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| <b>Institution:</b> University of Plymouth  |
| <b>Unit of Assessment:</b> 10 (Mathematical Sciences)   |
| <p><b>1. Unit context and structure, research and impact strategy</b></p> <p>UoA10 (Mathematical Sciences) at the University of Plymouth is focused on the 22 academics in the Centre for Mathematical Sciences. Significant research progress has been made since REF2014 including: increasing grant income from around £0.5m to nearly £2m (this includes Research Income-in-kind); growing a fully integrated community of postdoctoral and postgraduate researchers; becoming a founding partner in the Environmental Futures &amp; Big Data Impact Lab; and providing leadership in High Performance Computing.</p> <p><b>Structure, Research Groups and Strategy</b></p> <p>Our thriving Centre for Mathematical Sciences (CMS, <a href="http://math-sciences.org/">http://math-sciences.org/</a>, <a href="https://www.plymouth.ac.uk/research/centre-for-mathematical-sciences">https://www.plymouth.ac.uk/research/centre-for-mathematical-sciences</a>) was established early in the assessment period to provide an overarching <b>research structure</b>. Since 2019, CMS has been part of the School of Engineering, Computing and Mathematics (SECaM, <a href="https://www.plymouth.ac.uk/schools/school-of-engineering-computing-and-mathematics">https://www.plymouth.ac.uk/schools/school-of-engineering-computing-and-mathematics</a>), but for most of the period it was in the School of Computing, Electronics and Mathematics. SECaM is in the Faculty of Science and Engineering (<a href="https://www.plymouth.ac.uk/about-us/university-structure/faculties/science-engineering">FoSE, https://www.plymouth.ac.uk/about-us/university-structure/faculties/science-engineering</a>). Its Deputy Head (<b>Eales</b>, SFHEA), and three Associate Heads (AHoS) – Research (<b>Rago</b>), Mathematical Sciences (<b>Christopher</b>) and School Outreach &amp; Admissions (<b>Lavelle</b>) – are in CMS. In 2020, SECaM received an Athena Swan Bronze Award, following an application led by SECaM's Equality, Diversity and Inclusion (EDI) Committee Chair (<b>Wei</b>).</p> <p>CMS is built around five interacting research groups:</p> <p><b>Applied Mathematics [AM]</b> (<b>Craven*</b>, <b>Hughes</b>, <b>Sharp</b> and <b>Stuhlmeier*</b>, with <b>Davies</b>, <b>Dyke</b>, <b>Graham</b> and <b>Reis</b> having been members during the assessment period), conducting interdisciplinary research into dynamical systems, financial mathematics, fluid dynamics, stochastic algorithms and mathematics education. This work capitalizes on our expanded High Performance Computing (HPC) provision, and on laboratory facilities and impact-yielding synergetic engineering links that SECaM now provides.</p> <p><b>Pure Mathematics [PM]</b> (<b>Broomhead*</b>, <b>Christopher</b> and <b>Robertz*</b>, with <b>Huggett</b>, <b>Logares*</b> and <b>McCourt*</b> having been members), conducting research into algebraic geometry and representation theory including derived categories and moduli spaces, dynamical systems including algebraic and geometric aspects of integrability, and algorithmic algebra including computational group theory and differential algebra. The</p> |

\* Appointed since start of 2013/14 academic year.

group provides a theoretical underpinning for CMS's activities, and its research includes work at the interfaces with applied mathematics, computer science, cryptography, network analysis and theoretical physics.

**Quantum Electrodynamics at High Intensities [QEHI]** (**Heinzl**, **Ilderton**<sup>\*</sup>, **King**<sup>\*</sup>, **Lavelle** and **McMullan**), conducting research into the interaction of charged particles and photons with high-intensity lasers. It has undertaken consultancy work for the Central Laser Facility (Rutherford Laboratory), Extreme Light Infrastructure (Prague, Bucharest) and the LUXE experiment (DESY and EU.XFEL, Hamburg) that influences new experimental facilities world-wide.

**Lattice Field Theory [LFT]** (**Drach**<sup>\*</sup>, **McNeile**<sup>\*</sup> and **Rago**, with **Langfeld** and **Patella** having been members), conducting research into quantum field theories with emphasis on strongly interacting matter that contributes to an *ab-initio* description of the strong sector of the Standard Model of Particle Physics and Standard-Model extensions. Its activities are based on extensive experience with HPC simulations that are among the most computationally expensive world-wide. Because of this, the group leads Plymouth's HPC Centre and contributes to the management of the DiRAC (Distributed Research utilising Advanced Computing) consortium.

**Statistics and Data Science [SDS]** (**Cardinali**<sup>\*</sup>, **Dalla Valle**, **Eales**, **Lubert**<sup>\*</sup>, **Stander**, **Wei**<sup>\*</sup> and **Wojtys**<sup>\*</sup>, with **Hewson**, **Kaimi**, **Moyeed**, **Niu**<sup>\*</sup>, **Palacios**, **Shaw** and **Wright** having been members), developing computationally-intensive methodology to undertake impact-rich projects in Big Data, evidence synthesis, financial time series, Health Data Science, industrial monitoring, machine learning, multivariate modelling, and statistics education.

The overarching **objectives** of our REF2014 research strategy were to enhance our excellence by producing world-class, computer-assisted research, and to develop a vibrant and sustainable research environment. People and their development are central to our approach with a key objective being to ensure that all CMS staff are submitted to REF2021. CMS recruited strategically, identifying strengths and acknowledging areas needing support, and led colleagues back into research (e.g. **Eales**). Guided by international directions, funding opportunities and the University's long-term plans, CMS has made appointments with expertise in computationally intensive areas including Data Science, HPC and computer algebra to reinforce bridges between its groups. We have recruited from top research facilities including Bristol, CERN, Hannover, Oxford, Technion Israel Institute of Technology and UCL, evidencing our capacity to attract high-calibre researchers. The quality of our researchers is further illustrated by the destinations of staff as their careers evolved, e.g. Professorship at Humboldt University Berlin, or Head of Department in Liverpool and Leeds.

We measure ourselves by strict international standards. Our ability to attain these is exemplified by prize-winning and highly-cited top journal publications, including the 2016 High Power Laser Science and Engineering Editor-in-Chief Choice Award (**Heinzl**,

**King**), the American Physical Society (APS) Journals Editor's 2017 and 2018 suggested articles (**Heinzl, Ilderton**), a cover feature in *Physical Review Letters* (<https://journals.aps.org/prl/covers/113/1>), the 2018 *Journal of Statistics Education* Best Paper Award (**Stander, Dalla Valle**), a *Bulletin of the London Mathematical Society* award for a top downloaded new paper 2017/2018 (**Broomhead**), numerous rapidly-cited papers, e.g. 10.1103/PhysRevD.91.054508, 10.1103/PhysRevD.89.125003, 10.1002/sim.6381 and 10.1007/s00209-016-1690-1 (SciVal, exceeding 97<sup>th</sup>-percentile), and a globally featured media paper (<https://www.independent.co.uk/news/science/black-holes-laser-beam-stop-electrons-light-speed-travel-first-time-radiation-reaction-imperial-a8200531.html>).

Our strategy has enhanced the profile of our interdisciplinary and international collaborations and provides us with a flexible, structured and supported environment for future success. Our research grant expenditure (detailed in REF4b/c) has increased by 273%, from £534K (REF2014) to a healthy £1,994K. We will sustain and increase this through a strategy that includes strong support for the grant writing activities of newer members: e.g. very recently CMS has won an EPSRC ExCALIBUR award (**Rago**), a Science and Technology Facilities Council (STFC) Consolidated Grant (**McNeile, Drach**), and an EPSRC New Investigator Award (**Stuhlmeier**).

Our vibrant research environment has been supported by a growing number of successful PGRs (from 10 to 17), and of postdoctoral researchers (from 1 to 8). We have also supported a broader programme of international visitors, including researchers from Brazil, China, Europe, Israel, Mexico and North America. All this provides clear evidence of CMS's growth and strong forward momentum.

We expanded our multidisciplinary HPC Centre <https://www.plymouth.ac.uk/about-us/university-structure/faculties/science-engineering/hpc> in line with our strategic plan. Following an initial University investment of £350K, this Centre enjoyed rapid success including early bench testing of HPC management software with Intel, Nvidia seed-funding, the appointment of **Rago** (Chair) and **McNeile** to the DiRAC Particle Physics Research Allocation Committee, four plenary speakers (**Langfeld** 2016, **Patella** 2016, **Rago** 2017 and **Drach** 2019) at Lattice Symposia, and expanding CPD activities (CUDA and GPU programming, parallel programming (MPI), OpenMP and shared memory systems, and Binary coding). It also facilitated collaborations with the University's COAST Group (<https://www.plymouth.ac.uk/research/coast-engineering-research-group>) funded by two EPSRC grants (Virtual wave structure interaction simulation, WSI, £288K, 2013–2017 and Collaborative-Computational-Project on Wave-Structure-Interactions, CCP-WSI, £483K, 2015–2020) held by **Graham** and others, and also led to the EPSRC ExCALIBUR award (**Rago**).

