen** is PI on an STFC consolidated grant of £1,236K involving 5 PDRAs to study waves in the near-surface solar interior and atmosphere and develop the multi-scale theory and self-organisation of the Sun (2012-16). Together with **Ruderman**, he obtained a grant of £330K from STFC for 3 PDRAs to study waves and oscillations in the solar corona (2010-12). This grant also purchased a storage server for £70K for supercomputing and running gpu code. Another key grant from STFC of £611K with **von Fay-Siebenburgen** as PI has supported 5 PDRAs and is focused on MHD wave heating, and identifying the observational signatures of the various wave heating mechanisms using solar magneto-seismology (2008-11). **Kim** was PI (with **Jain** as co-I) of an STFC grant of £497K (2008-12) which employed a research assistant and three post-docs to investigate turbulent transport processes in stars, local helioseismology of the solar convection zone and the effects of magnetism on the sun's resonant acoustic oscillations.

MUCM2 (EPSRC £273K, 2010-12) was a continuation of the MUCM grant under the RCUK Basic Technology Translation Grant Scheme. This was an influential joint initiative with Aston, Durham, Exeter and LSE, but with Sheffield leading through **O'Hagan** and **Oakley**. The objective was to explore new directions to extend the research done under MUCM, which was also a full Basic Technology grant. MUCM2 focused on scoping extensions to statistical techniques for quantifying and managing uncertainty in models with stochastic outputs, models with non-homogeneous behaviour and models whose input space is itself a decision. Nine post-docs were supported overall with one based in Sheffield. Following on from MUCM, **Oakley** has obtained an award of £576K from EPSRC under the "Future Manufacturing with Mathematical Sciences" call

(2013-16) to develop and apply methods from MUCM and statistical process control in designing more robust automated manufacturing processes. The co-investigators include other SoMaS statisticians and two colleagues from the Sheffield Advanced Manufacturing Research Centre.

An award of £1.035M from EPSRC and NERC (2010-15) has been made to support the National Centre for Statistical Ecology (NCSE), a research consortium primarily based in Kent, St Andrews, Sheffield and Bath. At Sheffield, NCSE supports a PDRA, developing Bayesian methods of inference for continuous-time models of animal movement under the supervision of **Blackwell**. NCSE also funds part of **Blackwell**'s time for research in this area, and a "priority area" stipend enhancement for his NERC-funded PhD student Spence.

Proof-of-concept funding of £100K from the University's EPSRC Knowledge Transfer Account was awarded to promote the development of a novel rheometer that is being undertaken by the multidisciplinary team led by **Rees**. The funding was used to employ PDRA support to perform laboratory testing of a prototype device and computational modelling, including simulations of the temperature stability across the unit, for which precise control is essential for reliable operation. It was also used to commission the production of bespoke components for the rheometer from the university's technical workshops.

Greenlees has an EPSRC grant of £313K (2010-14) which supports both a PDRF and a graduate student to investigate rational equivariant cohomology theories. **Katzman** has an EPSRC grant of £220K (2012 -15*)* to support a PDRF to find new connections between local cohomology, D-modules and tight closure.

SoMaS has also been successful in obtaining EPSRC First Grants for new staff. **Berger** obtained an award of £72K in 2012 and Willis £72K in 2013. **Gurski** obtained an EPSRC Fellowship for £245K to develop applications of 2-category theory to algebraic topology.

SoMaS benefits from having its own statistical consulting unit – Statistical Services Unit (SSU). It has a director and five other staff (four full time and one part time) and provides expert statistical advice to a number of major companies including AstraZeneca and Unilever. From time to time, academic statisticians within the School may provide one-off consultancy services to the SSU when their expertise is relevant to a specific need. The Applied Probability Trust (which published "Journal of Applied Probability and "Advances in Applied Probability") is based in SoMaS and since 2009 has sponsored an annual lecture to take place in Sheffield given by a leading international expert.

Infrastructure:

The provision of IT equipment in SoMaS follows two routes:

1. On an annual basis, we review the computing support across the whole School (academics, PhDs, PDRAs and support staff) and both ask for requests for new equipment and actively suggest updates for staff with old machines. In recent years the School has allocated sufficient budget for most requests to be met and to ensure that all staff have adequate computing resources for their needs. This includes the provision of customised high power machines when staff needs required it.
2. When grant applications are submitted, staff request support for specific exceptional computing requirements. Because there exist active long-standing research groups in SoMaS with heavy computational needs (e.g. Solar Physics and Fluid Dynamics), this has led to the development of clusters of computing resource with high power, large storage, specialist software and excellent graphics capabilities.

