Institution: PHYESTA (Physics at Edinburgh and St Andrews)

Unit of Assessment: 9 (Physics)

a. Overview

PHYESTA (Physics at Edinburgh and St Andrews) was formed in 2010 by Scotland's two leading Schools of Physics & Astronomy, who share close research links and a common vision. PHYESTA stands within the wider Scottish Universities Physics Alliance (SUPA), founded in 2005 with support from the Scottish Funding Council (SFC). This funding was renewed (as SUPA-II) in 2009 and continues to resource SUPA's highly successful Graduate School and Knowledge Transfer team.

Our research is motivated by the desire to be at the forefront of understanding fundamental physics within our three key Research Themes:
1. Astronomy (AST), with 34.9 FTE Category A staff
2. Condensed Matter and Photonics (CMP), with 46.2 FTE Cat A staff
3. Particle and Nuclear Physics (PNP), with 22.0 FTE Cat A staff

Over the last few years we have demonstrated substantial progress in all areas. Major research breakthroughs in which we have played a leading role include:
- the discovery of the Higgs boson in 2012, leading to the Nobel Prize for Emeritus Professor *Peter Higgs* in 2013)
- the discovery and characterisation of more than 100 exoplanets
- the discovery of the earliest galaxies with the Hubble Space Telescope
- the best constraints on dark matter from direct searches in underground experiments
- the discovery of new states of order in crystals, superconductors, magnets and soft composites

Since 2008 PHYESTA has been ranked in the top three European Centres for scientific HPC (High Performance Computing); has developed a new activity in Physics and the Life Sciences (PALS) with links to Condensed Matter and Photonics; has established the UK Centre for Astrobiology as a national focus for interdisciplinary research; has created the Higgs Centre for Theoretical Physics; and has invested in major new laboratory facilities for Photonics, Condensed Matter and Particle Physics. These initiatives have brought a flow of outstanding young physicists into PHYESTA with the appointment of 33 new academic staff. We have also made a strategic decision to enhance PhD studentship support, resulting in a 75% increase in PhD student numbers between 2007 and 2013. Of our 105 Cat A staff, 22 currently hold full personal fellowships awarded competitively by EPSRC, STFC, RS, RSE, RAS, or EU; a further 9 hold ERC grants (4 Advanced, 1 Consolidator, 4 Starting). Since 2008 PHYESTA has spent over £90M of research funds and published about 4000 papers, of which at least 55 have over 100 citations.

b. Research Strategy

In creating PHYESTA, our strategy is to enhance and profit from the existing synergies between the Edinburgh and St Andrews Schools of Physics, by developing a research partnership covering a wide range of contemporary physics at a uniformly high level of activity and achievement. We aim to perform internationally leading research, and to maintain a critical mass of researchers, in each of our chosen Research Themes. We place strategic emphasis on linking experiment and theory, and on addressing the biggest problems in each field, which are often found at disciplinary boundaries. Subject to these principles, research quality is the overriding factor in determining our investment choices. We are prepared to make difficult prioritisation decisions where necessary.

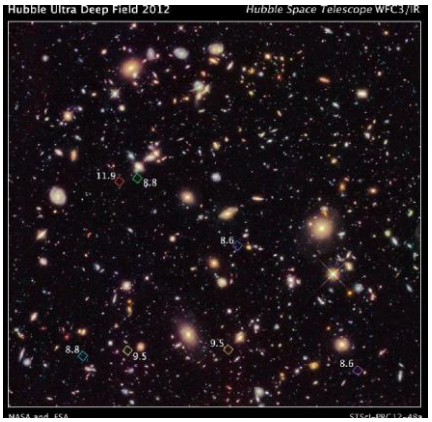
Delivery against these goals is the responsibility of our Research Strategy Board (RSB). This comprises Heads of School (*Trew*, *Cameron*), co-Directors of Research (*Playfer*, *Samuel*), co-Directors of KT (*Crain*, *Dholakia*) and two further senior researchers (currently *Cates* and *Mackenzie*). The RSB oversees and approves the plans of individual Themes and Research Groups, and advises Heads of School when prioritizing hiring decisions for all new academic posts. Such posts are allocated strategically rather than on a replacement or pro-rata basis. The Heads of School each control significant funds (including SUPA-II funds) that are set aside for new research initiatives rather than devolved to Theme or Research Group budgets.

A key strategic goal is to promote collaborative work that takes advantage of the scale of our research base. PHYESTA's two Schools provide open access to laboratory facilities at both sites,

have cross-representation on academic appointment committees, and share research grants and postgraduate training. We encourage cross-theme research and links to other disciplines by hosting and leading a number of research centres that provide advanced infrastructure. The largest of these is the Edinburgh Parallel Computing Centre (EPCC), which has powerful HPC facilities. The Centre for Science in Extreme Conditions (CSEC) is a collaborative research centre spanning Condensed Matter Physics, Chemistry, Engineering and Geosciences, while the Organic Semiconductor Centre (OSC) brings together Physics and Chemistry to develop novel materials. We enjoy close research links to the STFC-funded UK Astronomy Technology Centre (UKATC), located at the Royal Observatory Edinburgh. Through these and other channels PHYESTA maintains strong collaborative links with industrial partners and other non-academic stakeholders.

We now describe our Research Strategy in more detail at Theme/Group level.

1 Astronomy



AST Theme is organized as a single large research group of 35 Cat A staff (plus 1 UKATC staff member in Category C): *Best, Biller(ECR), Bonnell, Cameron, Cirasuolo(ECR), Cyganowski(ECR), Dominik, Driver, Dunlop, Evans(Cat C), Ferguson, Greaves, Gregory(ECR), Hambly, Helling, Heymans, Horne, Ivison, Jardine, Khochfar, Lawrence, Liddle, Mann, McLure, Meiksin, Peacock, Penarrubia(ECR), Rice, Scholz, Sicilia-Aguilar(ECR), Taylor, Vidotto(ECR), Weijmans(ECR), Wild(ECR), Woitke(ECR), Zhao*

AST's strategy is to combine observational astronomy, theory and numerical simulation with HPC to address four key scientific questions: What is the nature of dark matter and dark energy? How do galaxies and black holes form and evolve? What processes drive the formation of stars and planets? Are we alone in the universe? PHYESTA astronomers discovered over a hundred new exoplanets using transits (*Cameron*, Nature (2009) #1) and microlensing (*Dominik*, Science (2008) #1). We have extended our star formation simulations to include energy and momentum feedback into the interstellar medium, and investigated star formation near supermassive black holes (*Rice*, Science (2008) #1). Our Hubble Space Telescope wide field surveys of M31 (*Ferguson*, Nature (2009) #2) trace the history of a spiral galaxy similar to our own Milky Way. In the distant universe we discovered both the first quasar and the first galaxies at redshift z=7-12 (*McLure*, MNRAS (2013) #4, see Figure). Our expertise in statistical analysis and cosmology gives us leadership in weak lensing surveys (*Heymans*, MNRAS (2012) #2), high redshift astronomy, and studies of the cosmic microwave background (*Taylor*, Ap.J. (2009) #1). We host and lead the main data centre for wide field survey astronomy, releasing new data from UltraVISTA (*Dunlop*, MNRAS (2012) #3), and the first large scale dark matter maps and galaxy group mass functions (*Driver*, MNRAS (2010) #2*, Peacock*, A.& A. (2013) #4).

