Institution: University of Leicester

Unit of Assessment: UoA9 Physics

1. Unit context and structure, research and impact strategy

Unit Context and Structure

As this highly successful REF period closes, the Leicester UoA looks forward to a step change in breadth of work and funded activities with the development of Space Park Leicester (SPL). This development, and the major investment it entails, is testimony to the high level of confidence that the University has in the UoA as an international leader in Astrophysics, Planetary Science and Space Systems and Instrumentation. In the REF2021 period, we have made truly ground-breaking discoveries, delivered instruments for launch, secured involvement in future space missions and ground-based facilities, attracted high-quality staff, grown our technical teams, supported Early Career Researchers (ECR) to gain prestigious Fellowships, increased our grant and contract funding, achieved major successes in the impact programme, and provided national and international organisational leadership. We start with a selection of highlights demonstrating this breadth of the UoA's research and impact successes:

H.1. Major discoveries, through follow-up studies, of the first detection of the electromagnetic counterpart of a gravitational wave source and the subsequent birth of the new research field of Multi-Messenger Astronomy (**Tanvir**, et al., incl **O'Brien** and **Osborne**, 2017, *Ap. J. Letts.*, doi: 10.3847/2041-8213/aa90b6; Abbott et al., incl **Tanvir, O'Brien** and **Osborne**, 2017, *Nature*, doi: 10.1038/nature24471).

H.2. The discovery of seven temperate terrestrial planets around the nearby TRAPPIST-1 (Gillon et al., incl **Burleigh**, 2017, *Nature*, doi: 10.1038/nature21360).

H.3. The discovery of a new current system flowing between the inner edge of Saturn's ring system with the planet's ionosphere from the Cassini Grand Finale as the spacecraft reached hitherto unexplored depths in the planet's atmosphere (Dougherty et al, incl **Bunce**, 2018, *Science*, doi: 10.1126/science.aat5434).

H.4. The first results at Jupiter by NASA's Juno mission, on which we have the only UK Co-Investigators studying the magnetospheric environment closer to the planet than before and Jupiter's atmospheric circulation deep below the clouds (Connerney et al., incl **Cowley**, 2017, *Science*, doi: 10.1126/science.aam5928; **Fletcher** et al., 2020, doi: 10.1029/2020JE006399).

H.5. The only European Participating Scientist on Mars Science Laboratory (MSL) leading to the identification of samples of Martian crust that are more evolved than the previously known primitive basaltic crust on Mars (e.g. Sautter et al., incl **Bridges**, 2015, doi: 10.1038/NGEO2474).

H.6. The continuing evolution of the DiRAC HPC facility enables state-of-the-art hydrodynamic and radiative transfer simulations e.g. the dynamics and observable appearance of warped protoplanetary discs (Nealon [including **Alexander** and **Nixon**] et al., 2018, doi: 10.1093/mnras/sty2267).

H.7. The delivery of the Leicester-led (**Bunce**) Mercury Imaging X-Ray Spectrometer (MIXS) for BepiColombo, now launched and *en route* to Mercury to map the planet's atomic composition, elucidate the physical processes of its interior and its formation and evolution, and explore the interaction of the planetary surface with the surrounding space environment.

H.8. The delivery of the key Leicester contribution for the Raman Laser Spectrometer (RLS) for ExoMars, which will obtain precise information on the geochemistry and mineral phases present in samples extracted from the Martian sub-surface to identify any organic biomaterials preserved in the planetary geological record (Rull et al., incl **Hutchinson**, 2016, doi: 10.1089/ast.2016.1567).

H.9. The selection of the Leicester-led CHEC camera (**Lapington**) for the Small-Sized Telescope on the Cherenkov Telescope Array (CTA), the next generation ground-based very high-energy gamma-ray astronomy observatory, that will transform our understanding of the high-energy universe and explore physics questions of fundamental importance.

H10. A University, Government and industrial investment totalling over £100M to date in SPL. The investment will make the UK space sector more competitive, enable our research programme to contribute to the growth of local, national and international economies, advance the UK's internationalisation strategy for space, and have major societal impact.

H11. Continued success for our ECRs in gaining prestigious and highly competitive Fellowships from ERC, STFC, Leverhulme, Royal Society, and the RAS, plus the award of prestigious prizes to staff at all levels of seniority.

Our extremely successful research philosophy, which ensures sustained involvement in every step of a project's lifecycle (from concept definition, through launch, culminating in exploitation of science data), places us at the international forefront of Astrophysics, Planetary Science and Space Systems and Instrumentation. We are, therefore, regularly invited to join major new collaborative projects (e.g. Space based astronomical Variable Object Monitor (SVOM), Einstein Probe). This approach naturally supports our researchers being involved in cross-disciplinary research, leads to Impact, and in particular enables our ECRs to win competitive Fellowships.

The UoA is based solely within the School of Physics and Astronomy (SPA), one of 6 Schools within the College of Science and Engineering. SPA has 4 Research Groups: (i) **Astrophysics** (**AP**); (ii) **Planetary Science** (**PS**); (iii) **Space Research Centre** (**SRC**); and (iv) Earth Observation Science (EO). As EO focusses on Earth Environmental Science, a strategic decision was taken to submit EO researchers to UoA7. Staff frequently interact across disciplinary boundaries, stimulating interdisciplinary research and facilitating impactful collaborations with industrial partners.

Research and Impact Strategy

The particular nature of our research involves planning for space missions, large-scale ground-based projects, and national and international facilities, all of which have long lifetimes from inception to delivery, operations and science exploitation. Our research and impact strategy, therefore, must consider requirements over a longer time-scale than any individual REF period. Our previous strategy was:

(**R2014.1**) To continue a world leading research programme (see H1 – H6).

(**R2014.2**) To maintain a diverse and active research staff (see H11 and Section 2).

(**R2014.3)** To contribute and maintain access to major new research infrastructure (see H6 – H9).

(**I2014.1**) To develop staff's skills and experiences to generate impact (see H10).

(**I2014.2**) To foster links with existing industrial partners and develop new links (see H10).

(**I2014.3**) To be central to College and University initiatives (see H10).

(**I2014.4**) To develop our successful Outreach programme (see H10).

Following REF2014, the UoA made a conscious decision to refocus our research and impact strategy (RIS), to develop and invest in areas of strength, develop emergent research areas, maintain our collaborative and interdisciplinary approaches, and generate value from the strategic, programmatic and research elements of the SPL. A consequence has been a recent harmonisation of our research group structure. This strategy contains 4 components, all of which formed elements of our previous strategy:

RIS1 To continue a programme of world-leading research producing discovery science results. Usage of world-leading space missions, development of transformational new technologies, ground-based facilities and HPC help ensure our staff can produce ground-breaking discoveries over the next decade.