The recent creation of SECaM has produced a synergistic mix of researchers, creating opportunities for multidisciplinary collaborations between its core areas. SECaM aligns with Government priority areas of autonomy, clean growth, digitalisation and health technology, which themselves link with the University's strategic research institutes:

Health and Care, Marine and Sustainable Earth. The Supergen Offshore Renewable Energy (ORE) Hub led from Plymouth offers funded opportunities for the application of SDS research. SECaM also enhances **intradisciplinary research** in renewable energy undertaken by AM, existing collaborations between the HPC Centre and the COAST group, and between its health-technology areas and SDS. These links are further strengthened by an EPSRC Doctoral Training Partnership (DTP) in the fields of ORE and Health/Medical Technology. The University has recently approved a £50M investment in SECaM's interdisciplinary vision. This takes the form a new Engineering and Design Facility building (NEDF, due January 2023) that will provide accommodation for SECaM's research infrastructure. NEDF will house structures for the HPC Centre and virtual reality data visualization, with CMS design input.

### Impact

Seeding and supporting **research impact** are central to SECaM's culture. An **Industrial Strategy Group** comprises discipline-relevant industrialists from, for example, BT, the Met Office and Babcock International, and advises the School's research groupings on their strategic context, infrastructure, and impact-generation and commercialisation activities. Academic appointment panels include impact-potential as a scoring criterion, and internally funded research projects must demonstrate a well-developed impact pathway.

CMS has developed important structures and collaborations to **achieve research impact**:

**Rago** and **Dalla Valle** were part of a collaboration that won European Regional Development Funding (£925K to Plymouth), making CMS a founding partner in the Environmental Futures & Big Data Impact Lab (**Impact Lab**), with the Met Office, Plymouth Marine Laboratory, Rothamsted Research and Exeter CityFutures. The Impact Lab matches researchers to SMEs, and provides support as these teams develop research techniques to solve business and industrial problems. Since its September 2018 launch, the Impact Lab has worked with over 40 clients and delivered many research-based CPD activities. These have led to the establishment of Knowledge Transfer Partnerships (KTPs) including one with Software Solved Ltd (a national-reach data/software-solutions company), yielding £158K. The Impact Lab is a key part of our ongoing impact strategy and is discussed in an Impact Case Study (ICS).

CMS has developed the areas of medical statistics and health data science, supported by the University's medical research priority and the new strategic Plymouth Institute of Health and Care Research. We work with national and international organisations, including the Cochrane Collaboration, GlaxoSmithKline, National Institute for Health Research and the World Health Organisation (WHO). We have also strengthened collaborations with the Peninsula Medical and Dental Schools, University Hospitals Plymouth NHS Trust and other medical schools. These activities have generated funding of £378K (**Wei, Craven, Hewson, McNeile**), 1.25FTE research fellows, seven joint PGR students and collaborative Masters projects. Some of the

impact is detailed in an ICS. We have addressed questions arising from global challenges by, for example, establishing a Covid-19 team which collaborates with scientists world-wide (Sebastiani, Rome; Xia and Zhang, China).

We have increased our research-driven Mathematical Sciences education and public engagement contributions, as discussed in an ICS. Our Schools Outreach Programme involved 2600 pupils and 230 teachers from 200 schools in 2018/19. We publicize research using a blog <http://blog.math-sciences.org/>, YouTube, Twitter and Instagram, in on-line magazines such as *Significance* (**Stander**, SFHEA, nine articles since 2015, over 79,000 views), and in hardcopy/on-line magazines such as *Spektrum der Wissenschaft* (German descendant of *Scientific American*, 70,000 monthly copies; December 2019 cover story), *Europhysics News* and *Communicator*. CMS has provided scientific input to a theatrical production (see Section 4). In 2020, **Lubert**, an “Outstanding Faculty Member” (Highest Virginia State honour for teaching, research and public service excellence), was appointed to further strengthen this public engagement branch of our impact.

### Research Objectives

Our strategic five-year **research objectives** are designed to be resilient in the face of economic, political and health-related uncertainties, and to take maximum advantage of our wide-ranging research skills and impact-generating experience:

- Prioritize excellent, impact-yielding, UKRI aligned research that increases the number of world-leading publications by over 10%, by enhancing collaborations with the University’s strategic research institutes, with other SECaM research groups and internationally.
- Increase research income by 15%, by prioritizing grant applications and expanding income related to Health Data Science, HPC and industrial links.
- Maximize sustainable research impact, by taking full advantage of SECaM and its state-of-the-art infrastructure, of growing SME networks and multidisciplinary industrial projects provided by the Impact Lab, and of well-established international health organization links.
- Strengthen our CPD provision, and continue to expand our research-informed, pupil and public engagement programmes, by building on new online opportunities.
- Sustain and consolidate our outstanding team of postdoctoral researchers, and increase our complement of PGR students, by participating in strategically identified funding bids.



- Become a Big Data and HPC national resource for industry and academia that informs external facilities and policies, by capitalizing on University and industrial support.

### Open Access, Ethics and Integrity

CMS goes beyond the REF2021 **open access** policy and is committed to transparency and reproducibility in research. Reproducibility is discussed in a prize-winning paper (**Stander, Dalla Valle**) and some of our publications have been awarded open-data badges for full reproducibility. We post research on arXiv, data on Zenodo (<https://zenodo.org/>), and make code and data available on GitHub (e.g. <https://github.com/MJCraven/PCyclic>) or CRAN (e.g. <https://CRAN.R-project.org/package=costat>).

The University's Research Ethics and Integrity Policy

<https://www.plymouth.ac.uk/research/governance/research-ethics-policy> informs the University and Faculty Research Ethics and Integrity Committees, and provides the code of practice for professional standards, honesty, openness, and the documentation and storage of data. Ethics approval is required for grant applications and research projects with human or animal participants, and these projects are subsequently monitored by the Faculty's Ethics Committee. The committee comprises academic (e.g. **Wei**) and lay experts, is multidisciplinary and takes full account of equality, diversity and inclusion requirements (<https://www.plymouth.ac.uk/about-us/university-structure/service-areas/equality-diversity-and-inclusion>). All staff have to pass a GDPR and Information Security course annually, and CMS possesses statistical disclosure limitation expertise. New researchers are briefed on the University's expectations of good research practice so that all research projects are conducted according to the required ethical, legal, professional and moral obligations and standards, guaranteeing **integrity of research**.

## 2. People

### Academic Staff

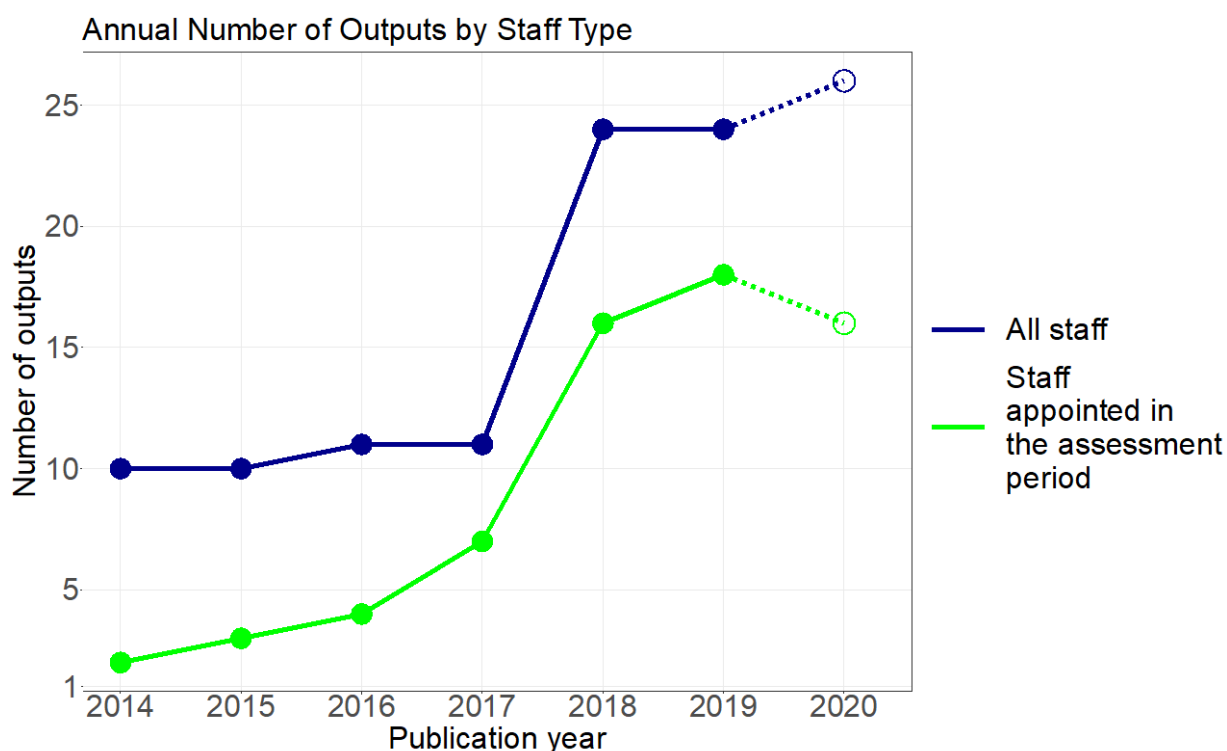
The University has made a considerable investment in UoA10 staff over the assessment period. Since 2013/2014 CMS's reputation has enabled it to appoint 15 researchers with high quality research track records. This represents a significant **increase in active research staff**. All CMS staff have permanent contracts with built-in research time (typically 40%). Grant income can lead to reduced non-research duties.