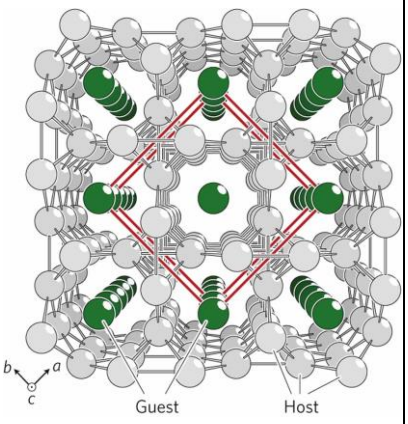
The above programme follows our strategy set out in RAE2008, and is supported by STFC consolidated grants of £4.9M (*Horne***,** *Peacock*), and a wide field astronomy grant of £2.0M (*Mann*). With the LCOGT robotic telescope network and HARPS-N both now operational, we are aiming for detection of exo-Earths, and will exploit these opportunities with new hires *Biller* (direct imaging) and *Cockell* (chair in astrobiology). Other new chairs are *Ivison* (radio astronomy) and *Liddle* (cosmology). Together with the appointments of *Heymans* (weak lensing); *Khochfar* and *Penarrubia* (galaxy evolution); *Weijmans* and *Wild* (galaxy and star formation); and *Cyganowski* (high-mass star formation), they will enable us to compare large scale simulations of galaxy formation and evolution with observational data. We are also expanding our theoretical and observational studies of brown dwarf and planetary atmospheres, planet formation and astrochemistry in protoplanetary discs, with new hires *Helling*, *Scholz***,** *Sicilia-Aguilar* and *Woitke*. Our investigations of the young universe will go deeper and extend to mm and radio wavelengths with ALMA, LOFAR and eventually SKA. We are now preparing the highest redshift galaxy targets for infrared spectroscopy with future facilities in which we play a leading role: KMOS, MOONS, JWST. Our leadership in survey astronomy continues as we host the main data centres for the forthcoming ESA missions GAIA (Milky Way) and EUCLID (dark Universe).

2 Condensed Matter and Photonics

PHYESTA's CMP Theme is organised into three Research Groups along scientific lines:
2.1 Hard Condensed Matter (HCM) studies correlated many-electron systems and the effects of extreme conditions on structure and dynamics of condensed phases.
2.2 Soft Matter, Statistical Physics and Biophysics (SMSB) studies colloidal materials, statistical mechanics and PALS (physics at the life science interface).
2.3 Photonics (PHOT) studies photonic materials, lasers and their applications.

2.1 Hard Condensed Matter

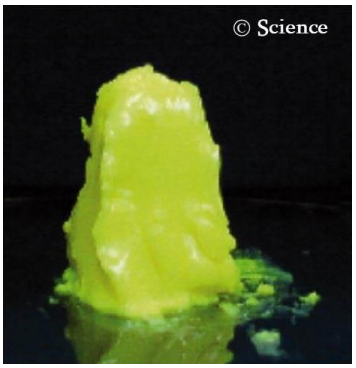
HCM has a headcount of 22 Cat A staff, some of whom are joint with Photonics(*) or SMSB(**): *Ackland, Baumberger, Braunecker, Cockell**, Davis, Degtyareva, Gregoryanz, Grigera, Hermann(ECR), Huxley, Keeling*, King(ECR), Lee, Loa, Mackenzie, Martinez-Canales(ECR), McMahon, McWilliams, Sanloup, Stock, Wahl, Yelland(ECR)*



HCM's strategy is to deploy state-of-the art instrumentation to explore the physics of condensed matter under conditions of extreme temperature (high and low), magnetic field and pressure, and to partner this with theory and simulation to develop a deep understanding of the phenomena under study. Our research ranges from exotically ordered quantum states at near-zero temperatures, to the formation of super-hard alloys and reactor materials at uncharted extremes of pressure. We have elucidated new states of order both in electron systems (*Yelland*, Nat.Phys. *(2011) #2*, *Wahl*, Nature (2010), *#2*) and in spin-ices (*Grigera*, Science *(2009) #2*), and shown electrons in solids to share universal behaviour with quark-gluon plasmas (*Mackenzie*, Science *(2013) #4*). At ultra-high pressure we have shown group I, II and V elements to adopt ever more complex 'hotel' structures (*Loa*, Nat.Mat. *(2012) #4*, see Figure), and found several new phases of hydrogen (*Gregoryanz*, PRL (2012) *#3*). Our studies have wide-ranging implications for materials science (*Ackland*, PRL (2009) *#1*), geophysics (*Cockell*, Science (2008) *#1; Sanloup*, Nature (2013) *#3*) and planetary science (*McWilliams*, Science (2012) *#4*).

Building on our RAE 2008 commitment to push back the boundaries of high pressure physics, and reinforced by new hires *Loa* and *McWilliams*, we now plan a new programme of shock wave research led by *McMahon*. Neutron scattering will be strengthened following the recent arrival of *Stock*. New laboratories for scanning tunnelling microscopy and angle-resolved photoemission spectroscopy will allow dramatic advances in the cryogenic surface science of correlated electrons, led by new hires *King* and *Wahl*. Our £6.8M EPSRC Programme Grant (*Wahl*) will address exotic states of quantum order relevant to quantum informatics. Led by *Ackland*, new hires *Braunecker*, *Hermann*, *Keeling* and *Martinez-Canales* will further strengthen our theoretical activities, and will create exciting new links to photonics.

2.2 Soft Matter, Statistical and Biophysics



SMSB has a headcount of 16 Cat A staff some of whom are joint with Photonics(*) or HCM(**): *Allen, Blythe, Cates, Clegg, Cockell**, Crain*, Evans, Henrich(ECR), MacPhee, Marenduzzo, Martinez(ECR), Morozov, Poon, Stratford, Thijssen(ECR), Waclaw(ECR)*

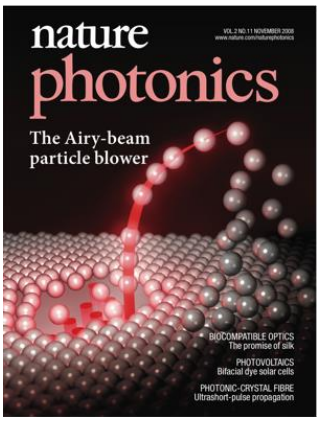
SMSB's strategy is to combine experiment, theory and HPC simulation to address the physics of colloids, polymers, liquid crystals, multiphase soft solids, biomolecules, and biological many-body systems such as bacteria. This diversity allows generic principles to be identified early and then fully exploited. We have pioneered new microscopies to deliver unprecedented statistics for particle trajectories in flowing colloids and motile organisms (*Martinez*, PRL (2011) *#1*); discovered exotic colloid-liquid crystal composites (*Poon*, Science (2011) *#4,* see Figure); and elucidated novel properties of bijels (*Clegg*, PRL (2009) *#1*; *Thijssen*, Adv.Func.Mat. (2013) *#2*) and of blue-phase

liquid crystals (*Stratford*, PRL (2011) *#4*). We rigorously address core issues in non-equilibrium statistical physics (*Evans* PRL (2011) *#3*), and use the resulting insights to understand arrest, glass formation and flow in soft materials (*Cates*, PNAS (2009) *#3*). This approach also elucidates PALS (Physics and Life Sciences) topics such as cellular propulsion (*Marenduzzo*, PNAS (2012) *#4*), bacterial dynamics (*Cates* PRL (2008) *#1*), and language (*Blythe*, Lang.Var.Change (2009) *#2*). We explore the molecular physics of biopolymers, including amyloid formation (*Allen*, Nat.Comm. (2013) *#4; MacPhee* PNAS (2013) *#3*) and DNA folding (*Marenduzzo*, PNAS *(2009) #2*).

In RAE 2008, we promised major investment in PALS while maintaining our core activity in soft matter. The work of *Cockell*, hired to our new PALS chair, expands our bacterial physics programme to address life in extreme conditions, with links to the HCM group and AST theme. New hires *Morozov* and *Waclaw* will strengthen the theory-experiment interface across soft matter and biophysics. *Cates* leads a £5M EPSRC Programme Grant on soft materials, and *Poon* a £2M ERC Advanced Grant on active colloids and bacteria. In future we plan to combine theory, simulation and experiment to study antimicrobial peptides, bacterial colonies, drug resistance, interfacial proteins, biopolymer organization, and composites of live and synthetic matter. We will strengthen our applied research via the new Edinburgh Complex Fluids Partnership (ECFP; see REF3a).

2.3 Photonics

Photonics has a headcount of 13 Cat A staff some of whom are joint with HCM(*) or SMSB(**): *Brown, Crain**, Dholakia, Di Falco(ECR), Gather, Hoefling, Keeling*, Koenig, Lovett, Mazilu(ECR), O'Faolain(ECR), Samuel, Turnbull*



The strategy in photonics is to pursue cutting edge research on light sources and photonic materials, with a continuing shift from metrology towards applications in communications, healthcare and energy. The femtosecond Ti:sapphire laser sources, invented by *Sibbett* (emeritus; Royal Medal 2009) have opened up a world of photonic materials and applications that we are now exploring. This includes studies of fundamental physics, such as the demonstration of an optical black hole (*Koenig*, Science (2008) *#1*), and the precise measurement of exciton diffusion, which is also vital for developing organic solar cells (*Samuel*, Adv.Mat. (2008) *#1*). We have pioneered the use of Airy light fields (*Mazilu*, Nat.Phot. (2008) *#2*, see Figure), leading to three patents and a new mode of biomedical imaging. We have used new photonic materials to explore both slow light and optical chaos (*O'Faolain* Nat.Phot. (2009) *#2*; *Di Falco*, Nat.Phot. (2013) *#3*).