RIS2 To work alongside industry to identify areas of basic and applied research in which cooperative collaborations can be nurtured. SPL is an invaluable asset in attracting new industrial partners (from multi-nationals to regional SMEs) to work in partnership with the UoA. SPL will strengthen existing relationships between academic and industrial sectors, particularly the space sector, and with the public.

RIS3 To maintain access to, and lead the development of, major new research infrastructure. Our involvement in many space missions is guaranteed through instrument development and technology programmes (e.g. Space Nuclear Power), while we respond to all calls for proposals for new missions both in Europe and the USA. We are a valued collaborator with many international groups.

RIS4 To invest in our staff and their careers, ensuring we maintain the quality and breadth of our research and impact. We have an excellent team and policies that deliver staff satisfaction across all job roles and families.

Refocusing and revitalising our research in this way has allowed our unit to adapt to changing research and impact priorities and capitalise on the opportunities provided by the major new investment in SPL.

Astrophysics (AP)
(**Alexander, Ambrosi, Barstow, Blain, Burleigh, Casewell, Goad, Hall, Hutchinson, King, Lapington, Nayakshin, Nixon, O'Brien, Osborne, Pounds, Sembay, Starling, Tanvir, Watson, Wilkinson, Willingale, Wynn, Vaughan**)

Our astrophysics research extends from stellar and planetary formation to the origins of first light objects in the universe. We study the formation of exoplanets, testing theory using detections from the Next-Generation Transit Survey (NGTS) facility; the formation and properties of compact objects ranging from stellar mass to super-massive black holes. Staff lead major research teams in the new field of multi-messenger astrophysics. Highlights, based on data from Swift and Visual and Infrared Survey Telescope for Astronomy (VISTA), include the discovery of the first ultraviolet and infrared source associated with a gravitational wave detection of a neutron-star binary merger, and characterisation of a blazar associated with the first neutrino detection outside the local group. We contribute to the Gaia data processing and production of the Gaia DR2 and eDR3 catalogues, which are revolutionising astronomy. We lead the production of data products for Swift. The knowledge gained from production of the microchannel plate optics for the MIXS instrument on BepiColombo has led to a French Space Agency (CNES) contract to build X-ray optics for the France-China SVOM mission and to test X-ray optics and detectors for the Chinese Einstein Probe mission. These three missions will dominate space-based transient science for the next decade. Such optics are also used in the Leicester led Soft X-ray Imager (SXI) instrument being developed for the Solar Wind Magnetosphere Ionosphere Link Explorer (SMILE) mission (see later). We are partners in the Gravitational wave Optical Transient Observer (GOTO) ground-based wide-field optical facility for following up gravitational-wave sources, which is a Large Synoptic Survey Telescope (LSST) pathfinder. Staff lead the development of data centre activities for the ESA Athena Wide Field Imager instrument, the development of a wide-field Soft X-ray Imager for the THESEUS mission, under Phase A study by ESA, and the UK provision of cameras for CTA. Our theoretical astrophysics programme complements this work strongly, particularly in the areas of accretion theory and feedback; compact objects; galactic dynamics and dark matter; and protoplanetary discs and planet formation. This strong linkage between theory and observation is demonstrated by our work on Active Galactic Nuclei outflows. Our theoretical work involves large numerical simulations and, as a result of this expertise in computational astrophysics, Leicester is one of four host institutions for the DiRAC HPC facility.

Planetary Science
(**Ambrosi, Bridges, Bunce, Cowley, Elsden, Fletcher, Hutchinson, Imber, Lester, Milan, Nichols, Sembay, Sims, Stallard,** Wright**, Yeoman**)

Our Planetary Science research investigates all the planets in our Solar System as well as minor bodies and dust with space missions, ground-based telescopes, laboratory investigations, and numerical simulations. We have world-leading research programmes in the analysis of *in situ* and remote sensing observations of planetary magnetospheres, ionospheres and atmospheres of the planets. Our magnetospheric, ionospheric and atmospheric research has produced significant discoveries at all solar system planets, as have our investigations of planetary surfaces, and laboratory-based analyses of extra-terrestrial material from the solar system. Staff have the PI role leading major instrument development for new space missions, e.g. MIXS, RLS and SXI on SMILE, a joint ESA-Chinese mission to study the terrestrial magnetosphere and ionosphere. We will deploy new radars in Finland and Cyprus, based on a novel design. Scientific highlights include research into the Saturnian and Jovian atmospheres, ionospheres and magnetospheres with the Cassini and Juno missions and world-leading investigations from ground- and space-based observatories (including Hubble and Spitzer). New results at Mars involving Mars Science Laboratory in Gale Crater and Mars Express have provided detailed knowledge of the surface and atmospheric variability, as well as the unique interaction of a comet with a planetary atmosphere. We have a major leadership role in the giant planet

programme of the James Webb Space Telescope (JWST), and guest investigator status on the BepiColombo mission cruise phase investigations. Looking forward, we are co-investigators on instruments for the JUICE mission, and have a major ESA Interdisciplinary Scientist role. We make leading contributions in proposals for new ESA and NASA missions, and are currently laboratory testing detectors for a proposed mission to Europa, funded by NASA.

Space Research Centre (SRC)
(**Ambrosi**, Bannister, **Barstow, Bridges, Hansford, Hutchinson, Lapington, Sembay, Sims, Williams, Willingale**)

SRC provides an essential role within the UoA, leading experimental aspects of each of the research themes, leading the development of new instrumentation for space missions and ground-based facilities, and pioneering new technologies and payloads for space science and exploration, e.g. novel space nuclear power technology. **SRC** also plays a key role in the UoA in the development of these technologies for non-space usage, leading to cross-disciplinary research and driving our strategy for the delivery of Impact.