CMS adheres to the '**Concordat to Support the Career Development of Researchers**'.

The fundamental principle when **recruiting staff** is the strength of the candidates' potential, but CMS also gives consideration to its strategic aims. For example, appointees have had expertise in SDS (**Cardinali, Logares, Niu, Wei, Wojtys**), LFT and HPC (**Drach, McNeile**) and engagement (**Lubert**). They strengthen and shape the evolution of our strategic REF2014 themes, and work in areas with considerable impact

potential. CMS has supported other research strengths, including AM (**Stuhlmeier**) with interdisciplinary connections to the University's world-leading Marine Institute and QEHI (**Ilderton**). It has also made a strategic investment in PM (**Broomhead, Robertz, Logares**), allowing it to attain a critical mass that provides a theoretical underpinning across CMS, enables fundamental research at the interface of other disciplines and supports a vibrant seminar series, externally funded workshops and visitors.

CMS has recruited early career researchers (ECRs), including **Broomhead** (from Hannover), **Drach** (CERN), **Stuhlmeier** (Israel Institute of Technology) and **Wojtys** (UCL). An important consequence of this is that our staff have considerable diversity in terms of career stage and experience that enhances interdisciplinary and impact generation work. The contribution of newly appointed staff has grown substantially, leading to a large overall increase in outputs. CMS's strategy is designed to enable this upward trajectory to continue, leading to further output growth and enhanced individual career development.



Source: SciVal. Data for 2020 is incomplete at the time of writing

The University's **Researcher Development Programme** provides support for staff at all career stages. New staff complete a postgraduate qualification which includes training in research management and embedding research in the curriculum. Staff undertake CPD activities aligned to their roles, such as courses on "Good Supervisory Practice" or "Funding opportunities for ECRs". SECaM further facilitates staff development by organizing regular Research Planning Days, where staff share expertise on funding opportunities and identify new interdisciplinary collaborations and impact areas.

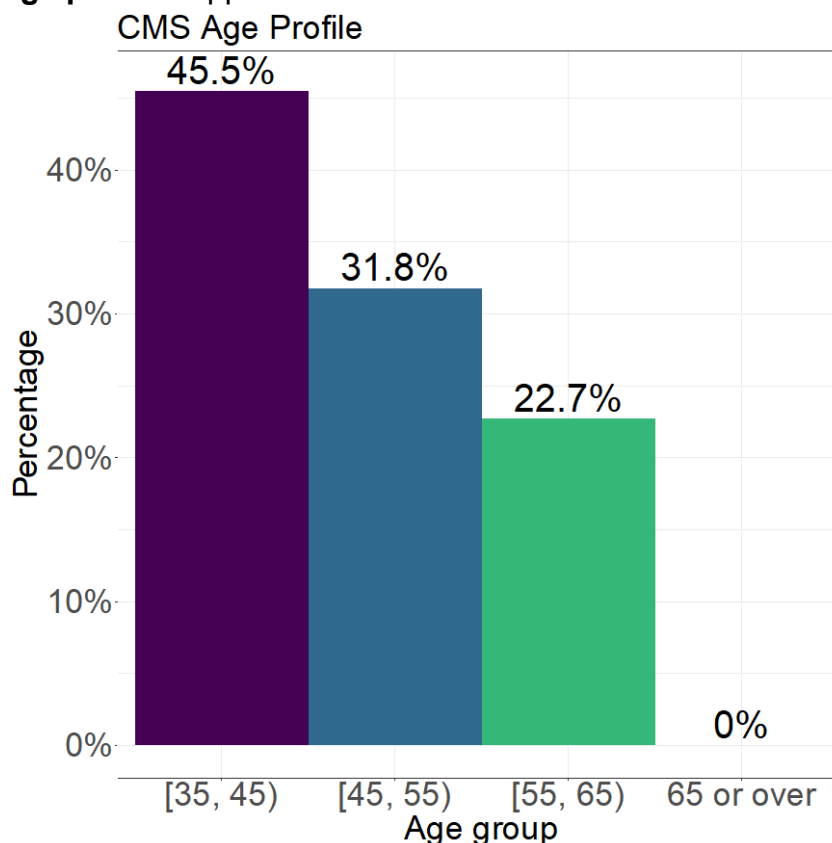
CMS was an early adopter in the University's **mentoring scheme**, which eases new staff into positions of leadership and responsibility by providing them with more

experienced mentors. There are **additional systems** to assist ECRs. For example, SECaM has offered ECRs competitive internal grants, ranked using criteria including research quality, multi-disciplinary collaboration and impact potential. There is also a yearly PGR fellowship competition in which the inclusion of ECRs in supervisory teams is supported. In 2019/20, it was compulsory to include an ECR as part of every supervisory team, and two out of three CMS ECRs now have PGRs.

Well-established structures ensure that staff development is monitored and that individuals can give feedback to SECaM and the University. During a year-long probation, new staff meet regularly with their research mentor and also a 'Performance Development Reviewer'. All staff have two Performance Development Review (PDR) meetings each year. During these, career and research plans are discussed and resources are identified, so that needs are supported. To maintain alignment with the University's research strategy and vision, senior CMS members meet regularly with the Deputy Vice Chancellor (DVC) for Research and Enterprise.

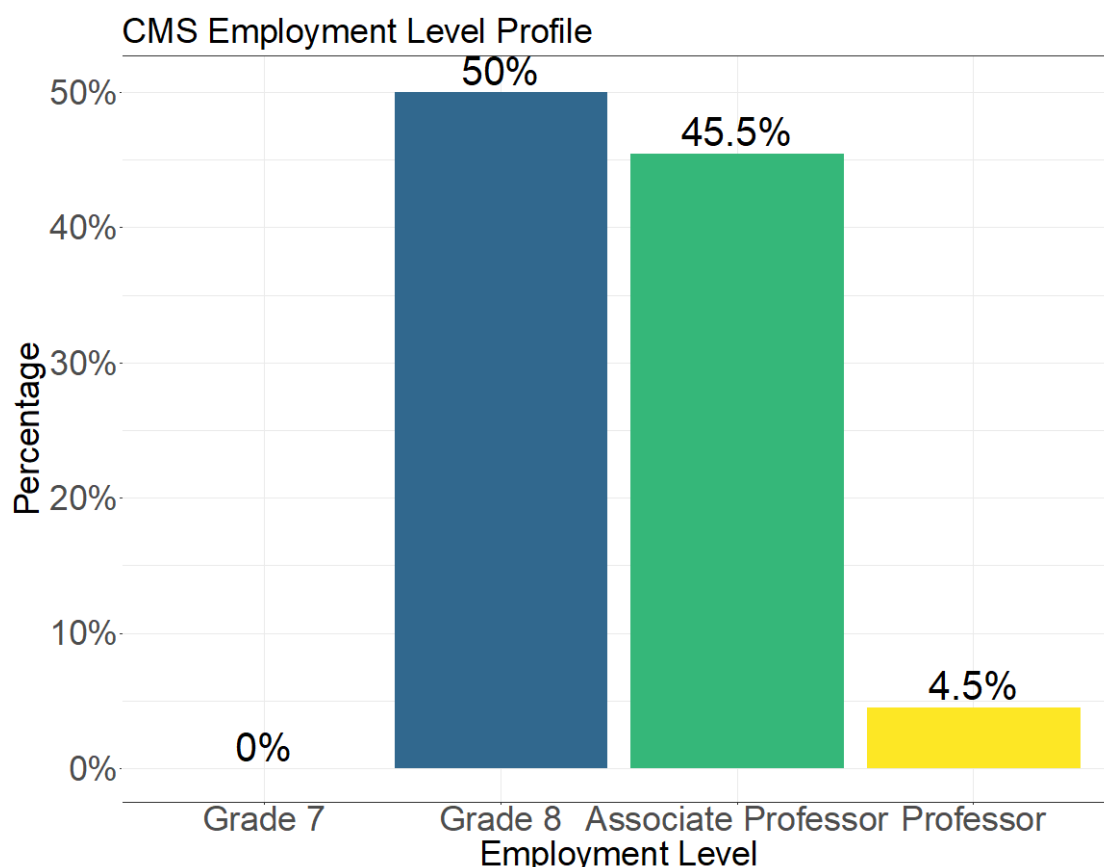
The PDR process also feeds into **succession planning**. This strategy facilitates forward-looking conversations, in which future roles are discussed with both continuity and development being considered. All CMS members understand that they play an important part in the success of the whole group and that they are in turn supported by it. A shadowing scheme ensures that key roles are maintained in the case of illness and provides opportunities for career development.