In RAE 2008 we planned to develop applications of photonics to biology and medicine. This led to a new £45M Medical Sciences in St.Andrews attached to the School of Physics and housing our £1.5M interdisciplinary biophotonics laboratories. Opened in 2011, this investment was a key factor in attracting *Gather* from T.U. Dresden to a chair, and *Mazilu* to a lectureship. With a £4.45M EPSRC Programme Grant (*Dholakia*) we aim to become the world's leading group in biophotonics with "structured light", where precise control of amplitude and phase is used to manipulate light propagation. *Samuel's* new ERC Advanced Grant will allow us to develop improved organic solar cell materials and devices. Our work on photonic materials will be carried forward by new hires *Di Falco*, *Hoefling* and *O'Faolain*, and will exploit a £3.7M EPSRC equipment grant for advanced nanofabrication and characterisation facilities. *Keeling*, *Lovett* and *Braunecker* will vastly strengthen photonics theory and create exciting new links to HCM.

3 Particle and Nuclear Physics

PHYESTA's PNP Theme is organised into three research groups along scientific lines:

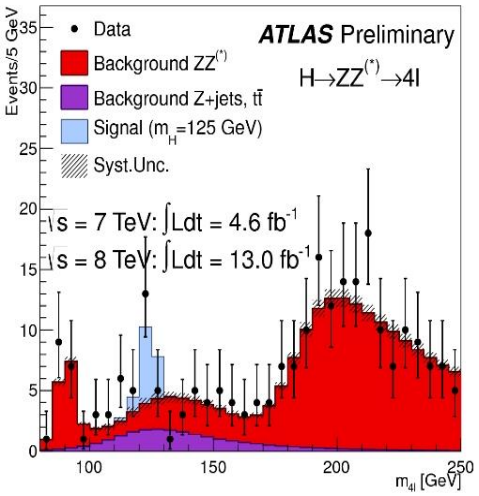
3.1 Particle Physics Experiment (PPE) is a major participant in both the ATLAS and the LHCb experiments at the Large Hadron Collider at CERN.

3.2 Particle Physics Theory (PPT) studies theories both within and beyond the Standard Model.

3.3 Nuclear Physics (NP) studies nuclear reactions of astrophysical significance, explores hadron physics, and conducts searches for dark matter.

3.1 Particle Physics Experiment

PPE has a headcount of 9 Cat A staff: *Clark, Clarke, Cowan (ECR), Leonidopoulos, Martin, Mills (ECR), Muheim, Needham (ECR), Playfer*



PPE's strategy is to search for evidence for new physics through the production of new particles at the energy frontier, and through precision studies of quark flavour physics. We are very active participants in the ATLAS and LHCb experiments at the Large Hadron Collider (LHC) at CERN. In LHCb we led the construction and commissioning of the Ring Imaging Cherenkov (RICH) detectors, and in ATLAS we contributed to the monitoring of the tracking and trigger systems. In both experiments we have leading roles in management, core computing and data analysis (see details in **Section (e)** below). We were directly involved in the discovery of the Higgs boson, analysing the ZZ* to 4 lepton channel (*Clark*, PLB (2012) *#3*, see Figure), and gave one of the first conference talks (QCD12, Montpellier). We are searching for H to bb decays using boosted WH and ZH production, and studying H to WW to confirm the nature of the Higgs (*Mills*, PLB (2013) *#1*). Our LHCb work has included the first accurate measurement of matter-antimatter asymmetries (CP violation) in Bs meson decays (*Clarke*, PRL (2012) *#3*); we led this analysis and gave the first conference talk on it (Moriond EW 2012). We are extending our work on CP violation to rare B decays that should be more sensitive to new physics contributions, and have some first results (*Muheim*, PRL (2013) *#4*).

Our plans from RAE2008 were modified because of the deferral of a decision on the International Linear Collider (ILC), pending first results from the LHC. We applied to join ATLAS, becoming members in 2009, and have appointed *Leonidopoulos* (ATLAS) and *Needham* (LHCb) as new lecturers to strengthen our activities at CERN. We have been awarded a £1M project grant to work on upgrades to ATLAS, and have just submitted a proposal for upgrades to LHCb. Our work is supported by a £2.6M STFC Consolidated Grant, and we have spent £1.1M on new laboratories for detector development and testing. Our key future plans are to lead the detector design and construction work for the ILC. *Martin* performed studies for the Technical Design Report (2013), and there is a keen interest from Japan to host ILC in the 2020s.

3.2 Particle Physics Theory

PPT has a headcount of 8 Cat A staff: *Ball, Boyle, Del Debbio, Gardi (ECR), Kenway, O'Connell (ECR), Smillie (ECR), Zwicky*

PPT's strategy is to focus on phenomenology of direct relevance to high-energy experiments, particularly at the LHC. The discovery of the HIggs boson in 2012 has led to the award of the 2013 Nobel Prize for Physics to Prof. *Peter Higgs* (emeritus), and we expect further discoveries at the LHC in the next few years. We have used perturbative Quantum ChromoDynamics (QCD) to deliver robust parton distribution functions with LHC data (*Ball*, NPB (2013) *#4*). These are key inputs used by all LHC experiments to determine production rates for the Higgs boson and other new particles. We have created Monte Carlo tools for the improved description of multijet events (*Smillie*, JHEP (2010) *#1*). We also study theories beyond the Standard Model and have explored their implications for anomalous results at the LHC (*Zwicky*, PRD (2008) *#1* and (2009) *#2*). We have extended our work on lattice field theory to include finer lattices and dynamical fermions at the physical light quark masses. With IBM we have developed a new generation of BlueGene supercomputers, and have used these to compute nonperturbative QCD parameters of central importance in quark flavour physics (*Boyle*, PRL (2008) *#1*; PRL (2012) *#4*). We have developed lattice theory candidates for strong electroweak symmetry breaking (*Del Debbio*, PRD (2010) *#2*). Other activities include algebraic properties of gauge amplitudes, aspects of fundamental field theories, baryogenesis and inflationary cosmology.

The strategy outlined above broadly follows our plans in RAE 2008, with an increasing focus on phenomenology being driven by the start of the LHC. We have strengthened these activities by appointing *Gardi* (gauge theories) and *Zwicky* (beyond the Standard Model). In the coming years

we will optimize the exploitation of new LHC data at the higher energy of 13-14 TeV to strongly constrain new physics in the electroweak and flavour sectors. In 2012 we established the Higgs Centre for Theoretical Physics, which links all areas of theoretical physics research across PHYESTA, including particle physics, condensed matter and cosmology. This initiative has allowed us to appoint two more new lecturers, *Smillie* and *O'Connell***,** further strengthening PPT research.

3.3 Nuclear Physics

NP has a headcount of 5 Cat A staff: *Aliotta, Beltrame(ECR), Murphy, Watts, Woods*

NP's strategy is to focus on nuclear reactions of astrophysical significance, critical to the synthesis of the elements in novae and supernovae. We lead experiments using radioactive ion beams at ANL (Chicago), GSI (Germany), TRIUMF (Canada), and CERN-ISOLDE, and are responsible for developing new silicon detection systems. Highlights include a reaction crucial for ^{26}Al production (*Woods*, PRL (2009), *#2*), and the superallowed beta decay of doubly magic ^{100}Sn (*Woods*, Nature (2012), *#4*). We conduct very low energy low cross-section experiments at LUNA (Gran Sasso, Italy), and in the Boulby mine. ZEPLIN-III (*Murphy*, PLB (2012), *#3*) and XENON100 (*Beltrame*, PRL (2012), *#1*) are the most sensitive direct dark matter searches using nuclear recoil. We have completed hadronic and photonuclear measurements at MAMI (Mainz) and Jefferson Lab including beam-spin asymmetries and neutral pion photoproduction on ^{12}C (*Watts*, PRL (2008), *#1*).