This Research Group structure allows staff to be members of more than one research group, facilitating cross-fertilisation of ideas and techniques, while cross-collaboration is encouraged at the boundaries of interest. The successful science case for the SXI instrument is an excellent recent example. This unique instrument will measure the X-ray flux from solar wind charge exchange with Earth's exosphere, to image directly the solar wind-magnetosphere interaction for the first time, and takes heritage from detectors originally proposed for X-Ray Astronomy missions (**AP** and **SRC**), and subsequently implemented in BepiColombo MIXS. The science, however, is very much planetary (**PS**). Other examples include: (i) atmospheric research at Earth and other planets, e.g. Saturn and Mars, as well as the coupling between the neutral and ionised layers of the atmosphere (**EO** and **PS**); (ii) exoplanets (**AP**) and how they relate to the Solar System (**PS**), e.g. in developing models of the predicted exoplanet radio signatures based on research from Jupiter; and (iii) the common use of spectroscopy by all research groups (**AP**, **EO**, **PS** and **SRC**).

Research Governance and Integrity
A recent re-structuring of the management of the School through the development of the School Management Group (SMG) includes the Director of Research and Enterprise who is the Chair of the School's Research and Enterprise Committee (REC). This Committee discusses Research Grant income, development of new experimental techniques, Fellowships, local infrastructure requirements, enterprise activities. The Committee is also responsible for promoting a culture of research integrity, ensuring that all researchers understand the expected standards and obligations, as outlined in the Concordat to Support Research Integrity. Members of the School also play full roles in University-wide Funder Groups that support research activity related to each of the funding organisations. The School's discussions feed into the wider College and University Research and Enterprise activities as the Chair is a member of the College's Research and Enterprise Committee, which encourages cross-disciplinary activities within the College. The REC reports to the School through the SMG and quarterly All-School workshops, allowing direct interaction with the ECR Forum and PGR students.

Open Research
Embedding a culture of open research is a strategic priority as we seek to increase global engagement with our research. We do this by: (i) ensuring our publications comply with REF and funder open access requirements and institutional policy (Institutional Environment Statement,

section 2.6); (ii) utilising open scholarly infrastructures to disseminate outputs and data, including the Leicester Research Archive and paper depositories such as arXiv, used extensively by members of **AP**; and (iii) incorporating open research outputs/data in funding applications, as well as making available through local research data depository. During the assessment period, 85% of our outputs were published open access, compared to the Russell Group average of 63% (SciVal). We have also made codes, preprints, conference papers, and reports openly accessible.

Realising Impact

To realise enterprising impact, our strategy aligns our research with major global and industrial challenges, thereby identifying opportunities to play positive roles in economic development regionally, nationally and internationally. We deploy our research to develop skills and capability within a broad spectrum of public and private sector industry, e.g. through training for MOD personnel, apprenticeship schemes through National Space Centre (NSC) Discovery. Our staff are regularly asked to provide expert advice and guidance to industry and policy makers, e.g. through contributions to Government policy on space nuclear power. It is also essential to ensure our valued intellectual property is transferred effectively, e.g. through spin out companies, patents etc. We seek to contribute to the wider cultural benefit of society through an enterprising engagement and outreach programme.

We have had a number of impact successes, some of which are included in our submitted Impact Case Studies. These cover Space Nuclear Power, in the UK and internationally (**Ambrosi**, ICS1), Global Food Security (**Ghent** ICS2), and a new SME, Earthsense, providing urban pollution monitors (**Leigh**, ICS3). There are a number of other activities leading to major impact. A prime example is the outreach activities by **Imber**, following her winning success on the BBC TV show, 'Astronauts: Do you have what it takes?', including over 80 invitational public lectures in the UK, Hong Kong, the US and Europe, and Podcast features with tens of thousands of hits. Notably we led an exhibit on BepiColombo at the Royal Society summer exhibition in 2019, which had more than ten thousand visitors.

Through DiRAC, we have a leading role in the Catalyst UK programme launched by HPE, which placed Arm-based HPC clusters at three leading UK universities (Leicester, Bristol, Edinburgh) to explore their viability for future supercomputing systems. The outputs of this initiative will have significant impact beyond the University, as they will inform future Arm hardware developments and provide a national/international prototype of production-level HPC services based on the Arm architecture.

A Wellcome Trust ISSF Fellow (**Williams**) is manufacturing a graphene-based conductive elastic composite 'prosthetic skin' able to sense motion, pressure and temperature stimulation and return signals to the brain. We continue developing medical applications of space mission sensors, notably a hand-held gamma-ray camera, and diagnostic units for emergency care. We have been testing the potential application for gamma-ray camera technology support nuclear decommissioning at Sellafield.

We have utilised funds provided by STFC through an Impact Accelerator account (IAA). This funding has allowed the proof of concept for over 30 projects in the last 7 years, some of which have led to patents. Critically, this has also enabled us to engage with a variety of partners in the UK and Europe in health diagnostics. We lead the £4.8M SPRINT SME support programme funded by Research England.

Future Plans

We look forward to an exciting new REF period as data will be available from upcoming space missions, ground-based facilities and HPC facilities, in which we play leading roles. Space missions include ExoMars, JWST, SVOM, SMILE, TRACERS, BepiColombo, PLATO, and JUICE cruise phase, and we shall continue to play leading roles in existing missions for which we have provided hardware, e.g. Swift. CTA will start observations of the high energy gamma-ray universe (first light scheduled for 2022), NGTS will continue to discover planets for further follow-up by our scientists, the first European mid-latitude SuperDARN will come online, and we will exploit the new EISCAT-3D radar in Scandinavia. We anticipate that HPC facilities will continue to be developed through enhancements to DiRAC. In addition, the next REF period will see the growing involvement of Leicester in future missions through the ESA Voyage 2050 programme, the ESA Lunar exploration programme and Mars Sample Return.

The University has invested heavily in the last 6 years in the provision of major new infrastructure enhancing our future research and impact outcomes. The main investment, Space Park Leicester (discussed more fully in Section 3; see also IES, 2.4, 4.4), consists of three separate phases of development. Phase 1, opening in April 2021, will engage with local and national SMEs whose interests are in developing novel usage of EO data. Phase 2, opening in late 2021, will provide laboratory infrastructure, including clean rooms, mechanical and electrical workshops and test facilities. In Phase 3, we plan a new complex for the Low Cost Access to Space (LOCAS) programme to be supported by significant industrial stakeholder development, including from major space industries. This will provide a key spacecraft and subsystem manufacturing capability in the UK.

2. People

Ensuring we have a pool of talented research staff

Our staff has evolved since the last REF submission, partly through the usual changes due to retirement and movement of staff, and partly resulting from the re-focussing of our research strategy. We have made excellent new appointments to the academic staff (**Fletcher, Nixon**) and there has been an increase in the number of Research only staff across all research groups. This growth has been partly a result of the award of ERC grants to **Alexander** and **Fletcher**, and the success of a number of staff in winning prestigious Fellowships (Table 1).