CMS's **broad age profile** supports robustness in terms of research continuity:





There are considerable opportunities for **career progression**. SECaM's strategy ensures that all staff belong to an active research group, so that new appointments immediately receive subject specific support. Promotion to Associate Professor or Professor is conducted through a transparent process, based on three pathways, research, education or balanced (research and education). SECaM supports promotion in various ways including "Promotions Workshops" where the process is explained and experiences are shared. A mark of this strategy's success is that in the period **Dalla Valle, Ilderton, King and Wei** were promoted to Associate Professor, leading to the following CMS employment level profile:



### Postdoctoral Researchers

CMS's community of **postdoctoral researchers** enhances its environment by providing fresh perspectives. During the assessment period, CMS has had eight postdoctoral researchers, as well as one linked through the Impact Lab. These researchers have PhDs from universities including Durham, Heidelberg, Marseille, Strathclyde, Sussex, Trinity College Dublin and Umeå Sweden, and strong publication records for their career stage. Postdoctoral researchers are fully included in CMS life. They are mentored, have access to all facilities, take part in seminar programmes and engagement activities, and attend staff meetings. They also benefit from the 'Research Development Programme' offered by the Doctoral College (DC). Their growth as independent researchers is prioritized, although they are also encouraged to dedicate time to their career development with ten days factored into annual workloads for this.

CMS facilitates the **development of impact-yielding collaborations for postdoctoral researchers** by means of its industry and health links, the Impact Lab and KTP projects. Postdoctoral researchers also work with staff to produce world-leading research and grant applications, with numerous publications having resulted from such collaborations. They support and collaborate with PGR students, and contribute to PGR training in courses provided by the DC and Impact Lab (e.g. Bayesian methods). CMS postdoctoral researchers have gone on to positions in Bonn, Leeds, Liverpool and research organizations such as the J. Stefan Institute.

### Visitors, Visits and Developing Staff and Impact

The vitality of the CMS environment is further enhanced by our **academic visitors** programme. As well as numerous short-term visitors, researchers at all career stages have visited from countries including Brazil, China, Germany, Italy and Spain for periods from several weeks to a year. Visiting researcher programmes have been established with Chinese Universities, and **Wei** hosted two Chinese academics for year-long visits in 2019. Visitors often produce collaborative papers, e.g. papers with Adamo (Edinburgh), Czado (TU Munich), Gregori (Oxford) and Liseo (Sapienza Rome). Many have been externally funded by, for example, the London Mathematical Society (LMS), the Royal Society, the Gothenburg Centre for Advanced Studies, and the Brazilian and Chinese governments. We have also had two visitors as part of the Erasmus plus Traineeship programme, both of whom produced joint papers (with **Stander** and **Dalla Valle**). We are proud of CMS's Erasmus and other bilateral international exchanges with many universities. For staff, these have provided study-leave opportunities, allowing CMS members to increase their knowledge in an international context. As the value of such international opportunities cannot be understated, we remain committed to growing our **international collaborators** network post-Brexit, with funding from the China Scholarship Council (CSC) for example, and during lockdowns using alternative communication methods.

CMS strongly encourages **secondment and sabbaticals**. Examples include **Rago** and **Patella** who undertook a one-year sabbatical and a five-year secondment to CERN, and **Moyeed** who worked for the Peninsula Medical School and for the Royal Statistical Society (RSS) Centre for Statistical Education (a year each, 50%).

Staff development activities, such as attendance at conferences, workshops and training events, have been supported by SECaM through a transparent process. All applications below £500 were reviewed by the HoS, while larger requests were considered by the Senior Management Team. This funding was available to staff at all career stages including fixed-term and part-time staff and postdoctoral researchers. SECaM also part-funds CMS seminars.

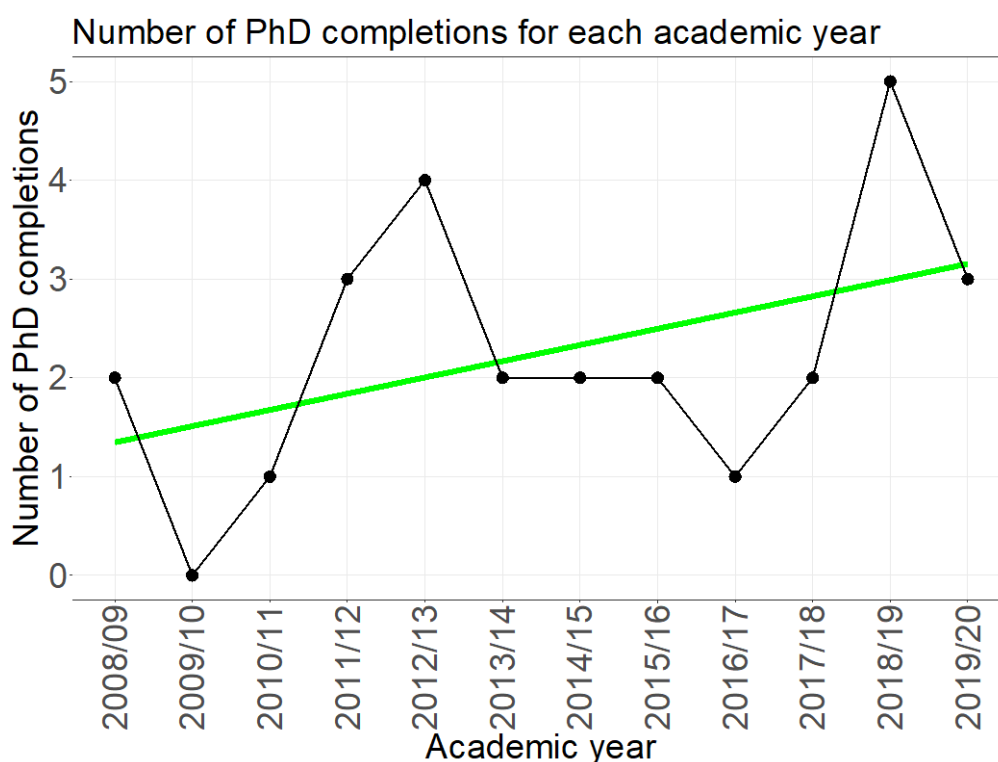
CMS offers **courses** on HPC and Data Science techniques to its researchers as well as to the wider University and industrial sector, providing opportunities to engage with innovative techniques and develop cross-disciplinary research strands and impact-yielding exchanges with business. To broaden our skills-base we have invited world-

leading experts with unique knowledge to deliver courses on GPU programming (Hietanen, CP3 Odense) and Big Data Gaussian process techniques (Dai, Amazon).

CMS also works with the University's Research Impact and Partnerships Office to facilitate industry links. Members are encouraged to participate in impact generation by the University's Research Impact & Innovation and R&D Solutions Funds, and by events such as the Celebrating and Developing Community Engagement and the University's annual Research Festivals. Major achievements are **rewarded** with recognition payments or promotion (e.g. **Dalla Valle**).

### PGR Students

As of October 2020, 86% of academic staff (in post for more than 6 months) had supervised a PGR student during the assessment period. CMS has had 17 internal PhD completions, 70% more than in the previous assessment period:



CMS members (e.g. **Craven, Dalla Valle, Graham, Hughes and Wei**) have also co-supervised other PGRs, including within SECaM (on Coastal Engineering and on Renewable Energy) and with the Peninsula Medical and Dental Schools.

We adopt a rigorous approach to appointing PGRs. Each internally funded studentship is widely advertised, and the selection process includes an in-depth interview and careful consideration of references. Most of our PGR students at appointment hold well respected MSc degrees and some have publications.