In line with our 2008 RAE plans, we are strongly involved in the Facility for Antiproton & Ion Research (FAIR) at GSI, which has a start date of 2018. We are developing Cherenkov detectors for the PANDA experiment, which will search for glueballs and hybrid mesons. We have proposed moving the existing GSI storage ring to CERN-ISOLDE, to allow shorter half-life beams to be used for nuclear astrophysics studies. We have begun developing laser driven plasma accelerators (SCAPA). We plan to improve the sensitivity of our dark matter searches as part of the LUX and LZ collaborations, with LUX having just announced their first world-leading results in October 2013.

4. Inter-theme and Interdisciplinary Research

As well as performing world-leading work within each of our Research Themes, a key strategic goal of PHYESTA is to tackle the profound problems that often arise at the boundaries between traditional sub-disciplines, and to seize the opportunities presented by applying methods developed in one field, to another. To further promote interdisciplinary work, we are actively developing a number of strategic links between Research Themes: Astronomy and Condensed Matter through the new centre for Astrobiology; Astronomy and Photonics in radiation transfer software and fast laser combs; Astronomy, Condensed Matter and PPT in theoretical physics through the Higgs centre; and between all research areas and EPCC in computational physics. We will also work to promote interdisciplinary research through links with other academic units including Chemistry, Biology, Medicine and Geosciences. Alongside these we will develop our multidisciplinary links to industry, particularly through investment in the in-house Knowledge Transfer activities of EPCC, Edinburgh Complex Fluids Partnership, and the Photonics Innovation Centre (see REF3a for details of these). By profiting from the new critical mass and opportunities that PHYESTA provides, combined with the substantial new investment that we are attracting, we will ensure a bright and vibrant future for physics research across the two collaborating institutions.

c. People

i. Staffing Strategy and Staff Development

Staff Recruitment & Turnover: PHYESTA recruits outstanding physicists globally, by competitive advertisement, in research fields targeted by its Strategy Board. Since 2008 we have appointed 33 highly qualified staff to academic posts; 20 are from overseas and 6 are women. This has improved our age profile, which now has a mean age of 45 and standard deviation of 7, with 25% of our academic staff under 40. New chairs include *Cockell* (Astrobiology), *Gather* (Biophotonics), *Hoefling* (Photonic Materials), *Ivison* (Radio Astronomy), and *Liddle* (Cosmology). Several staff have moved to high-profile positions elsewhere: *Bates* (UBC), *Green* (UCL), *Heavens* (Imperial), *Krauss* (York), *Leonhardt* (Weizmann), *Pickard* (UCL), *Plehn* (Heidelberg), and also *Baumberger* (Geneva) who retains a 0.2FTE position in PHYESTA. We believe this level of staff turnover is a

sign of vigour, showing that we both attract outstanding researchers, and develop their careers. *Mackenzie* will take up a Directorship at MPI Dresden late in 2013, but also retain a 0.1FTE contract and continue to supervise PHYESTA students through our MPI partnership, and Davis has held a 0.2FTE post since 2007. Among recently hired staff, *Biller, Leonidopoulos, Loa, Martinez-Canales, McWilliams,* and *Stock* all hold 5-year Chancellor's Fellowships at Edinburgh. These University-funded tenure-track posts allow early-career staff to initially focus on developing their independent research, but carry the clear expectation of conversion into permanent lectureships or readerships. PHYESTA treats them as permanent academic positions for recruitment and planning purposes. A further round of recruitment to these positions will take place in 2014.

Fellows and Research Associates: Our 105 Category A staff currently hold 22 full-time personal fellowships awarded competitively by STFC, EPSRC, Royal Society, Royal Astronomical Society, Royal Society of Edinburgh and EU. (University-funded Fellowships are excluded from this figure). Of these 7 are held by non-tenured staff (*Cirasuolo, Cowan, Degtyareva, Gregory, Thijssen, Vidotto, Yelland)*, and 15 by proleptic or permanent academics. A further 9 Category A staff hold individual ERC Grants (4 Advanced, 1 Consolidator, 4 Starting). 7 non-tenured personal fellows have recently left for academic posts elsewhere (*Joachimi, Kitching, Korn, Lotay, Norberg, Perry, Zachariae).* We host several SUPA-II funded Advanced Fellows who are not Category A staff but reinforce key research projects in Soft Matter, PALS, PPE/ATLAS, NP/SCAPA, and Photonics. About 10% of our other Research Associates are funded via strategic funds available to PHYESTA, and the other 90% through research grants. The total number of Research Associates has increased by 20% from 94 in 2008 to 114 in 2013.

Staff Development & Training: We are committed to maintaining a supportive environment in which staff are given every opportunity for their research to flourish. New appointees are assigned a mentor to assist and advise them in all aspects of their work. We offer flexible start-up packages which include funding for new facilities, PDRAs or travel. New academics get preferential access to PhD studentships, and a gradual ramp-up of their teaching load over the first 5 years. Each Fellow or PDRA is also supported by a mentor from within their research group. While focusing on research, they are encouraged to gain experience in teaching through tutorial workshops, graduate lectures or undergraduate projects. PHYESTA supports the career development of all staff through annual personal development reviews, and access to a wide range of professional development courses provided at University level or via SUPA. They include induction courses for new staff, training in PhD supervision, workshops in research grant applications and other aspects of research management, and courses on best practice in KT, outreach, and teaching and learning.

Equality & Diversity: PHYESTA has an E&D strategy with action plans overseen by an E&D coordination team. These range from family-friendly scheduling of staff meetings to proactive re-integration strategies following career breaks. Specific E&D training, in both online and workshop formats, is provided for all staff, and mandatory for those involved in recruitment or research management. We have improved the proportion of women at all levels: 26% of PhD students, 22% of PDRAs, and 15% of academic staff, including 3 Chairs and 4 Readers. In future we aim to further improve these figures and those for other minority groups. Our progress has been recognised by both Schools being awarded the IoP's Juno Practitioner status, and we will soon be applying for Juno Champion and Athena Swan Silver awards.

Concordat: We recognise the importance of contract research staff (CRS) and fully endorse the UK Concordat for their career development. We have also implemented the principles of the European Charter for Researchers, leading to the EC 'HR Excellence in Research Award'. We have a code of practice in place for the management of research staff, with an action plan that supports their career development. Examples include a mentoring scheme in which CRS are mentored by an academic who is not their line manager, a CRS forum for identification and resolution of issues affecting CRS, and supportive appraisals in which career goals are discussed and associated training identified and fulfilled, often by courses designed specifically for CRS.

Sabbaticals: These are encouraged as they create links with other top research institutions. Each year several academic staff take a half or full year of leave to develop new contacts and gain better access to facilities. Examples in the REF period include *Bonnell* (Bordeaux), *Boyle* (KEK), *Clark* (CERN), *Clarke* (CERN), *Dunlop* (UBC), *Evans* (Orsay), *Ferguson* (Potsdam), *Lawrence* (SLAC),

Mackenzie (Stanford), *McMahon* (AWE), *Muheim* (CERN), *O'Faolain* (Stanford), *Samuel* (Santa Barbara), *Woods* (Frankfurt), and *Zhao* (Leiden).