Awardee	Fellowship	Year
Casewell	STFC Ernest Rutherford Fellowship	2019-2023
Elsden	Leverhulme Trust Early Career Fellow	2019-2022
Fletcher	Royal Society University Research Fellow	2015-2020
Hall	RAS Winton Capital Fellowship	2017-2020
Hansford	Royal Society Industrial Fellow	2018-2022
Nixon	STFC Ernest Rutherford Fellowship	2016-2021
Rossotti	STFC Ernest Rutherford Fellowship	2020-2025
Williams	Wellcome Trust ISSF Fellowship	2020
PDRA Carter	L'Oreal UNESCO FWIS Physical Sciences Fellowship	2020

Table 1. List of current staff supported by Research Fellowships.

Critically we have grown our talented project and engineering research staff who underpin our instrumentation, technology and operations work. The nature of our research programme means we have a high proportion, 59%, of research-only staff funded through short-term research grants, albeit often through long-term project grants. Staff on short-term contracts are automatically placed on open-ended contracts after 4 years.

Our staffing strategy is centred simply on ensuring that we appoint the best staff for the roles, including those who are Research and Teaching staff, Research only staff at all grades and job families, e.g. PDRA, Engineers, Technical, Workshop and Administrative staff. Appointments at all levels link directly to our RIS priorities.

A key element of our strategy is to enable all our staff to develop their careers. A notable success has been in the support given to our ECRs to be successful in winning Fellowships. In 2014–2020 4 applicants won STFC Ernest Rutherford Fellowships, a success rate over double that of the national average. We are very proud of our achievement in the training provision for our ECRs, a further 7 have moved with Fellowships or permanent positions at Universities around the UK and Internationally. A list of staff who have held Fellowships is available to our ECRs enabling them to seek additional support from successful applicants, both locally and elsewhere. This activity is supported by centrally-provided careers sessions and support, as well as the Doctoral College, which has central responsibility for ECRs.

Each new member of staff serves a probationary period at the start of their term, in which they undertake a series of induction sessions. All researchers work within a research group thereby benefiting from the support of their peers within that environment. A high proportion of our academic and research staff choose to stay in the UoA long-term. We have a long history of successfully bridging staff between project grants, and PhD students between write-up and first PDRA position. This is increasingly difficult as grants are eroded, but remains a School ideal. Leavers' data largely reflects contract end or retirement as the reason for departure, while the fraction of female leavers is proportionate to the fraction of females in the PDRA population.

Advice through mentoring is available to all staff to aid career development at any stage. Mentors can be sought from other Schools and the Doctoral College provides skills training and career events for ECRs, including PGR students, PDRAs and academics. Participation is required for academic staff on probation. For PDRAs an informal, department-initiated scheme was established and announced at the Research Staff Forum in 2015. An initial review using informal feedback from mentors and mentees found all pairs met at least once during the first 6 months (2017) and that meetings were valuable and would continue. At present (2020) there are 10 mentoring pairs, and, in a local poll, 43% of staff reported involvement in a mentoring scheme.

Workload modelling is undertaken for all staff on Research and Teaching contracts and Teaching Dominant contracts, while Research staff typically spend 100% of their time on research or project work. Indeed, Physics has a long-standing workload model, which the University has utilised to develop a consistent University-wide model. The model is transparent and consulted upon on a yearly basis. All Research Staff are encouraged to participate in external 'esteem indicator' activities and this is viewed as a natural part of the line manager/supervisor, personal development and mentoring conversations. In a 2017 poll of all staff, 62% reported participation in such activities. They are valued within the promotion and merit processes as both citizenship and leadership & development, and we are encouraged that,

as a result of representation among researchers, 27% of respondents participating in external activities were female, above the female fraction (8%) of academic staff.

Uptake and perceived value of annual Personal Development Discussions (PDDs) has shown a dramatic shift over the past ~5 years, going from below 50% to 88% in the last complete round (14% above the University average). This demonstrates the real culture change our UoA is experiencing, where people are keen to discuss their career trajectories.

Linked to the PDDs, greater opportunities for personal and professional growth, and a culture change towards encouragement and nomination rather than self-initiation, we have had a successful period of promotions with 10 staff being promoted to Associate Professor and 7 to Professor. Typically HoS and mentors discuss individual promotion cases prior to submission, and crucially offer advice to all unsuccessful applicants. The citizenship category included in the promotion criteria and in our workload model is taken seriously by School staff, recognition for citizenship activities is clear, and we believe this emphasis boosts the sense of community felt by our staff and students.

Research Students

Our talented research staff includes our postgraduate student cohort. In this REF period the number of PGR students who have successfully completed their Ph.D. is 90, of which 27% identify as female. We continue to work to increase out studentships pa through involvement in doctoral training programmes, College funded Studentships, and responding to new initiatives and calls on Doctoral Programmes. We aim to continue to grow our research student cohort to above the sector average and anticipate that investment in SPL will enable us to attract more CASE awards and industrial sponsorship for studentships.

Our UoA is highly successful in our PGR training. In the 2019 Postgraduate Research Experience Survey (PRES), it ranked in the top quartile for five out of eight of the questionnaire sub-sections, and in the top three of three sub-sections. The programme of training is focused on an adaptive training environment where students are taught to identify and plan to address their own development needs. Ensuring students reflect on ongoing training is a key component to this process, with meetings with a panel that guides this self-reflection three months into the PhD, and annually towards the end of each year.

The UoA's PGR programme has been repeatedly highlighted as 'a model of good practice across the College' by University senior staff. We take direct feedback from our students at both PGR forum meetings and through three SMG student representatives, covering Research, Equality and Diversity, and Wellbeing and Mental Health. This interaction was highlighted nationally as good practice in the STFC accreditation process and our PGR programme was highlighted in invited talks for the IOP Higher Education Groups PhD supervisor network meeting.

We provide a range of PGR training, based around skills and academic targets. Our students have access to a wide range of skills training within the School and at College and University level. Training is often directly related to the research field, e.g. 6 STFC supported PhD students have received training in ground-based observation techniques as a result of our involvement in NGTS, while in other related areas all students are supported to attend training on telescopes. Our academic training is given within the School, and also shared across DTPs and within the East-Midlands MPAGS training scheme. The award-winning University Careers Service is open to our PhD Students.