CMS has been awarded the status of **exceptional training centre** by the STFC which provides a yearly contribution to PGR scholarships. Other students have been funded

by SECaM studentships, the DTP, and the Iraqi and Libyan governments. **Wei** secured a CSC funded Doctoral Training Programme for up to six Yunnan University statistics students to visit Plymouth. Covid-19 extensions have been available to some PGRs.

Our PGR recruitment procedures follow the principles of **Athena SWAN**

<https://www.plymouth.ac.uk/about-us/university-structure/service-areas/equality-diversity-and-inclusion/athena-swan>. In an August 2019 analysis of PGR students, 67% identified as female, and one-third of supervisory teams were of mixed gender.

CMS has a structured system of PGR support, training and supervision. Each student has a Director of Studies and at least one additional supervisor; this team oversees research and offers well-being advice. PGR students are carefully supported from their first day until after graduation by regular meetings, an open-door policy providing access to all staff and email support. During the pandemic, virtual spaces were established for PGRs and postdoctoral researchers, and subject specific reading group activities were increased. A session on support for PGR students, postdoctoral researchers and ECRs was included in a recent Research Planning Day so that good practice could be shared.

All PGR support activities are managed by the **University's Doctoral College (DC)** which is led by a Director, supported by Deputy Directors from each Faculty. Each School has a DC academic lead who pays attention to the needs of their PGRs. GradBook software is used to **monitor all PGRs**. It allows students to record meeting notes and to submit milestone forms. It operates a traffic light approach to show students if they are on track (green), approaching a milestone (amber) or have missed one (red). Supervisors use GradBook to check deadlines, arrange meetings, monitor progress and approve forms.

The DC runs University-level **induction** for new PGRs, providing cohort development, networking opportunities and mentoring, as well as **training sessions** for supervisors and examiners. It also has a team which arranges **training courses** in the form of a Research Development Programme, supported by Research Councils UK, Vitae and employers of researchers. This is divided into four domains: Knowledge and Intellectual Abilities, Personal Effectiveness, Research Governance and Organisation, and Engagement, Influence and Impact. It covers poster and thesis production, the transfer and viva processes, publishing, ethical approval, intellectual property and leadership, for example.

PGRs also attend University modules and workshops run by the Impact Lab. They have opportunities to go to **external courses**, such as those run by the Academy for PhD Training in Statistics. To gain presentation skills, they discuss work internally and at conferences such as the British Applied Mathematics Colloquium, European Conference on Fluid Dynamics, EVOSTAR, GECCO, IAHR European Congress, Research Students' Conference in Probability and Statistics, and UK High Powered Laser meeting, sometimes serving as session chairs.

PGR students are **represented** by elected peers on the School and Faculty Research Committees and the Equality, Diversity and Inclusion Committee.

### Equality and Diversity

SECaM has the strategic aim to be a beacon for EDI. Following the recent Athena SWAN Bronze Award, SECaM plans to apply for a Silver Award within the next three years. CMS strongly supports the **commitment to equality and diversity** laid out in the University's Equality Scheme and its equality, diversity and inclusion policy, and line managers receive EDI training.

CMS is committed to increasing the **participation of women** in the Mathematical Sciences at all levels. We won a bid to host the 2021 LMS Women in Mathematics Day, additionally supported by the RSS, which will include a panel discussion on careers for women in mathematics. CMS's Head of School, Professor Deborah Greaves OBE (UoA12), has been actively involved in events aimed at attracting women into STEM. **Dalla Valle** serves as an ambassador for Women in STEM and as a member of R-Ladies Global. CMS is aware that lockdowns may have a detrimental effect on women's careers and members have followed a Diversity and Inclusion Post-Covid-19 WISE webinar to mitigate this.

CMS's aim to have a **staffing mix** with an equal proportion of women and men participating at all levels has been supported by the appointments of **Logares, Lubert, Wei** and **Wojtys** and the promotion of **Dalla Valle** and **Wei**. Currently over a fifth of CMS are female, with a similar proportion among Associate Professors/Professors, comparable with LMS benchmarking data. To increase this proportion, staff have equality and diversity, and unconscious bias training, and there is additional instruction for appointment panel members. All panels (appointments, promotion, internal grant and funding allocation) are gender balanced and adhere to the University's equality and diversity strategy. SECaM has a policy which seeks to ensure the shortlisting of at least one female candidate whenever possible.

CMS supports each '**protected characteristic**'. It takes no consideration of age, gender reassignment, marriage or civil partnership status, race, religion or belief, or sexual orientation, at appointment or during career progression. It provides the same development opportunities to everyone throughout their careers no matter what contract type they possess. CMS makes adjustments to support physical and mental disability such as by providing multiple offices and access to support workers.

CMS nurtures staff wellbeing and **quality of life** alongside skills and career development. We are committed to LGBTQ-inclusivity, and celebrate diversity. The University is a proud Stonewall Diversity Champion, sponsoring Plymouth Pride and Pride on Campus.

The University has a range of policies to support staff and PGRs, including those on maternity, paternity and parental leave, which go beyond statutory requirements:

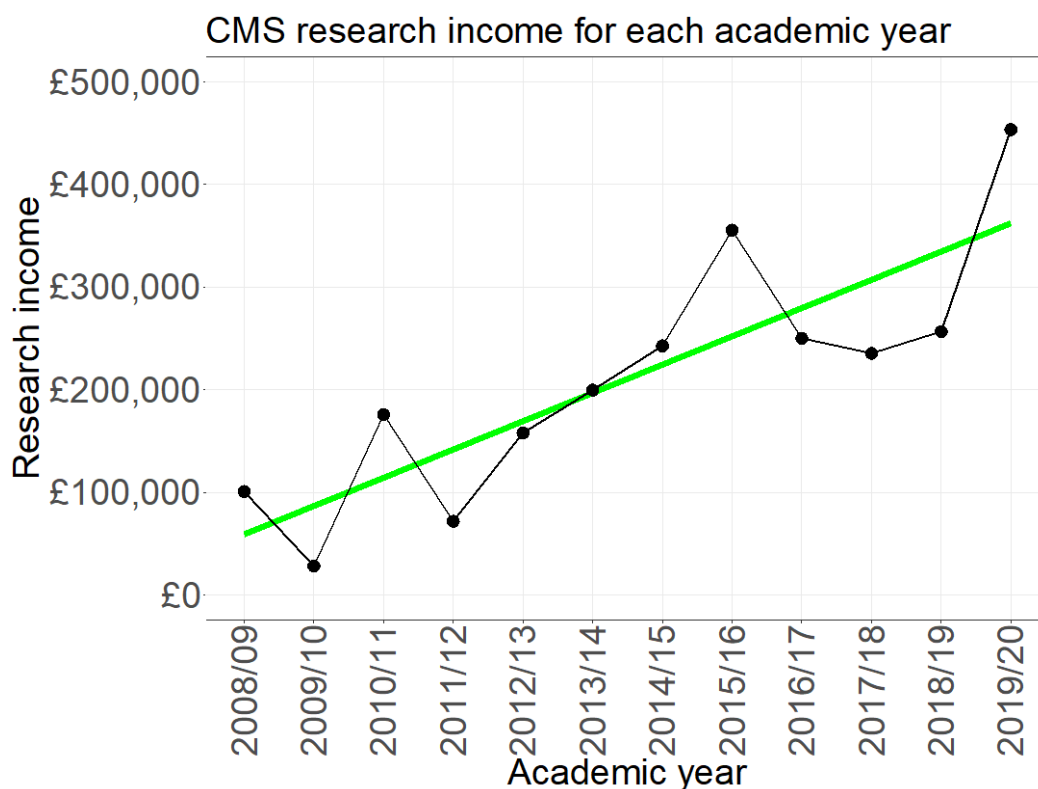
**Broomhead** and **Drach** recently benefitted from full-pay paternity leave, enhanced locally by timetable adjustments and duty rearrangement. CMS operates a flexible-working policy to aid those caring for children, and has a similarly supportive approach towards staff and PGRs with other caring responsibilities. The Freshlings' Nursery, situated on campus, offers a nurturing environment for children and childcare vouchers.

When staff suffer **illness** – including long-term problems – they are given support either to recover or to manage their condition. Arrangements, including phased returns, are made to facilitate re-entry to work. As a mutually-supportive group, all CMS members are always willing to help colleagues. The University also has structures and resources to support health and well-being. These include Occupational Health and the University Medical Centre, providing access to doctors and nurses, and the Staff Counselling Service. There is also an established system of University funded staff networks. These include the LGBT+ Staff Forum, the Women's network and a network for staff with disabilities. New well-being networks can easily be established. The Sports Centre has a gym and offers well-being classes.