Visitors and Visitor Programmes: We host visitors from a wide range of countries; these include senior researchers on sabbatical leave for up to a year (some funded as SUPA Distinguished Visitors) as well as regular visits by our long term collaborators. A thriving new visitor programme (linking PPT with all other theory areas) has been established via PHYESTA's strategic investment in the Higgs Centre, while several major grants in CMP and AST also include visitor funding. Below we list examples of recent visitors to PHYESTA (all staying more than one week):

Astronomy: Blake (Melbourne), Elvis (Harvard), Ferreira (Oxford), Gibson (Ohio), Guedel (Vienna), Guzzo (Milan), Hayashi (Subaru), Trujillo (Tenerife), Van Der Werf (Leyden), Van Warbeke (UBC), Wyse (Baltimore), Zinnecker (Potsdam)

Condensed Matter & Photonics: Bangura (RIKEN), Baym (Illinois), Chaikin (NYU), Chubukov (Wisconsin), Collins (LLNL), Derrida (ENS), Fuchs (Konstanz), Goncharov (Carnegie Inst), Larson (Michigan), Leggett (Illinois), Majumdar (Paris-Sud), Mineev (Landau Inst), Mukamel (Weizmann), Newns (IBM), Orenstein (Berkeley), Ramaswamy (Hyderabad), Sauls (Northwestern), Sheikin (Grenoble), Weeks (Emory), Wright (Arizona), Zaccarelli (Rome), Zemanek (Brno)

Particle & Nuclear Physics: Bastero-Gil (Granada), Bernstein (MIT), Briscoe (GWU), Britto (Saclay), Christ (Columbia), Cossi (KEK), Cundy (Seoul), Del Duca (Frascati), Duhr (ETH), Magnea (Turin), Strieder (Bochum)

ii. Research Students

PHYESTA delivers a highly developed and closely integrated programme of graduate education via the SUPA Graduate School, established in 2006. This offers over 60 courses for physics PhD students across Scotland, as well as transferable skills training tailored to a physics background. Most courses are delivered by live video links and many use SUPA's e-learning portal. There are also tutorials, lab classes and workshops. These courses are aligned to pan-SUPA research themes (Astronomy, Condensed Matter, Energy, Nuclear and Particle Physics, Photonics, and Physics & Life Sciences) which cover all areas of research within PHYESTA. Each PhD student must take for assessment at least 40 contact hours of academic courses and 20 hours of skills courses in their first two years. In 2012/13 PHYESTA hosted 217/538 (40%) of all SUPA's graduate students, and taught 36/69 (52%) of its courses.

Student Numbers: We have seen a steady increase in our postgraduate student admissions from 48 in 2008 to 59 in 2013, and in 2013 we had 6.5 applicants per studentship awarded. The current numbers of students within PHYESTA's Research Themes are: AST 46, CMP 131, PNP 45. Of these 67% are from the UK, 19% from the EU and 14% from further afield. Our FTE headcount on 31/7 is up from 123 in 2007 to 217 in 2013.

Training Centres: Since 2009 PHYESTA has co-hosted (with Heriot-Watt) a £6M EPSRC Centre for Doctoral Training in Condensed Matter (CM-DTC). We currently supervise 38/52 of its students. CM-DTC provides comprehensive training across the breadth of condensed matter, plus industrial partnership, outreach, and exchange programmes; much of this training is available to our non-DTC students. We participate in the Industrial Doctorate Centre in Optics and Photonics Technologies, and the CDT in Integrated Magnetic Resonance, and are partners in two newly funded CDT bids, one in Photonics and one in Soft Matter. We are members of EU Marie Curie training networks including Comploids (colloids), IIIOS (photonics) and MaMiNa (metallic alloys).

Funding & Sponsorship: UK students mainly hold EPSRC (93) and STFC (50) studentships. We make full use of our Universities' internally funded studentships (mainly for EU and international students), and attract each year several winners of SUPA's prestigious international Prize Studentships. Our international students have come from 18 countries, many with their own funding. We host studentships co-funded by NPL, AWE and ESO, and CASE and iCASE awards from NPL, Johnson Matthey, Syngenta and Mars, with approval for others from Fraunhofer UK and the Diamond Light Source. Our new strategic partnership with the Max Planck Society envisages 4 jointly supervised students annually from 2013/14. RCUK-funded students are assigned DTG funds for minor equipment and for travel to national and international conferences (which is encouraged).

Between 2008 and 2013 PHYESTA received Doctoral Training Grant (DTG) funding of £5.6M from EPSRC and £5.0M from STFC. In STFC-funded areas there is additional resource for long term secondments to overseas facilities. For non-RCUK students the equivalent costs are met from University, SUPA and PHYESTA funds.

Training & Support: All research groups have regular seminars aimed at graduate students, and both Schools run colloquia of general interest to all such students. The Higgs centre has a regular series of colloquia and lectures in theoretical physics, held mainly in Edinburgh. There are student-run interdisciplinary seminars where those from different groups exchange ideas, and postgraduate staff-student liaison committees to discuss training and support issues. Both Universities organise training workshops, courses, and online resources specifically for PhD students, including introductions to research, thesis writing workshops, preparation for a viva, presentation skills, professional development and time- and career management. Our PhD students are trained for undergraduate teaching duties, and take part through tutorial workshops, computing and experimental laboratories. The students are also particularly enthusiastic contributors to our public outreach events (see REF3a).

Progress Monitoring: Each PhD student has a first and second supervisor from within her or his research group. Progress is monitored through regular meetings with the supervisors and through annual reports, written by students and assessed at interview by two other members staff. Second-year students also present their PhD work in PHYESTA-run poster and seminar competitions.

Summer Schools: Scottish Universities Summer Schools in Physics (SUSSP) has run 1 or 2 schools per year since 1960. We organised schools on High Pressure (2008), Electron Spin Resonance (2008), and LHC Physics (2009 and 2012), each attended by ~100 students from all over the world. In 2010-2012 we partnered OREA, an Erasmus school on organic electronics. CM-DTC runs its own biennial summer schools; our students in CMP attend these and other EPSRC and IoP schools, while students in AST and PNP attend STFC schools. All students are encouraged to participate in overseas graduate schools; most attend at least one during their PhD.

d. Income, Infrastructure and Facilities

i. Research Income

PHYESTA has a strong record of winning competitively awarded research funding. We have spent £94M of research income since 2008, as reported in REF4b, an increase of 30% from £14.5M p.a. in RAE 2008 to £19M p.a in the REF period. From all sources we have been awarded grants of £148M, although some of these are for managing national facilities and/or industry links. Our direct research expenditure is £110M over the REF period**.** We provide training and mentoring for staff preparing proposals, and have in place internal review procedures for quality assurance. We believe this contributes to the high success rate of our funding applications (~ 50% for the past two years). Within this growing income we have attracted funding from a wide range of sources: the breakdown for 2012/13 is 37% STFC, 27% EPSRC, 24% EU/ERC, 12% Other (Industry, RS/RSE, BBSRC). We currently hold 24 large grants (over £0.75M each), whose values for each Research Theme amount to: AST £13M, CMP £28M, and PNP £8M. In addition, EPCC holds current HPC grants of £13M.

ii. Local Infrastructure & Facilities

PHYESTA has extensive in-house facilities open to all research staff and students. An exemplar of this is the work of *Huxley* and *Yelland* on quantum order which combines facilities at St Andrews and Edinburgh on a daily basis, with students and PDRAs based in both locations, and *Yelland* holding a joint appointment. Within SUPA we also pool resources and equipment more widely across Scotland. Since 2008 we have made strategic investments in facilities for all research areas. Technical support for PHYESTA is provided by 23 research technicians (excluding computing staff) and by mechanical and electrical workshops.

Computing and Data Facilities: EPCC is ranked among Europe's 3 leading centres for scientific HPC and its applications, and is managed and led entirely from within PHYESTA. EPCC's 75 staff undertake research with industry and academia; lead several European projects on computing technologies; and support national facilities. EPCC hosts and manages the HECToR and DiRAC

(BlueGene/Q) facilities and coordinates the CRESTA project (collaborative research into exascale computing). It holds a £10M EPSRC infrastructure award, a £7M EPSRC contract to run ARCHER (the next UK HPC facility), and an £8M contract from BIS to expand the UK Research Data Facility. Agreement has been reached for EPCC to host all national HPC services for the next 20 years. Under its contracts with RCUK, 5% of all national facilities time hosted by EPCC is reserved for use by PHYESTA researchers. This 'Director's time' is excluded from the RCUK figures in REF4b and was worth £8.2M over the period. We also make use of EPCC's NVidia GPU HPC hardware; of the Edinburgh Compute and Data Facility (ECDF), an IBM server cluster with ~3k core processors, ~7TB of RAM, and 1PB of data storage (valued at £125k annually); and of the UKMHD cluster through ERC-ECOGAL (£400k). Recognising the importance of scientific computing and HPC to all areas of its research, we employ 25 people (excluding EPCC staff), in computing support roles including software developers, database managers, systems administrators and computing officers.