Equality, Diversity and Inclusivity (EDI)

The UoA has a dedicated committee overseeing our EDI action plan. EDI is embedded across all management committees, with EDI as a standing agenda item. The co-Chairs of the EDI committee sit on the SMG and the newly-formed staffing committee, where promotion cases will be discussed and staff supported. The Committee promotes equality and diversity in the workplace, continually assesses and improves working practices, and provides a culture of participation and inclusivity. The EDI Committee, comprising 12 members representing a wide range of job families and career stages, is led by two co-chairs, one a research-only staff member and one an academic staff member. The Postgraduate and Research Staff Fora are represented as is the Leicester Women in Physics network and University Women's Staff Forum and we have sought external advisors from other Schools and Universities. We strive for appropriate representation on our School committees, which is updated yearly, and seek inputs from across the School at all career levels for committee membership, where appropriate.

The University's success with Athena SWAN (Silver 2018), UN HeForShe and pledges via other initiatives such as TimetoChange, Stonewall (top 50 employers) and University of Sanctuary (2018+) provide a strong backdrop to ensure that EDI issues remain at the fore for everyone. The UoA is proud to hold current Athena SWAN Bronze and IOP Juno Practitioner awards after successful renewals in 2018. Following very positive feedback from our last application, we will apply for Juno Champion status in 2021/22. The importance with which we take inclusivity is demonstrated by our active celebrations of LGBT+ history month, Black history month, international women's day and the international day of persons with disabilities.

Our EDI actions are driven by an evidence-based approach. Staffing data by gender are collected annually, including statistics on population, recruitment and leavers, promotion, appraisal, training, parental leave and flexible working. We carry out a survey open to staff and PhD students at least biennially, to take the pulse of the School in areas like culture and job satisfaction. Analysis of trends and comparison with benchmarking data (IOP and HESA) is undertaken by the Equality and Diversity Committee and reported to all staff.

Consultation forms an integral part of the UoA strategy for change, and we analyse data from our own surveys (63-67% return rates in 2016-17) as well as break-downs from PRES, LGBT+ Climate Survey, Gender Gap in Science Survey, Royal Society Diversity Report, among others. Focus groups are held sporadically, when views on one topic are sought from a specific set of people, for example maternity provision.

We had an exemplary 94% completion of our Equality and Diversity Training in Physics & Astronomy Dept. (May 2017), compared to an 80% university average. This training encompasses all protected characteristics, with gender awareness comprising the first section. Members of our UoA played a key role in developing the training package, volunteering to take part in the trial version and feedback.

In the interests of inclusion, activities are kept as far as possible to core hours, 10am-4pm, indicated in the Induction Staff Handbook. Research meetings and committees are often flexible by nature and typically arranged by poll. We promote inclusivity through better communication, shared common spaces, and regular open all-school meetings. Formal flexible work arrangements are accessible for academics and the teaching timetable is then fitted around them. Staff in all roles, including PGR students, can request part-time or flexible working arrangements, as stated in the Staff Handbook. These are usually agreed formally so that duties

including teaching can be organised as necessary. Currently, several staff have formal flexible working arrangements, including those in leadership roles.

3. Income, infrastructure and facilities

The research income for this UoA is strong (see data metrics). In summary, the total research income for this UoA is currently £46.0M, an annual average over the REF period of £6.6M. Figure 1 gives the total income for each of the last 7 years and demonstrates a growth of 68% from 2015/16 to 2019/20. Income in 2019/20 is equivalent to £253k per FTE based on the FTE in the submission.

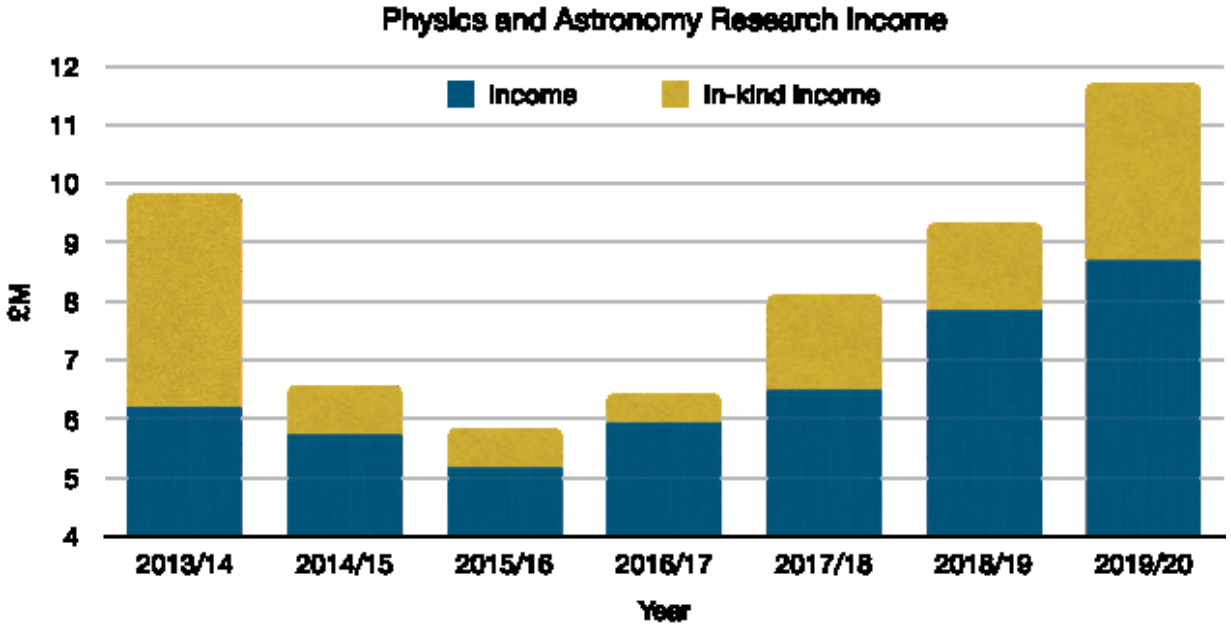

Figure 1. Annual Research Income (Blue) plus In-Kind Income (Yellow).

We are major users of research facilities such as the major telescopes, space missions, the Diamond facility and atmospheric radars. The in-kind income from UK supported facilities totals nearly £11.7M in the REF period, an average to date over 7 years of nearly £1.7M pa. We also use non-UK supported facilities (Figure 1) and have been successful in winning time on facilities such as SAAO (nearly 500 nights), Subaru (10 nights), Gemini (6 hours), IRTF (36 hours), VLA (10 nights), and the Low Frequency Array radio telescope (20 hours)

The University has provided a generous return of overhead on research awards to Colleges, Schools and Research Groups. This resource is an invaluable contribution to our work, enabling us to pump prime a range of activities, including future mission development that is critical to the long-term strategy of the UoA, support for our Impact programme, bridging of key staff between research grants, additional travel support, and support for publication charges.