Technical support is through 1.5 members of staff who advise on all aspects of IT and report to the Director of Computing. Planning meetings are typically held twice a year, one to ensure that we have sufficient provision for incoming PhDs (we have a policy of providing all new PhDs with a new machine according to a specification set out by their supervisor) and another about 6 months later for the annual review of staff machines, leading to proposals for updates (within available budget), which the Computing Support staff then discuss with individual members of staff.

The University's Corporate Information and Computer Services unit (CICS) is committed to supporting research in all disciplines and strengthening relationships with researchers by facilitating collaboration, providing research computing facilities, supporting research applications,

and helping departments with research costing management. For example, researchers throughout the university can make use of Iceberg which is a Linux based high performance computing cluster and the Solar Physics group is a particularly heavy user of this facility. The University is also a partner in the N8 Tier 2 High Performance Computing facility which is used for particularly challenging computational problems such as arise in Solar Physics and Fluid Dynamics. The University has invested significant resource of some £2m over the REF period into the HPC facilities.

CICS also provides licenses for SPSS, Matlab and Maple. Sheffield is a member of the N8 Research Partnership of research intensive universities in the north of England. This enables us to utilise the Polaris facility which is an SG1 high performance computing cluster with 332 compute nodes.

The University Library offers a wide variety of learned journals in both print and electronic form. There is also access to databases such as Zetoc and Journal TOCs. The Library's Netvibes Universe is an online resource which brings together useful web-based current awareness services, including news feeds, and makes them easily available from one page. The Library helps to administer the repository White Rose Research Online (WRRO) which houses research outputs from the Universities of Leeds, Sheffield and York. Depositing a research paper in WRRO satisfies the requirements for Green Open Access. For the period April 2013-March 2015, RCUK has supplied a block grant to the University of Sheffield to form part of a University Publication Fund. This fund is being administered through the Library, and is used to support the payment of Open Access Article Processing Charges for RCUK-funded research.

e. Collaboration or contribution to the discipline or research base

Support for research collaboration, with academics, industry.

Support for and exemplars of Interdisciplinary research: First, at the University level, the Faculty based organisation has removed many of the barriers, partly for structural reasons and partly because of the active support of the Faculty Pro Vice Chancellors. Within the School, perhaps the most important support is to recognize that the value of the research is not purely in its mathematical science content. The range of interests in the School encourages a breadth of interest and an understanding of the diversity of research cultures and makes allowance, in appointments and rewards, for the long term value of interdisciplinary work.

Examples of interdisciplinary research: Quegan's leadership of the carbon cycle theme in the NERC National Centre for Earth Observation involves collaboration with Ian Woodward from Animal and Plant Science at Sheffield and also Edinburgh (John Grace, John Moncrieff and Mat Williams) and Leicester (Paul Monks, Hartmut Boesch, Sue Page), UCL (Phil Lewis and Mat Disney) & KCL (Martin Wooster). It brings together our best knowledge of ocean, land and atmosphere processes, expressed in computer models, with a wide range of measurements from space and supporting ground data, to make the best possible picture of how the carbon cycle behaves and to improve climate models. His work on the BIOMASS project for ESA involves collaboration with the Politecnico di Milano (Fabio Rocca), the Danish Technical University (Jorgen Dall) and the German Aerospace Research Organisation (DLR) (Kostas Papathanassiou).

Buck has on-going collaborations with archaeologists and with palaeoenvironmental scientists. Most notable of these are two NERC funded projects, one with Glynis Jones in the Department of Archaeology at the University of Sheffield and Mike Charles in the School of Archaeology at the University of Oxford and the other with a large team of scientists from around the world led by Paula Reimer in the School of Geography, Archaeology and Palaeoecology at Queen's University Belfast. The former collaboration focuses on modelling the spread of early farming through Europe and the latter on providing models and methods for estimating the internationally-agreed radiocarbon calibration curves.