Astronomy: We enjoy close research links to the STFC-funded UK Astronomy Technology Centre (UKATC), located at the Royal Observatory Edinburgh, which is the national centre for the design and construction of astronomical instruments. Examples include Gemini, HARPS-N, SCUBA2, VISTA, JCMT, UKIRT, and KMOS for the ESO VLT. UKATC also provide project management and software expertise. The Wide Field Astronomy Unit (WFAU) is a leading data centre managed by PHYESTA, building sky survey archives and contributing to the International Virtual Observatory. WFAU has received £5.2M in grants during the REF period, and its archives exceed 0.7PB. WFAU is contributing to the ESA mission Gaia, and will host the UK Science Data Centre for Euclid. While the UKATC and WFAU deliver services for all UK astronomers, their proximity brings significant added benefits to PHYESTA by providing local expertise in the detailed properties of the survey data, leading to improved scientific exploitation.

Condensed Matter and Photonics: The HCM Group makes extensive use of the Centre for Science in Extreme Conditions. CSEC brings together facilities for optical spectroscopy, x-ray diffraction, crystal growth and characterisation, which are unique in the UK and rare in the world. This enables studies of the structure and properties of materials to Mbar pressures and mK temperatures. We have invested £0.5M in lasers and IR detectors, £1M in low temperature facilities, and £0.5M for a new SQUID. Outwith CSEC we have state-of-the-art cryostats; a sophisticated angle-resolved photoemission laboratory; a materials growth laboratory; a helium liquifier; and an STM. These were funded by £1.5M of EPSRC and ERC grants with SFC and PHYESTA support. We also host a Wellcome Trust facility in advanced pulsed EPR.

The SMSB Group make extensive use of COSMIC (Collaborative Optical Spectroscopy, Micro-manipulation and Imaging Centre), a PHYESTA-run interdisciplinary facility for spatially resolved spectroscopy, coherent anti-Stokes Raman spectroscopy (CARS), and fast confocal microscopy coupled to rheometric flow cells for particle tracking in flowing colloids. With £0.4M from SUPA-II, we have also set up microbiological wet-labs with a full copy of the Keio library of *E. coli* mutants.

The Photonics Group uses facilities at the Organic Semiconductor Centre (OSC) to fabricate and test organic optoelectronic materials and devices; equipment includes several evaporators, glove boxes, pulsed laser systems, and a spectroscopic ellipsometer. An amplified laser facility enables the measurement of fluorescence from fs to µs. Nanophotonics is enabled by electron beam and nano-imprint lithography, and we have also invested £1.5M in new biophotonics laboratories.

Infrastructure under construction in CMP includes ultra-low vibration labs (£2M from SUPA-II) for scanning tunnelling spectroscopy of superconductors, which will house a state-of-the-art low temperature STM setup brought in by *Wahl*. With £0.8M from SUPA-II we are trebling our clean room to 180 sqm and installing advanced nanoscale fabrication and characterisation equipment worth £5.3M (including £3.7M from EPSRC). CSEC, with the Centre for Astrobiology, will soon commission a £0.3M planetary simulator to investigate life in exoplanetary conditions.

Particle and Nuclear Physics: For Particle Physics Experiments we have built new state-of-the-art facilities for detector development with £1.1M of PHYESTA and SFC funds, and have access to similar detector laboratories in Glasgow as part of SUPA. We will use these to participate in the planned upgrades to the LHCb and ATLAS detectors, and eventually for the ILC. Nuclear Physics have advanced in-house laboratory facilities for the construction of silicon detector systems, and also have access through SUPA to SCAPA, a prototype plasma accelerator at Strathclyde.

iii. External Facilities

PHYESTA researchers make extensive use of world-leading national and international facilities, and are involved in the planning of several future facilities. Some of our facility usage is directly supported by RCUK, while in a few cases PHYESTA has provided its own funding. Other facilities are open to all researchers, with a competitive bidding process for awarding time. In this section we are asked to report the equivalent value of such time wherever possible, and do so below. We note that the equivalent values reported are approximate, and the total is always an underestimate because of the facilities for which an equivalent value is not known.

Astronomy: Our total facility usage funded by RCUK is £21.4M (from REF4c). We benefit from UK membership of the European Space Agency (ESA) and the European Southern Observatory (ESO), with a combined value attributed to us of £3.9M p.a.. We estimate competitively awarded time as PI or co-PI on the ESA/ESO funded facilities HST, Herschel, Vista and VLT as equivalent to ~£7M. Facility usage not captured in the ESA/ESO subscriptions is estimated at a further £18.5M, based on a typical cost of £17k(30k)/night for a 4m(8m) telescope. This comes mostly from our leadership of major surveys using UKIRT (£12M), HARPS-N (£2M), JCMT (£1M), AAT (£0.1M) and IRAM (£0.3M). We have made a range of investments to gain access to other radio and optical surveys, including the HARPS-N exoplanet survey (£0.7M), the low-frequency radio survey LOFAR (£0.2M), the continuous sky survey PanSTARRS (£0.2M), the global network of robotic telescopes LCOGT (£2M), and the Sloan Digital Sky Survey III. Future planned facilities include the James Webb Space Telescope (JWST), KMOS and MOONS on the VLT, the European Extremely Large Telescope (ELT), the Square Kilometre Array (SKA), and the ESA missions GAIA and EUCLID.

Condensed Matter & Photonics: Our RCUK facility usage of £4.9M includes large-scale use of the Diamond and ISIS facilities at Rutherford Appleton Laboratory, and of the ESRF and ILL in Grenoble, for X-ray and neutron scattering. The estimated value of our non-RCUK usage of facilities is £15.9M (costing beam-time at an RCUK-based rate of £12k/day unless otherwise stated below). At the Paul Scherrer Institute (PSI, Switzerland), we use SINQ (neutrons), LMS (muons), and the SLS synchrotron, and were awarded 132 days of beamtime (£1.6M). We make heavy use of neutron sources including NIST, FRM2 (Munich), HZB (Berlin), HIFR (Oak Ridge), NRC (Chalk River), Janus (Argonne) and LLB (Saclay), totalling 295 days of beam-time (£3.5M). We use the Grenoble and Nijmegen high field facilities (48 days, £0.6M). Other synchrotrons used include Soleil (France), ASTRID (Denmark), ALS (Berkeley), NSLS (Brookhaven), PETRA (DESY), and SSRL (Stanford), totalling 159 days of beam-time (£1.9M). Our use of the free electron laser at LCLS (SLAC) and the OMEGA Laser (Rochester) was costed by providers at £0.9M and £0.5M respectively. *Cockell* ran a major project on the International Space Station (£6.5M at £12k/day). Our RCUK total includes £0.9M of HECToR time; costed on the same basis we won a further £0.4M for HPC resources in the USA (ANL, Oak Ridge) and Europe (PRACE). We plan continuing use of the central facilities listed above, and, from 2016, the European X-ray Laser (XFEL, DESY). We will further explore extremes of pressure with the inertial laser confinement facilities at LLNL.

Particle and Nuclear Physics: Our total facility usage funded by RCUK is £18.4M. Other facility usage is estimated to have an equivalent value of ~£20M. The NP group has competitive access to several international laboratories, with estimated equivalent cost of ~£15M based on ~£2k per hour of beam-time. We use radioactive beams at TRIUMF, GSI, ANL and CERN-ISOLDE. Since 2008 we have led experiments at (with beam-time allocations in weeks): ANL(5), CERN-ISOLDE(2), GSI(6), JLAB(25), LUNA(16), MAMI(20), Texas A&M(4), TRIUMF(8), RIKEN(1), GANIL(1). Our dark matter research has been conducted at the Boulby mine, and at the Sanford Underground Laboratory. The PPE group has access to CERN, with an equivalent value to us of £3.5M p.a. according to RCUK. We also benefit greatly from the LHC Computing Grid (LCG) and STFC Particle Physics and Technical Department resources at RAL. Other international facilities used are DESY (Hamburg), FNAL (Chicago), SLAC (Stanford) for which no equivalent values are known. The PPT group is the largest user of the BlueGene/Q (DiRAC) facility, and of its predecessor QCDOC, both managed by EPCC. They also have extensive access to other HPC resources worldwide (ANL, BNL, KEK, LLNL, PRACE).

e. Collaboration and Contribution to the Discipline / Research Base

i. Collaborations

Astronomy: Due to the international nature of astronomy facilities, and their high costs, most of our research now takes place as part of large collaborations. These include: HARPS-N (*Cameron*, Co-PI); SuperWASP (*Cameron,* Co-PI) and microlensing surveys (*Dominik*, PI); HiZELS, LOFAR (*Best*, UK PI); UltraVISTA (*Dunlop*, PI); SCUBA-2 (*Dunlop*, Co-PI); Hubble Space Telescope (Ultra Deep Field, STAGES, COSMOS, CANDELS); GAIA, Pan-STARRS (*Peacock*, Board); EUCLID (*Ferguson*, co-lead SWG; *Taylor*, UK PI); CFHT weak-lensing, SDSS (*Lawrence*, PI); Planck (*Liddle*, Review Board); UKIRT, GAMA, CALIFA, and the International Virtual Observatory. Heymans leads an ESO WG on weak lensing, and Greaves is PI for an ESA key project, DEBRIS.