Local Infrastructure and Facilities

Local infrastructure and facilities are a key part of our success. The SRC has 3 clean rooms: a planetary laboratory (15 m^2), a large clean room (70 m^2) and a smaller clean room (20 m^2). The main Physics building has a clean assembly room (25 m^2) associated with a recently-upgraded

beam line facility (energy range 0.1 keV to 60 keV) supporting a range of missions, including BepiColombo, SVOM, SMILE and THESEUS. There is an upgraded Spectroscopy Laboratory for work on detector development, while 2 newly-furbished electronics laboratories are in heavy use in support of SMILE and Athena, in particular. The UoA has a mechanical workshop providing support for all research areas in the construction of laboratory, radar and space mission hardware.

The locally-hosted National STFC DiRAC High Performance Computing (HPC) Facility is the main national provider of HPC resources for the STFC theory communities in astrophysics, particle physics, cosmology and nuclear physics (IES, 4.3). It provides essential support for the delivery of the STFC theory research programme, via services at four host universities (Cambridge, Durham, Edinburgh, and Leicester). A founder member of DiRAC in 2009, UoL has co-hosted the Data Intensive Service since 2011 with the University of Cambridge. The presence of DiRAC has cemented the reputation of UoL as a provider of national HPC services, building on two decades of experience which started with the UK Astrophysical Fluids Facility in the early 2000s. Since July 2017, **Wilkinson** has been Director of the DiRAC Facility and he is responsible for delivering and implementing the strategic plan of the DiRAC facility and securing funding for the enhanced DiRAC infrastructure required to deliver the DiRAC science programme. A DiRAC-brokered partnership with Hewlett Packard Enterprise (HPE) led to matched funding commitment of £2.3M for the UoL UKRPIF bid 'METEOR' to support Phase 2 of the SPL development. This commitment includes potential opportunities for early access to next generation computing hardware and to help optimise and future-proof software pipelines in all research fields.

Our research into the nature and origin of samples from space missions such as Hayabusa 2 (**Bridges**) benefits from the College-wide Advanced Microscopy Facility (IES, 4.2). The centre includes micro-Raman, a scanning tunnelling microscope (STM), a scanning probe microscope (SPM), two field emission gun scanning electron microscopes (SEM), a Focussed Ion Beam SEM and a Transmission Electron Microscope (TEM). This facility has benefited from significant investment (>£1M) through the University's Research and Enterprise Infrastructure Fund.

Research in the UoA is supported by an award-winning central Library, as well as excellent IT services. In addition we are supported by active, engaged and interested staff from the Research and Enterprise Division (RED). RED provides support for all Funder Groups, Research Committees, and to all researchers from planning and writing proposals, through to the submission process. Our Finance Office is also actively engaged throughout the process.

National and International Infrastructure and Facilities

Our access to world-leading facilities and missions, funded by external research grants, leads to ground-breaking new research exemplified by 4* research outputs. This access is guaranteed through our involvement in instrument building for space missions and new ground-based facilities, as well as invitations to lead on science activities. The former include the leadership of instruments or manufacture of parts of instruments on the currently operating Swift (UoL Lead **Osborne**), XMM (UoL Lead **Sembay**), BepiColombo (MIXS PI **Bunce** and SIXS Co-I **Bunce**) missions, while ExoMars (RLS UK Lead **Hutchinson**) is scheduled for launch in 2022. The current REF period has also seen the award of the PI role (**Sembay**) for SXI on the joint ESA/CAS mission, SMILE, (due for launch in 2024). We have several key Co-I roles on the ESA L1 mission Jupiter Icy Moons Explorer (JUICE) due for launch in 2024, including deputy PI (**Bunce**) for the magnetometer, an Interdisciplinary Scientist and Co-I on MAJIS (**Fletcher**), and Co-I on UVS instruments (**Bunce**, **Fletcher**). We are Co-I (**Osborne, Watson**) on one of the

main instruments on the ESA L2 mission, Athena, due for launch in 2031, and the only UK Co-I (**Sembay**) on the Lunar Environment X-Ray Imager (LEXI) which will be deployed on the lunar surface in 2023. The Gaia Data Analysis & Processing Consortium (UoL Lead **Barstow**) has delivered the transformational Gaia DR2 and eDR3 catalogues. Key Leicester contributions are modelling the instrument PSF and understanding the cumulative effects of radiation damage, which underpin the photometric and astrometric precision of the data.

Our excellence in space instrumentation is confirmed by the number of invitations to be involved in bi- or multi-lateral missions since 2014, including our work on SVOM (UoL Lead **Osborne,** Co-Is **O'Brien, Willingale**). We are providing the full characterisation and testing of the WXT instrument flight optics and CMOS detectors (funded by ESA) for the Einstein Probe, a joint ESA/Chinese Academy of Sciences mission due for launch in 2022 (UoL Leads **O'Brien, Hutchinson**). We are collaborating with partners at JPL and Washington University as part of a two-year technology development effort under the ICEE-2 program, focussing on the design, build and qualification of the instrument data processor and camera system for the Compact Integrated Raman Spectrometer (CIRS) for the ICEE2 Europa Lander Mission (**Hutchinson**).

In the last 6 years we have continued as UK lead for the operations of the X-Ray Instrument on the Swift satellite (**Osborne, O'Brien, Willingale**), which requires rapid follow-up following the detection of gamma ray bursts. Leicester's role has been, and continues to be, central to the success of this NASA mission, which has contributed to the follow-up observations on the detection of gravitational waves. We have major scientific involvement in a number of other current space missions, Gaia (**Barstow, Wilkinson**), Juno (**Cowley, Bunce, Nichols, Fletcher**), Mars Express (**Lester**), Mars Reconnaissance Orbiter (**Bridges**), ExoMars Trace Gas Orbiter (**Bridges**), Mars Science Laboratory (**Bridges**) and as a Guest Investigator for the cruise phase of BepiColombo (PDRA Sanchez-Cano).