### 3. Income, infrastructure and facilities

#### Grant Income

CMS has a strong and growing track-record of winning prestigious grants. Our assessment period income (as PIs) recorded in REF4b/c is 273% more than for REF2014. CMS research income for each year is shown in this graph:



Major research council and charitable foundation grants have supported research during the period: **Graham** (PI) (2013–2017, EPSRC, WSI, £288K); **Langfeld** (PI) and **Rago** (Co-I) (2013, Leverhulme Trust Project, £180K); **Langfeld** (PI), **Rago** and **Patella** (Co-



Is) (2013, Science and Technology Facilities Council (STFC) Consolidated, £230K); **Graham** (Co-I) (2015–2020, EPSRC, CCP-WSI, £483K); **Heinzl** (PI) and **Ilderton** (Fellow) (2016–2018, Marie Curie International Fellowship, £180K); **King** (PI) (2016–2018, EPSRC First Grant, £125K); **King** (PI) (2016, Royal Society International Exchange Scheme, £2K); **Rago** (PI), **McNeile** and **Patella** (Co-Is) (2017, STFC Consolidated, £340K); **Ilderton** (PI) and **King** (co-PI) (2018–2020, EPSRC Standard, £450K); **Ilderton** (PI) and **Heinzl** (co-PI) (2019–2021, Leverhulme, £122K); **Rago** (Co-I) (2020, EPSRC Standard, £86K); **Drach** (2019–2020, STFC New Applicant Scheme, £4K); **Dalla Valle** and **Stander** (2017–2019, Royal Society International Exchanges, £11K); very recently, **McNeile** (PI) and **Drach** (Co-I) (1/10/2020, STFC Consolidated Grant, £40K); **Stuhlmeier** (award date 12/2020, EPSRC New Investigator Award, £208K).

Some of these grants have supported postdoctoral researchers who broaden CMS expertise, enrich its atmosphere and increase its productivity. **Ilderton**, holder of the Marie Curie fellowship, was subsequently appointed as a lecturer, and then won an EPSRC standard grant as PI. **Graham's** first EPSRC grant was used to stimulate multidisciplinary research with the Marine Institute and led to papers in the *International Journal of Offshore and Polar Engineering*. This work informed **Graham's** second EPSRC grant which also provided extensive resources and training for industry.

### Income related to HPC

One of our assessment period highlights has been the expansion of the flourishing multidisciplinary HPC Centre. An important contributory factor to its success was a NVIDIA equipment award to establish a Graphics Processing Unit Research Centre, the status of which has been renewed twice. This equipment led to Asthana *et al.* (2016, <https://www.ncbi.nlm.nih.gov/books/NBK361065/>), to the development of techniques now used routinely at City Science (<https://www.cityscience.com/>) and WiFi SPARK (<https://www.wifispark.com/>), and to a general broadening of interest and expertise in HPC (e.g. **Craven** and **Robertz**, 2016, <https://doi.org/10.1515/gcc-2016-0012>).

Much of the work performed using the NVIDIA equipment translated naturally to the HPC Centre. The University has already contributed £350K to our HPC infrastructure and is considering making a tactical investment of over £1M to expand the HPC Centre to serve both Big Data research across the University, and an extended field of external and industry users. The HPC Centre is led by CMS staff (**Rago**, **Drach**, **McNeile**) who oversee its design, strategic evolution and operation. It also provides CPD events, which help to strengthen connections with regional and national enterprises through the Impact Lab. This activity contributes to our strategy for developing impact in industry.

Our HPC research method is to tune code in our Centre and then to apply to national facilities for large-scale runs. We have been extremely successful in obtaining research time on these facilities with awards totalling over 400 Million core hours, which the STFC approximates as being worth £630K for REF4c Research Income-in-kind. Contributing awards include **Rago** (Dirac Consortium-STFC: 2012, PI, 130M; 2013, PI, 12M; 2016,

PI, 154.8M; 2018, CI, 20M; 2018, PI, 5M, Director's Discretionary Award); **Drach** (2018, PI, 4.58M; 2019, CI, 13.13M; 2020, PI, 16.8M); **Rago** (PRACE-EU, 2019, CI, 60M). In addition, **Rago** was awarded software engineering time (6 months, EPCC Edinburgh, £33K, STFC-DiRAC), while **Ilderton** was awarded time worth £32K at a STFC Central Laser Facility.

### Income related to Health Data Science

A third strand of research and impact, supported by external funding, has been in Statistics and Health Data Science. SDS has obtained funding for collaborative health and medicine projects, including one from the National Institute for Health Research (£154K, **Wei** Co-I) related to substance use disorders, two from GlaxoSmithKline (£44K, £55K, **Wei** Co-I) developing a questionnaire for asthma patients' quality of life and another from Medicem (£14K, **Hewson, Craven** Co-I). **Wei** (PI) was awarded an NHS grant, part-funding with the DTP a studentship to develop kidney transplant prediction models (£77K). **McNeile** (PI) obtained funding from Bausch and Lomb (£32K) to model visual acuity following cataract surgery.

### Income Supporting Collaborations

CMS members have secured a significant number of **awards that support collaboration** between academics world-wide. **Rago** had a year-long sabbatical as a CERN Scientific Associate (£100K). There were two Royal Society International Exchange Scheme grants: one (**King**) funded a five week visit to Mianyang China and led to a paper in *Phys. Rev. D.*, while the other (**Dalla Valle, Stander**) enabled interaction with Liseo (Sapienza Rome) and resulted in a *Statistics in Medicine* publication. **Ilderton** and Edwards (UMSNH) also received a Royal Society Newton Mobility Award (£6K) which funded three research visits and resulted in papers in the *Journal of High Energy Physics* and in *Physical Review D*. **Broomhead, Logares, McCourt, Robertz** and **Stuhlmeier** have obtained seven LMS grants which were used to host high profile researchers including Baur (Graz), Dancer (Oxford), Martens (Edinburgh), Mazzocco (Birmingham), Newstead (Liverpool) and Szendroi (Oxford).

CMS members also obtained **funding for travel** from external sources, including: Bielefeld University, Casa Matemática Oaxaca, Chinese University of Hong Kong, Oberwolfach Research Institute for Mathematics, University of Stuttgart (**Broomhead**); Napier University (**Craven**); Global Challenges for Women in Mathematical Science Grant, International Centre for Mathematical Sciences India, Simon's Centre for Geometry and Physics, Tata Institute (**Logares**); Erwin Schrödinger International Institute for Mathematics and Physics, an IMA small grant (**Stuhlmeier**).

## Other Income

During the assessment period, **income generated from other sources**, such as research-based courses for PGRs, was paid into researchers' Strategic Research Accounts, and was used to support international research collaboration and presentations at important conferences.

The RSS South West Group (**Stander, Wei, Dalla Valle**) is based at Plymouth and makes a major contribution to funding part of CMS's seminar programme.

## Income Strategy

CMS's successful strategy to **increase the amount of grant and related income** from UK and international sources is partly based on continually building the grant writing expertise of its newer members. For example, **King** and very recently **Stuhlmeier** have been awarded EPSRC First or New Investigator Grants and **Drach** won an STFC New Applicant Scheme award. CMS is also promoting and expanding its **research and consultancy links with industry** and increasing the number of KTPs or equivalent partnerships in which it is involved. It has a KTP with Software Solved (**Dalla Valle**) which has produced software for industry, and other industry grants including two from GlaxoSmithKline (**Wei**) and one from Bausch and Lomb (**McNeile**). There are fruitful collaborations with BT Research and Plymouth Community Homes (**McNeile, Wei, Wojtys**), including recent work on the analysis of broadband network performance, that uses our HPC facilities and that we plan to expand to increase HPC related income. The Impact Lab, discussed in Section 1, provides CMS with a firm foundation for future funded impact generation. Our Health Data Science income will be increased by capitalizing on our new Covid-19 research direction, by increasing our collaborations with the University's strategic Health and Care Institute, and by continuing to play an important role in SECaM's strategic bids

## Infrastructure and Support

The University provides substantial **infrastructure and facilities** to assist researchers. CMS members and visitors have well-equipped individual offices and access to state-of-the-art equipment for on-line working. The University has recently approved a £50M investment in the new NEDF building that will provide purpose-built accommodation for SECaM's research infrastructure. NEDF will house structures for the HPC Centre and virtual reality data visualization, with CMS design input. These facilities support CMS's Big Data theme by furthering the development of impact generating research and CPD activities. They will also cater for our rapidly growing Data Science PGT provision that is designed to yield a continual supply of interdisciplinary and impact-rich projects, further supported by visiting PGT students from China. There will be facilities supporting the development of Health/Medical Technologies which will strengthen existing medical sector links, and spaces to stimulate interaction with the arts, architecture and environmental sciences. NEDF will house state-of-the-art seminar facilities, one of

which will be named after a female mathematician, such as Arianna Rosenbluth. The building will provide a transformative research resource to sustain CMS in the long-term and further increase its international significance.