Condensed Matter and Photonics: We are members of 14 EU Networks spanning all our research areas. We are partners in EPSRC networks, addressing life physics and nonequilibrium systems, and lead 2 EPSRC-NSF joint awards (*Poon, Samuel*), and one EPSRC-China award (*Samuel*). We are full members of the US-based ICAM network and the Scotland-Stanford photonics partnership (*Samuel* leads its energy theme). Our partners within the Max Planck Society include MPIs in Dresden (hard condensed matter, biophysics), and Erlangen (photonics). Interdisciplinary projects include nuclear reactor materials (*Ackland*/Engineering); Li-ion battery electrodes (*Clegg*/Chemistry); photovoltaics (*Samuel*/Chemistry); molecular biophysics (*Crain*, *MacPhee*/Biology); and biophotonics (*Gather*/Medicine). We also collaborate with geoscientists (*Sanloup*, *Cockell*) and chemical engineers (*Morozov*, *Poon*). Our CSEC, COSMIC and OSM laboratories are all organized on fully interdisciplinary lines. Industrial collaborations inform our basic research: work on flowing chocolate has led to new theories of suspension flow; work on photo-therapy to new studies of structured light; and work on organic display materials to basic insights into excited-state physics. Collaboration with AWE has influenced our strategic decision to work with free electron lasers. REF3a contains more details of the industrial partnerships involved.

Particle and Nuclear Physics: PPE group are members of the ATLAS and LHCb collaborations, with leading roles taken by *Clark* (ATLAS simulation), *Clarke* (LHCb deputy computing coordinator), *Muheim* (LHCb UK spokesperson 2008-2012), *Cowan* and *Needham* (physics analysis group convenors). We are also members of GridPP (*Clark*, *Clarke*). *Martin* has been a member of CDF at Fermilab, *Playfer* of BaBar at SLAC, and *Leonidopoulos* of CMS (2008-2012). *Martin* is in several R&D collaborations related to the International Linear Collider (LCFI, ILD, CLIC). In PPT there are large collaborations in Lattice QCD (UKQCD, JLQCD, QCDSF), where *Kenway* plays a leading role in securing HPC resources and *Boyle* has a close collaboration with IBM (see REF3a and REF3b/supercomputers). The NNPDF collaboration extracts parton density functions from collider data. Nuclear physics research takes place in small to medium-sized collaborations with PI roles taken by *Woods*, *Watts* and *Murphy*. Underground experiments include LUNA, LUX, ZEPLIN and DRIFT, with *Aliotta* and *Murphy* taking leading roles.

ii. Contributions to the Discipline

We list exemplars in each research area for both senior and junior staff. Listings for conference organization are limited to strategic and senior roles (abbreviations: International Advisory Committee IAC, Programme Committee PC, Scientific Committee SC etc.). Invited talks are restricted to those bearing official Keynote or Plenary designation as assigned by the conference organizers (or, in Astronomy, Invited Reviews). Abbreviated conference titles are official and can be found by web searches.

Astronomy

Fellowships: *Horne* has an RS Leverhulme Senior fellowship; *Dominik* an RSURF; *Vidotto* is an RAS Research fellow; *Cirasuolo* and *Gregory* are STFC fellows. *Bonnell* and *Dunlop* have ERC Advanced grants, *McLure* an ERC Consolidator grant, and *Helling*, *Heymans* and *Wild* hold ERC Starter grants. *Bonnell* (2008), Jardine (2012) and *Taylor* (2011) became FRSE during the period.

Prizes: There have been two RAS Wolfson Merit awards (*Dunlop*, *Liddle*) and four group achievement awards (*Cameron*, *Driver*, *Horne*, *Lawrence*). *Ferguson* is a Herschel distinguished visitor. *Heymans* (2010) was recognised as a European outstanding young astronomer.

Review panels: *Lawrence* is the chair of the STFC Astronomy grants panel (2010-2013), of which *Driver*, *Greaves* and *Taylor* have been members. *Ivison* is the UK member of ESO STC and was on the STFC panel for Ground-based facilities. *Greaves* is an RAS council member, as *Ivison* was previously. *Cameron* was a review board member for the ESA CHEOPS mission, and an advisor to Pic du Midi, France. *Vidotto* is on a NASA panel on Astronomy theory.

Policy advice: *Cameron* is an International Astronomical Union (IAU) C53 Council member, and a leader of their exoplanet activities, including nomenclature and discovery rights. *Ivison* is chair of the ALMA science advisory committee, and a member of the NRAO advisory panel. *Zhao* advised on LISA pathfinder. *Bonnell* and *Liddle* were members of STFC Education and Training panel.

Conference organisation: Cool Stars 15, St Andrews 2008 (*Cameron*/*Jardine*, co-Chairs); International Astronomy Conference, Doha 2013 (*Dominik* co-chair); The Origins of Galaxies, Austria 2009 (*Dunlop* Chair); Galaxy Evolution, Guilin China 2010 (*Dunlop* SC); The First Galaxies, Germany 2011 (*Khochfar* Chair); Dark Energy workshop, Porto 2008 (*Taylor* SC); Origins of the Expanding Universe, Lowell Observatory 2012 (*Peacock* SC); Calibration of Star Formation Rate Measurements, Beijing 2012 (*Wild* SC); The Gas, Stars and Black Hole Ecosystem, Leiden, 2012 (*Wild* co-chair); Dark Universe with Extragalactic Lensing, Paris 2009 & Edinburgh 2010 (*Heymans*/*Taylor* SC); Summer school on Dark Energy in the Universe, Japan 2010 (*Peacock* SC).

Journal editorships: MNRAS (*Cameron*, *Liddle* & *Taylor*); Astro.Comp. (*Lawrence*); Ast. & Comp. (*Mann*); Annals of Physics and Ast. & Astroparticle (*Peacock*); Open Astronomy (*Zhao*).

Key invited talks: Radio AGN Populations in the nearby Universe, Bonn 2013 (*Best*); Mind the Gap, Cambridge 2013 (*Bonnell*); Towards other Earths, Porto 2009 (*Cameron*); The Spectral Energy Distribution of Galaxies, Preston 2011 (*Driver*); Observational Studies of First Light and Reionization, Chicago 2013 (*Dunlop*); From Atoms to Pebbles, Grenoble 2012 (*Greaves*); The GAIA radiation damage challenge, Heidelberg 2009 (*Hambly*); Causes and Consequences of the Extended Solar Minimum, Florida 2013 (*Jardine*); Random Models of Inflation, CERN 2009 (*Liddle*); The Origin of Galaxies, Obergurgl 2009 (*McLure*); Galaxy Evolution over 5 Decades, Cambridge 2013 (*Peacock*); Lensing of Large Scale Structure, Sydney 2008 (*Taylor*); Modelling Planet-Forming Circumstellar Discs, Grenoble 2012 (*Woitke*).

Condensed Matter and Photonics

Fellowships: *Cates* holds a RS Research Professorship (renewed in 2012). *Samuel* and *Poon* (EPSRC senior fellows until 2011/12) both now hold ERC Advanced grants. *Gregoryanz* has an EPSRC Leadership award. *McMahon* has an AWE William Penny fellowship (2010-14) and a Humboldt award (2013). *Allen*, *Lovett*, *King*, and *Yelland* all have RSURFs. *Di Falco*, *Keeling*, and *Morozov* hold EPSRC Career Acceleration fellowships. *Sanloup* has an ERC Starting grant; *Degtyareva* a RS Dorothy Hodgkin award; *Thijssen* and *Waclaw* RSE BP/Enterprise fellowships; and *Martinez* a Marie Curie fellowship. *Clegg* held an RS Industry fellowship (2011/13).