Looking ahead, we have additional leadership roles on JWST, through the leadership of the Guaranteed-Time Observation Programme (GTO) for the giant planets (**Fletcher**), and Co-Is on the early-release programme for Jupiter (**Fletcher, Stallard**), and GTO time through our role as Co-I on MIRI (Pye). Membership of the early-release teams (**Casewell**) and key science contributions to ESA's M3 Exoplanet mission, PLATO (**Alexander, Burleigh, Casewell**) will provide direct links to the data from that mission. We have a leadership roles in ESA's Ariel, in leading the brown dwarf working group (**Casewell**), while we will have a key role in provision of ground-based radar support for the NASA TRACERS mission to investigate Earth's magnetospheric cusps (**Yeoman**).

Ground-based facilities are an integral part of our work. Examples of our leadership include the leading UK role on the CTA, the next generation very-high energy gamma-ray observatory developed by an international consortium of 31 countries. Leicester (UoL Lead **Lapington**) heads the consortium of UK universities (Leicester, Durham, Liverpool, Oxford, Armagh Observatory), pivotal in the development of the CHEC camera for the Small-Sized Telescope (SST), an array of 70 four-metre telescopes to be located at CTA's southern hemisphere Paranal site at 2500 m altitude in the Chilean Andes. The CHEC camera was selected competitively in 2019. The SST will begin its production phase in 2021 with telescope array deployment completed in 2025. **Lapington** also contributes directly to our Impact programme, through a series of small awards to investigate how the high speed detectors can be utilised in the medical field.

The NGTS (**Burleigh, Casewell, Goad, Alexander**), a ground-based red-sensitive wide-field survey aimed at discovering Neptune and Super-Earth sized planets around nearby late-type stars via the transit method, is based at Paranal, Chile, one of the premier observing sites in the world. It is operated by a consortium of UK universities (Leicester, Warwick, Queens University Belfast, Cambridge) and International partners (Germany (DLR Berlin), Switzerland (Observatoire de Geneve), and Universidad de Chile). Operations and research are in part supported in the UK by STFC. UoL plays a leading role in NGTS exoplanet discoveries, performing the majority of photometric follow-up observations of candidate exoplanets, necessary for transit confirmation, and prior to Radial Velocity measurements. In that role we have won competitively nearly 500 nights of observing time on major international ground-based facilities such as SAAO.

We play a leading role in the SuperDARN consortium of upper atmosphere radars, in particular through the scientific leadership of the programme (**Lester, Yeoman, Milan**). As a result of our leadership in this project and in the SMILE mission, and based on our expertise in handling both the SXI data and also the SuperDARN data, we are playing leading roles in data fusion facilities for SMILE, and in ground-based and other science working groups for this mission. This latter work is led by PDRA Carter and demonstrates how we provide support for our ECRs to develop their leadership roles to further their careers.

Infrastructure in the Space Park Leicester Era

SPL is a new approach to academia/industry collaboration, creating a gear-shift in the innovation landscape (IES, 2.2, 4.4). Originated by members of the School (**Ambrosi,** Bannister**, Barstow** (lead), **Sims**), it forms a leading part of the research and enterprise strategy for School, College and University, as highlighted in the institutional strategic plan.

This ambitious project is led by the University in partnership with the City Council, LLEP and National Space Centre (NSC). It has secured ~£100M of investment and the first buildings are almost complete, opening in summer and autumn 2021. The University has contributed £25M capital to the project and the project team have secured external investment from the Local Growth Fund (£7.8M), UKRPIF (£13.8M, PI **Barstow**), ERDF (£2.3M, PI **Sims**) and the Wolfson Foundation (£0.5M, PI Bannister) plus significant contributions from NERC and the Satellite Applications Catapult. The UKRPIF funding is matched by contributions from industry partners totalling £33M.

UoA staff lead SPL activities, including building design and associated infrastructure (**Sims**), industrial engagement (**Ambrosi, Barstow, Sims**) and as Director of Educations and Skills Development (Bannister). The new and novel research programme is focussed on the UKRPIF-funded element, the METEOR Centre (PI **Ambrosi,** Bannister**, Barstow** and **Sims**). This new Centre provides core infrastructure and expertise to realise the broader vision of SPL - to drive the research excellence that underpins industry growth in the sector. This research will translate into and support a planned Low Cost Access to Space Facility (LOCAS), providing facilities to businesses for the manufacture of small to mid-range (30 kg – 200 kg) satellites, supporting growth of the UK space sector. Planning for LOCAS continues in conjunction with local government and national and international industrial partners.

There are 4 main areas of activity within METEOR: the Space4.0 Advanced Manufacturing Research Laboratory, Next Generation Intelligent Systems Facility, INEOT: Services and Solutions Laboratory, and a Skills capacity and Building Research Capacity. These all underpin our strategy for research, impact and training developments. To further support industrial

collaboration, the ERDF grant provides state of the art manufacturing equipment including additive manufacturing (3D printing) and 5-axis CNC to work with SME's in the local economic area on prototyping new products and to provide equipment for use within SPL. The Wolfson award (PI Bannister) will support the Wolfson Deep Space Exploration Centre at SPL and will play an important role in delivering skills and training for future scientists and engineers, as well as supporting the aims of LOCAS.

Looking ahead to the next decade, we are leading the UK contribution to the study phase for THESEUS (UK PI **O'Brien**), one of two possible missions for ESA's M5 selection, demonstrating that we continue to look for new opportunities. We will play a lead role in the Athena Wide-field Instrument Science Centre (WISC), building on our successful role for the EPIC instrument on XMM. In addition, a number of space exploration initiatives are targeting opportunities to host science instruments on space missions. These are capitalising on a growing collaboration with 'new space' commercial partners and new emerging space faring nations. These include working with ispace, a Japanese space exploration company that is targeting commercial lunar missions in the early 2020s and which is offering science instrument hosting opportunities (**Hutchinson,** Bannister**, Ambrosi**). Enabling technologies like radioisotope power are baselined for ESA's EL3 (European Large Logistics Lander) mission, targeting the late 2020s. The SRC is working with ESA, NASA and Thales Alenia Space to develop a new Double Walled Isolator for Mars Sample Return (**Bridges,** Holt). We are the only UK members of the study team for another NASA mission, this time to Mars, the Mars Orbiters for Surface-Atmosphere-Ionosphere Connections, MOSAIC (UoL Lead **Lester**). We are Co-I on the Geopsace Dynamics Constellation mission (**Milan**).