Walters is working with Santibanez-Koref at the Institute for Human Genetics, Newcastle, UK on probabilistic models of DNA methylation propagation in lung tumour development and with Milo from Biomedical Sciences, UoS on eQTL detection from exome sequence data via Bayesian shrinkage models.

Monk is working with Schmidt (Plant Sciences, Academia Sinica, Taiwan) with funding from a Royal Society Collaboration grant to develop mathematical models which explore the ways in which genetic and environmental factors are integrated during root hair development in plants. He also collaborates with Fleming (Animal and Plant Sciences, Sheffield) using EU funding (**Monk** is a co-I) to apply genetics, atomic force microscopy and mathematical modelling to understand the development of leaves.

Rees is working on interdisciplinary projects in the field of engineering fluid mechanics. Her main collaborators are Fairclough (Chemistry) and Zimmerman (Chemical and Biological Engineering, CBE). They are developing a novel rheometer for the inline monitoring and control of industrial processes that involve fluids. This research has been supported by the University's EPSRC KTA and HEIF POC mechanisms. **Rees** also works with Cowell and Whiteside in the Dept. of Human Communication Sciences on wavelet analysis of speech waves. This project has received funding from the University's EPSRC Bridging-the-Gaps Programme.

Leadership in Community: Academic staff in SoMaS have served on over 30 editorial boards of international journals since 2008 including “Bernoulli” (**Applebaum**), “Advances in Applied Probability” (**Biggins**), “Bayesian Analysis” (**Buck**), “Algebraic and Geometric Topology” (**Greenlees**), “Astrophysical Journal Letters” (**Jain**), “Journal of Pure and Applied Algebra” (**Moerdijk**), “Annals of Pure and Applied Logic” (**Moerdijk**, co-ordinating editor), “Nonlinearity” (**Ohkitani**) and “JRSS Series B” (**Oakley**). In addition **Applebaum** is a guest editor of a special issue of IEEE Journal of Special Topics in Signal Processing devoted to applications of differential geometry (2012-13).

Moerdijk won the 2011 Descartes-Huygens prize of the French Academy of Sciences and the 2012 Spinoza prize of 2.5 million euros. He was also one of the judges for the 2012 ECM prize.

Greenlees is Vice President of LMS (2009-13), a member of the scientific committee of ICMS (Edinburgh) and of the REF Mathematical Sciences subpanel. **von Fay-Siebenburgen** is the Solar Physics and Solar Systems Science representative on the STFC Science Board. **Ruderman** was awarded a Royal Society Leverhulme Trust Senior Research Fellowship for the 2011/2012 academic year. **Winstanley** served on the LMS council (2008-9) and was awarded the Australian Institute of Physics Women in Physics Lectureship in 2010. **Buck** was a member of the panel for International Evaluation of Research and Doctoral Training for University of Helsinki (2011). **Quegan** is chair of the European Space Agency BIOMASS mission assessment group and leads the Carbon Cycle Theme within the NERC National Centre for Earth Observation. **Whitehouse** was a team leader at the Women in Topology workshop at BIRS, Banff (August 2013) where the international Women in Topology network was launched. **Oakley** has served as an expert advisor on the National Institute for Health and Clinical Excellence (NICE) Scientific Advice Programme. **D.Jordan** is the Chair of the Scientific Committee of the British Mathematical Colloquium.

Conference organisation: **Applebaum** was on the Scientific Committee for the 7th Conference on Levy Processes (Wroclaw 2013) and organised the stochastic analysis session at the 8th International Isaac Congress (Moscow 2011), **Berger** was a co-organiser for the conference on Galois Representations and Automorphic Forms (Bedlewo 2011) **Greenlees** has organized an ICMS meeting on the Kervaire Invariant (2012) and two Oberwolfach meetings in Homotopy Theory (2008, 2012). Visits for scientific collaboration to universities in the UK and elsewhere are extensive and include **Applebaum**, University of New South Wales (two months 2012), **Moerdijk**, University of Paris VII (one month 2012), **Ruderman**, Katholieke Universiteit Leuven (three months 2008) and Russian Academy of Sciences (one month in both 2009 and 2010), **Triantafyllopoulos**, Imperial College (2 months 2010), **Willis**, Max Planck Institute, Goettingen (4 months 2010), **Winstanley**, Australian National University, Canberra (2 weeks 2009).