Prizes: *Grigera* was awarded the 2012 EPS prize. *Cates* received the 2013 Weissenberg award (European Society of Rheology) and the IoP Dirac Medal (2009). *Mackenzie* won the IoP Mott Medal (2008), *McMahon* the 2010 Louis Delbaere Award (Canada) and *Samuel* the 2008 Sturgeon Prize (British LC Society). *Davis* was elected to the NAS, and won the 2009 Kamerlingh-Onnes Prize. *Dholakia*, *Mackenzie*, *Poon* and *Samuel* have RS Wolfson Merit awards. *Marenduzzo* won the 2010 IUPAP StatPhys Young Scientist prize, *King* the 2009 IoP Roy Prize, 2013 Gerhard Ertl Award and 2013 CR Burch Prize, *Hermann* the 2009 RSNZ Hatherton Award, and *Gather* the 2013 Rudolf-Kaiser-Preis. *Ackland* was a 2013 Lee Hsun Lecturer (Chinese Acad Sci) and *Evans* a Weston Visiting Professor at the Weizmann Institute.

Review panels: *Cates* serves on an ERC Advanced Grants panel and was on RSE and (as chair) RS Sectional committees. *Dholakia* chaired two EPSRC panels; *Cockell*, *Huxley*, *Lee*, *MacPhee*, *McMahon* and *Poon* served on EPSRC/BBSRC/NERC/STFC grants panels. *Allen*, *Lovett* and *MacPhee* served on RS grants panels, *Gregoryanz* on STFC's photon science panel and on a DFG review panel in Germany, *Poon* was on a grants panel for the Danish RC, *Samuel* for NSF and *Stock* for NSERC Canada. Facilities panel members have included *Baumberger* (CLS, Artemis), *Huxley* (ISIS, LLB), *Lee* (PSI, ISIS), *McMahon* (ALS, LCLS), and *Stock* (ISIS, Oak Ridge, NIST).

Policy advice: *Cates* serves on RS Council, and was on the REF expert advisory group and REF impact pilot study. *Dholakia* is on OSA's international council, and chaired its Fellows committee in

2012. *Mackenzie* was on EPSRC's Technical Opportunities Panel and now serves on its Strategic Advisory Network. *Cockell* is on NASA, ESA, and UK Space Agency panels. *Crain* was on a Blackett review panel for civil contingencies, and a CBI sub-committee on industry/academic ties. *Thijssen* served on RSE advisory groups on renewable energy and open data. *MacPhee* is a STEM and Women in Science ambassador. *Ackland* chaired an OECD/Nuclear Energy Authority Expert Group on structural materials. *Loa* serves on the IUCR High Pressure Commission.

Conference organisation: SMINS-3, Idaho 2013 (*Ackland*, IOC); StatPhys25, Seoul 2013 (*Cates*, IAC); European Astrobiology 2009-13 (*Cockell*, IOC); SPIE Optical Trapping V-X (*Dholakia*, Conf. Chair 2008-13); SPIE Photonics Europe, Strasbourg 2008 (*Di Falco*, PC); SPIE Photonics West, San Francisco 2013/14 (*Gather*, PC); IUPAP LT27, Buenos Aires 2014 (*Grigera*, Chair, Cryogenics PC); ICM 2012, Busan (*Huxley*, IPC); ICSCE6, Stanford 2012 (*Keeling*, IPC); SAS2009, Oxford (*Lee*, SOC); IUCrHP, Mito 2012 (*Loa*, IPC); GRC on High Pressure, Maine 2012 (*McMahon*, Chair); Flow Instabilities and Turbulence in Viscoelastic Fluids, Leiden 2010 (*Morozov*, SOC); EPS Liquids, Lisbon 2014 (*Poon* IAC, *Cates* IPC); ERPOS-12, Vilnius 2011 (*Samuel*, IPC); 22nd Goldschmidt Conf., Montreal 2012 (*Sanloup*, ISC), EOSAM 2012, Aberdeen (*Turnbull*, Organic Photonics PC).

Journal editorships: Phys.Rev.Lett. (*Blythe*); J.Rheology (*Cates*); Astrobiology (*Cockell*); J.Optics, J.Biophotonics, and Sci. Repts. (*Dholakia*); Phot. & Nanostruct. (*Di Falco*); J.Stat.Phys., J.Stat. Mech. and J.Phys.A (*Evans*); Super Hard Materials (*Gregoryanz*); Science (*Mackenzie*); J.Stat.Phys. (*Marenduzzo*); J.Stat.Mech (*Poon*), Synthetic Metals, J.Phot.Energy (*Samuel*).

Key invited talks: SMINS-2, Daejeon 2010 (*Ackland*); AERC 2013, Leuven (*Cates*); StatPhys 24, Cairns 2009 (*Cates*); NSTI Nanotech, Anaheim 2010 (*Clegg*); Extremophiles 2012, Seville (*Cockell*); M2S-IX, Tokyo 2009 (*Davis*); CYTO 2010, Seattle (*Dholakia*); SPIE Photonics Europe, Brussels 2010 (*Dholakia*); EPS Liquids, Vienna 2011 (*Henrich*, *Cates*, *Poon*); 100th Anniv. of Superconductivity, Leiden 2011 (*Huxley*); SCES 2010, Santa Fe (*Mackenzie*, *Davis*); ECM26, Darmstadt 2010 (*McMahon*); IBEREO 2013, Malaga (*Morozov*); Solvay Conference on Macromolecules, Les Houches 2013 (*Poon*), SPIE Optics and Photonics, San Diego 2011 (*Samuel*). We also gave 15 invited talks at Gordon Research Conferences during the period.

Particle and Nuclear Physics

Fellowships: *Buckley*, *Clark*, *Clarke* have been CERN associates. Personal fellowships include *Smillie* (RSURF); *Cowan*, *Needham* (STFC). *Clarke* (2011) and *Woods* (2008) became FRSE.

Prizes: *Boyle* received the Ken Wilson award (Lattice 2012), and a Gauss supercomputing award. *Murphy* won the Lord Kelvin award from the British Science Association in 2009. Honorary professorships are held by *Woods* in Germany and China, and *Zwicky* in Denmark. *Kenway* received an OBE (2008) for contributions to HPC. Emeritus Professor *Peter Higgs* won the 2013 Nobel Prize for Physics, and became a Companion of Honour in January 2013.

Review panels: *Murphy* is on the European strategy panel NUPECC, STFC Science Board and PPAN (2011-present), and took part in the 2011 programmatic review. *Del Debbio* is a member of PPGP. *Aliotta* and *Martin* have been PPRP members.

Policy advice: *Murphy* is chair of the IoP Astroparticle group. *Kenway* is programme chair of PRACE, advises RCUK on HPC, and is chair of the SUPA Board of Directors. *Clarke* chaired an STFC e-Science panel, and was on a panel enquiring into the “climategate” emails at East Anglia.

Conference organisation: Computing in High Energy Physics, 2008-2012 (*Clarke*, IAC); Lattice, 2010-2013 (*Del Debbio*, IAC); Baryons 2013, Glasgow (*Watts* IAC); Rutherford Centennial, Manchester, 2011 (*Watts*, SOC); Narrow Nucleons 2009 (*Watts*, Chair); SUSSP on LHC physics 2009 and 2012 (*Muheim*, Co-director

Journal editorships: J.Phys.G (*Woods*)

Key invited talks: Nuclear Physics, Zakopane 2012 (*Aliotta*); Lattice, Adelaide 2012 (*Boyle*); Hadron Collider Physics, Kyoto 2012 (*Clark*); Moriond Electroweak, 2012 (*Clarke*) & 2013 (*Martin*); Strongly Coupled Gauge Theories, Nagoya 2012 (*Del Debbio*); Supercomputing, Hamburg 2010 (*Kenway*); Europhysics HEP, Grenoble 2011 (*Leonidopoulos*); Flavour Physics and CP Violation, Turin 2012 (*Muheim*); Meson, Krakow 2012 (*Watts*); Nucl Phys in Astrophys, Eilat 2011 (*Woods*).