Other significant research infrastructures within the University include:

- The COAST Laboratory wave tank, which has been key to some of AM's interdisciplinary work. It has led to a blind test series for wave energy converters, funded by the EPSRC WSI (**Graham**, £288K) and CCP WSI (**Graham**, £483K) grants. Experiments on plate impacts, tsunami generation and wave-energy devices led to publications by **Hughes**. The tank was used to demonstrate novel algorithms for identifying wave breaking to international researchers attending the "Water Waves: Mathematical Theory & Applications" workshop organised by **Stuhlmeier**. It facilitated a joint PhD project on smoothed-particle hydrodynamics supervised by **Hughes** and Greaves (UoA12).
- The Immersive Vision Theatre, which supports CMS research and outreach in Mathematics Education and Data Visualization.

The University's 10-year strategy prioritizes research and impact growth. **Research strategy development** is led by the DVC (Research and Enterprise), and overseen within the Faculty by an Associate Dean (Research). **Rago**, AHoS (Research), from CMS, has research responsibility across SECaM and is assisted by the School Research Committee comprising staff and PGRs elected to represent all interests.

SECaM has a **Technical Manager**, partially funded by a STFC Consolidated Grant, who manages the HPC Centre, and provides support for staff and PGR students.

The **University's IT services** ensure that computers of staff and PGR students are regularly maintained and replaced on a rolling basis, with the last University upgrade being in 2018/19. They also provide general IT support and ensure that everyone has access to the software that they need. Staff can opt for a variety of equipment including Macs. Specialist teams operate the COAST Laboratory wave tank and the Immersive Vision Theatre.

In addition to CMS support, there are University structures such as the Research and Commercialisation Office and the Research Impact and Partnerships Office that assist with grant applications and impact generation. These offices provide training courses, open to all but offering special assistance to ECRs, that cover impact, ethics, intellectual property and research commercialisation.

CMS is proud of the very substantial improvement in external income and international collaborations achieved over the assessment period. The creation of SECaM and the associated £50M University investment in the NEDF building considerably strengthen our long-term strategy for growing external income to support research and impact generation in the Mathematical Sciences.

#### 4. Collaboration and contribution to the research base, economy and society

##### Collaborations and Relationships

CMS has a proven track record of research that solves real problems from industry, health organisations and research institutes such as HR Wallingford. Because of this, CMS understands the importance of well-established collaborations to create excellent impact-yielding research and has strong **research collaboration arrangements**. For example, CMS maintains a record of past collaborations to encourage new staff to work with more established researchers across the University and beyond, in order to develop their research skills in a multidisciplinary context. This has led to papers in over ten interdisciplinary journals including *Fluids*, *International Journal of Acoustics and Vibration*, *International Journal of Electronic Security and Digital Forensics*, *Multidimensional Systems and Signal Processing*, *Nature Geoscience*, *Ocean Engineering*, *Philosophical Transactions of the Royal Society A*), as well as the impact in the ICSs.

In addition to **research networks and partnerships** that arise from and lead to interdisciplinary, world-wide collaborations, our Cochrane Statistical Methods Group membership (**Wei**) allows us to contribute to and benefit from links with the Cochrane Collaboration, so informing our meta-analysis and systematic reviews research. **Wei** is also a member of the WHO “Zika Virus Meta-analysis Initiative” working group. CMS contributes to the HIBEF User Consortium (**Heinzl, King**), the International Lattice Data Grid (**McNeile**) and the UK High-Power Laser Community and User Forum (**Heinzl, Ilderton, King**). Two grants from DiRAC (**Rago, Drach**) have established collaborations with Edinburgh, Odense and Ljubljana. Recently, **Rago** has been awarded a grant from EPSRC’s ExCALIBUR call with Swansea, Edinburgh and Southampton to develop a roadmap to establish a broad community to exploit exascale facilities, further evidencing our HPC excellence and commitment. **Drach** serves on the UKLFT management board, a STFC-funded Virtual Centre for Lattice Field Theory which facilitates collaboration between European researchers. **McNeile** worked with the international HPQCD collaboration (<http://www.physics.gla.ac.uk/HPQCD/>) on supercomputer simulations for experiments at Fermilab.

Collaborations have also been supported by a one-year sabbatical (**Rago**) and a five-year secondment (**Patella**) to CERN, two Global Challenges for Women in Math Science grants with TU Munich (**Dalla Valle**), and a Royal Society International Exchanges grant for research with Sapienza Rome involving the Great Ormond Street Institute of Child Health (**Stander, Dalla Valle**). **Broomhead** was funded to visit the Oberwolfach Research Institute under their Research in Pairs initiative.

The PDR process means that CMS members are conscious of the importance of continually developing strong relationships with **key research users** and these collaborations are enhanced in many ways. They may arise informally from personal contacts or enquiries to CMS. More formally, **Dalla Valle** and **Rago** have been involved



in the establishment of the Impact Lab, facilitating a broad range of collaboration including one with the Met Office. CMS also invites strategically identified partners to 'European Study Groups with Industry' meetings. This access to external problems enriches our environment by providing new interactions with external scientists, their projects and data, including Argand Solutions and the Devon and Cornwall Police.

### Contributions

Examples of **wider contributions** to the economy and society include KTP work on data integration with the insurance industry (**Dalla Valle**), on portfolio optimization with a private London finance company (**Cardinali**), on flood risk coastal engineering with HR Wallingford (**Dalla Valle**, SECaM colleagues and a PGR student), on paediatric visual acuity with the Great Ormond Street Institute of Child Health (**Stander, Dalla Valle**), and on data integration to encourage business collaboration (**Dalla Valle**). Our medical statistics and Health Data Science research (**Wei, Craven, McNeile**), with the University Hospitals Plymouth NHS Trust, the Peninsula Medical School and the Health and Care Institute, is improving treatment practices. The Impact Lab (**Rago, Dalla Valle**) makes a substantial contribution to the regional economy. CMS members (**Craven, Dalla Valle, McNeile, Niu, Rago, Stander, Wojtys**) have regularly presented Impact Lab Workshops including: Tweet Analysis, Bayesian Methods, Immersive Data Visualisation, Introductory and Advanced R, and Neural Networks.

Over the assessment period CMS has established a new research strand in Mathematical Science Education that has enriched our environment. **Sharp** has established a network of over 200 primary and secondary schools with whom we share our research and expertise in mathematics and statistics pedagogy. In addition, CMS is highly active in public engagement and outreach activities, an aim of which is to present our research to a broad audience. CMS runs a Mathematics Enrichment Programme which has organized many outreach events, masterclasses and schools talks (**Sharp, Broomhead, Craven, Drach, Heinzl, Ilderton, King, Lavelle, McMullan, Rago, Stander**) including one by Professor Sir David Spiegelhalter, an honorary doctor of the University. CMS have contributed strongly to the International Year of Light Teachers' Training Day 2018 (**Heinzl**), the Festival of Physics 2019 (**Heinzl, McNeile**) and International Masterclasses in Particle Physics (2017, 2020 postponed to 2021, **Drach, McNeile**). We have given talks to the Plymouth Astronomical Society and Armada Con (**Lavelle, McMullan**), regularly hosted the RSS Guy Lecture and contributed to the Royal Institution's Masterclass Programme (**Sharp**), delivering country-wide research-based enhancement classes exposing many school pupils to our research and its impact. We advised on a theatre play *Fireworks* about the Higgs Boson and led a Q&A session after performances in Plymouth, Exeter and Cornwall (**Drach, Ilderton, Lavelle, McMullan, Rago**). **Broomhead, Sharp** and **Stander** have provided work placement opportunities to Year 12 and 13 students, one of whom produced a *Significance* article. **Wei** and a PGR student organized a Health Data Science symposium in 2020, with RSS and Impact Lab sponsorship. **Huggett** organized the 'Conversations across Art and Mathematics' exhibition to publicize the relationship between these disciplines. We have



made substantial contributions to radio programmes (More or Less, Surfology, German public radio, for example, **Stander**, **Stuhlmeier**), to Plymouth Argyle Football Club's programme and website (**Eales**), and to the University's Annual Research festival (led by **McNeile**). All this activity strongly evidences that CMS engages with diverse communities and publics.

### Service, Sustainability and International Priorities

CMS makes a strong, international contribution to the reputation and the **sustainability of the discipline**. We have given long-term service to a range of learned organizations, often in a leadership or decision-making capacity. For example, **Huggett** served as the LMS General Secretary (2012–2020), and **Stander** was an elected RSS Council member (2012–2015) and acted as Treasurer of the Committee of Professors of Statistics for twenty years and as Chair and Treasurer of the RSS South West Group. **Lubert** was Co-founder/President of the Association for Women in Science, Blue Ridge Chapter, USA. **Dalla Valle** has given service to the Exeter Initiative for Statistics and its Applications, the European Network for Business and Industrial Statistics and R-Ladies Global. Others have been members of the Central Laser Facility User Forum (**Heinzl**, **Ilderton**, **King**), the HIBEF User Consortium (**Heinzl**, **King**), and the Vulcan 20 Petawatt Project (**Heinzl**).

CMS and the Research Impact and Partnerships Office conduct and support research that responds to **national and international priorities**. Examples include environmental modelling which provides a better understanding of flood risk prevention (**Dalla Valle**), meta-analysis (**Wei**) which quantifies the link between portion size and obesity, business default probability estimation (**Dalla Valle**), and work for the UK National Cybersecurity Strategy (**Craven**). In response to the pandemic, CMS established a Covid-19 team and a collaboration with Sebastiani, who regularly speaks on Italian television, which led to the publication of <https://www.significancemagazine.com/science/657-some-comparisons-between-italy-and-the-uk-for-covid-19-march-to-april-2020> and <https://www.significancemagazine.com/science/687-returning-to-schools-and-universities-in-the-time-of-coronavirus-some-statistical-suggestions>.

We are involved in **editorial work and other publishing support**: for example, Associate Editor, *Journal of Official Statistics* (**Dalla Valle**); Statistical Editor, *Cochrane Developmental Psychosocial Learning Problems Group* (**Wei**); Co-Editor Special Issue of *Mathematics in Computer Science* 2019 (**Robertz**); Subject Editor (Noise), *Publication of the Acoustical Society of America* (**Lubert**). We provide outstanding **refereeing service** (awards from *Physics Letters B* (**Heinzl**, **Ilderton**) and *Physical Review* (**Heinzl**)), together with refereeing work for many journals and funding bodies.

CMS members have participated in **grant committees and advisory work for funding bodies** including: DiRAC Particle Physics Research Allocation Committee (**Rago** Chair, **McNeile**); DiRAC RAC Particle/Nuclear Physics Sub-Panel for super-computing (**Rago**);

EPSRC Peer Review College (**Ilderton**); STFC Particle Physics Panel (**Rago**); German Research Foundation “Quantum Vacuum” Review Panel €6M, International Station of Extreme Light Review Panel to be built in Shanghai and worth approximately \$100M (**Heinzl**); LUXE experiment at EU.XFEL (**Heinzl**, **Ilderton** and **King**, who led the Conceptual Design Report theory section); Panel for Rutherford Laboratory experimental proposals (**Ilderton**); DiRAC Consortium Extreme Scaling Machine board (**Rago**); Austrian Foundation for the Promotion of Science (**Stuhlmeier**); Commonwealth Scholarship Committee Advisor (**Broomhead**); Erwin Schrödinger International Institute for Mathematics and Physics Austria (**Stuhlmeier**); LMS (**Broomhead**, **Huggett**); Czech Science Foundation, DFG Research Unit Germany, German Research Foundation, Helmholtz Society, Humboldt Foundation, National Research Foundation South Africa, Royal Society (**Heinzl**); FONDECYT Chile (**Lavelle**).

We have won prestigious **prizes**: 2016 High Power Laser Science and Engineering Editor-in-Chief Choice Award (**Heinzl**, **King**); APS journals editor’s choice articles (**Heinzl**, **Ilderton**, 2017, 2018); the 2017 Journal of Statistics Education Best Paper Award (**Stander**, **Dalla Valle**).

We provided **plenary speakers** for Lattice Symposia (**Langfield** 2016, **Patella** 2016, **Rago** 2017, **Drach** 2019), and delivered invited plenaries or keynotes at the BIRS-CMO workshop on Stability Conditions and Representation Theory (**Broomhead**), 3<sup>rd</sup> Elba Workshop on Forward Physics 2016 (**McNeile**), ExHiLP 2017, 2019 (**Heinzl**, **Ilderton**, **King**), International Laser Physics Workshop 2015–2019 (**Heinzl**, **Ilderton**, **King**), the first LUXE meeting (**Ilderton**), Nankai Symposium on Physics, Geometry and Number Theory (**Broomhead**), Non-perturbative QED workshop SLAC 2019 (**Ilderton**), PGCS Symposium (**Craven**), Schwinger Effect Workshop 2021 (**Ilderton**), UK Flavour 2017 (**Rago**). **Drach** was an invited speaker at “Interdisciplinary approach to QCD-like composite dark matter” (Trento, 2018), “Fundamental Composite Dynamics” (FCD2019, Mainz) and Mass 2019 (Odense).

**Ilderton** and **King** presented and were invited session chairs at LPHYS (2014 Sofia) and LNPC (2017 Yokohama). **Heinzl**, **Ilderton** and **King** presented and chaired at the International Laser Physics workshop (2015 Shanghai, 2016 Yerevan, 2018 Nottingham, 2019 Gyeongju) and at ExHILP conferences (2015 Heidelberg and 2017 Lisbon). **Langfeld** and **Rago** served on the organizing committee, while **Patella** was on the advisory committee for Lattice 2016 (Southampton, 420 participants). **Langfeld**, **McNeile**, **Patella** and **Rago** organized the eXtreme QCD conference (Plymouth, 2016, 80 participants). **McNeile** was an invited speaker at 3<sup>rd</sup> Elba Workshop on Forward Physics. **Heinzl** gave invited talks at HED-XFEL 2017 (DESY), ICEL 2019 (Prague) and “Probing Extreme Light” (2017 Shanghai) and was invited to a HIBEF (2018 Dresden) and the “Vacuum Fluctuations” workshop (2019 Sardinia). **Logares** organized Current Trends in Hichin Systems (2018 Argentina). **Ilderton** was invited to the “Non-perturbative QED” workshop (2019 Stanford), and a working group of theorists planning a particle collider for the SLAC National Accelerator Laboratory (2019). **King** was

invited to present at “Extreme Light Fields” 2020 and co-organized the LUXE Workshop (2020 Hamburg).

The CMS has hosted a number of workshops supported by LMS Celebrating New Appointment grants including “Water Waves – Mathematical Theory & Applications” 2019, organised by **Stuhlmeier**, “Differential Algebra” 2014 (**Robertz**), “Combinatorics” 2014 (**McCourt**) and “Geometry, Derived Categories and Moduli Spaces” 2018 (**Broomhead, Logares**). **Robertz** organized an LMS Regional Meeting.

**Heinzl** gave courses on “Nonlinear Quantum Electrodynamics” (24th Chris Engelbrecht Summer School, South Africa, 2014) and on “Extreme Light and Quantum Fields” (Arnold-Sommerfeld Colloquium, 2015). **Ilderton** taught courses on “Light by light scattering” (European Light Infrastructure Summer School, 2015 and 2017) and on “Quantum effects in laser-matter interactions” (UK-India Laser-Plasma Theory Workshop, International Centre for Theoretical Sciences, Bangalore, 2017), and gave a PGR course on “Strong Field QED” (Chalmers University, Sweden, 2018). **King** lectured on “Strong-field QED in Intense Lasers” (“High Energy Density Physics Summer School”, National University of Defence Technology, Changsha, China, 2017). **Logares** presented a workshop at the Simons Center for Geometry and Physics during a month-long invited visit, 2019. **Rago** delivered advanced research lectures on Finite Density Lattice Field Theory (2017, Odense). **Wei** presented a course on Medical Statistics at the University of Electronic Science and Technology of China postgraduate summer school, 2015. **Craven, Dalla Valle, McNeile, Niu, Rago, Stander** and **Wojtys** ran a week CPD event on Big Data and have presented Impact Lab Workshops.

### PGR Training and Examining

CMS is a Member Institution of the Academy for **PhD Training** in Statistics (APTS) and includes APTS courses as a regular component of its PGR training. **Stander** serves on the London Taught Course Centre Advisory Board. **Robertz** presented an invited tutorial at the 41<sup>st</sup> International Symposium on Symbolic and Algebraic Computation 2016 and a course at Journées Nationales de Calcul Formel 2018.

CMS Members have examined PhDs including **Craven**, Greenwich (2019); **Ilderton**, Chalmers University (2016, three), Friedrich-Schiller University Jena (2016), Umeå (2019); **King**, Ludwig Maximilian University of Munich (2016), Chalmers University (2019), Oxford (2020); **McNeile**, Cambridge (2018), Adelaide (2019); **Rago**, Edinburgh (2013); **Wei**, Liverpool (2019), Essex (2020).

In short, CMS’s supportive and highly successful environment is the fruit of a sustainable research and impact strategy centred on investment in and the well-being of its people. This environment and the support, infrastructure and opportunities offered by SECaM have not only led to a continually increasing amount of funded research and impact, but have also facilitated cross-disciplinary collaborations that will continue to address real-world problems and global challenges. Our extensive engagement activities mean that

CMS also widely shares its vitality and excitement with young people and broader society.