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

Collaborations

Our research and impact is inherently collaborative at a national and international level. Building instrumentation for space missions and ground-based facilities and the subsequent operations and data analysis involves multiple institutes from across different countries. ESA projects are European collaborations, including all 22 member states, plus 2 additional states with bi-lateral agreements, in the Agency. Our collaboration with other major space faring nations, such as USA, Japan, China and Russia, sometimes results from ESA related missions and sometimes through direct engagement. Missions during the last 6 years in which have direct involvement with Space Agencies from these countries include Cassini, Swift, Juno, JWST (USA), Hayabusa 1, and Hayabusa 2, BepiColombo (Japan), SVOM, SMILE, Einstein Probe (China), ExoMars (Russia). We are developing links to the smaller space faring nations, such as India, Nigeria, South Korea and Brazil, the first two of which have been involved in collaborative GCRF projects with us.

Many ground-based facilities are also multi-national. Here we point to NGTS, which in addition to having international partners in the consortium, results in us using a number of non-UK led telescopes for follow-up observations, such as South African Astronomy Observatory, SAAO. The SuperDARN programme consists of 12 current international partners from those countries mentioned above plus Australia. Discussions with South Korea have also led to an MOU which focuses on collaboration between Leicester, National Nuclear Laboratory and Korea Atomic Energy Research Institute in support of the South Korean lunar exploration programme. Links with a number of other countries such as for example South Korea, Mexico, Ethiopia, Cote'd'Ivoire also have been initiated through a variety of routes including GCRF funding and

postgraduate studentships. Leicester has been helping coordinate GOTO follow-up of GRBs detected by Swift and Fermi, and modelling the required observing cadence required to maximise scientific observations of Tidal Disruption Events. We are also instrumental in a number of collaborations responsible for arranging follow-up science of gravitational wave observations including VINROUGE, STARGATE and ENGRAVE (**Tanvir**).

Direct engagement leading to impact has been described elsewhere, while looking to the future, we see SPL as a major stimulus to our engagement with industry. Currently, UoL leads the £4.8M SPRINT programme (PI **Barstow**), a consortium including Universities of Edinburgh, Southampton, Surrey and the Open University. SPRINT makes I/P, academic staff time and facilities available to nurture SMEs and drive their growth. This engagement develops Impact and includes bodies such as Innovate UK, UKSA and several others involved in the space sector. UoA9 staff are leading the University side in 10 of 30 current funded projects at UoL, involving 6 different companies. Overall, SPRINT has engaged with more than 400 business and supported more than 90 projects. Through DiRAC we are part of the UKRI ExCALIBUR Hardware & Enabling Software programme, which is deploying test hardware around the UK in preparation for a future UK exascale system.

Sustainability of the discipline.
Our involvement in wider national and international programmes contributes significantly to the long-term sustainability and health of our discipline. Our research involves programmes with lifetimes in excess of 20 years, leading to general sustainability on that timescale. However, our work on developing the next mission or facility is critical for continued success, both internally and nationally, of our research disciplines. Long-term sustainability includes the provision of the necessary local infrastructure, ensuring long term support for key technical and research staff, and provision of the next generation of scientists and engineers, e.g. through SPL, whilst delivering the research from existing programmes.

For example, our contributions to the development of new space missions in the last 6 years include a range of new science missions and space agencies, including SMILE. The design of this instrument is similar to the design of the instrument for BepiColombo, in particular the optics. The BepiColombo instrument provides the basic design for an instrument on SVOM, a joint China-France mission under contract to the CNES, which led to China requesting our involvement in Einstein Probe, funded by ESA. Our high-quality technical expertise in optics, detectors, and space systems, leads to many offers of involvement in bi- and multi-lateral missions. Often this is through contractual work, ensures that the technical expertise remains at Leicester (and in the UK), and enables us to be involved in the subsequent data analysis and exploitation of these missions. In addition to SVOM, we are involved in instrument development on Einstein Probe and ICEE-3: Europa Lander missions.

We play leading roles in responding to calls for new missions by the major space agencies. Since 2014 we either played the PI or Co-I role a number of proposals for new missions. These are not always successful, although the work done on these often leads to other research collaborations which may not have already been planned. Example mission proposals include THESEUS (**O'Brien** et al.), currently under study by ESA for selection as their M5 mission, Europa Lander (**Hutchinson** et al.), MOSAIC (**Lester** et al.), Trident (**Stallard**).

Ground-based facilities are as important as their space counterparts for our research. Examples include GOTO (**O'Brien**), CTA (**Lapington**), HESS (**O'Brien**), SuperDARN (**Lester** et al.), EISCAT-3D (**Milan**) as well Laboratory facilities such as Diamond (**Bridges, Hansford**).

As a lead institute in the DiRAC consortium for HPC provision through STFC, we play a leading role in the long-term sustainability of HPC capability for the STFC communities of Astrophysics and Particle Physics. This is an essential role as the technical capability of HPC is improving rapidly and the use of such facilities has significant potential of long-term Impact, in terms of developing new processors/technology and the use to generate impact through direct collaboration with other companies. SPL will ensure the sustainability of our impact programme, engaging directly with SMEs and larger companies in a spectrum of activities, including space nuclear power, as well as enabling the 'spin-out' of new technologies developed for the medical sector.

Prizes

A number of our staff have been awarded major prizes by organisations such as the Royal Astronomical Society, the British Interplanetary Society, and the European Geophysical Union (see Table 2).

Awardee	Prize	Year
King	RAS Eddington Medal	2014
Fraser	RAS Jackson Gwilt Medal	2014
Lester	RAS Service Award for Geophysics	2014
Cassini Magnetometer Team **incl Bunce, Cowley, Nichols, Fletche**r	RAS Team Award Geophysics	2014
UK Gaia Science Team incl **Barstow**	Arthur C Clarke Award for Space Achievement (Academic Study/Research)	2017
SuperDARN **PI Lester, incl Yeoman, Milan, Imber,** Wright	RAS Team Award Geophysics	2017
Bunce	Wolfson Merit Award	2018-2022
Bunce	RAS Chapman Medal	2018
Stallard	RAS Chapman Medal	2019
Tanvir	RAS Hershel Medal	2019
Imber	BIS Outreach Award	2019
Pounds	BIS Lifetime Achievement	2019
PDRA Sanchez-Cano	Arne Richter Early Career Research Award	2020

Table 2. List of Prize Winners

Membership of Research Council or Similar Bodies

In the REF period, we have been significantly involved in the leadership of the Royal Astronomical Society, including two Presidents of the Society (**Barstow,** 2014–2016, **Bunce**, 2020-2022), the Geophysics Secretary (**Lester**, 2017-2022) and member of Council (**Watson**, 2016-2019).

We have provided a Chair of STFC's Astronomy Advisory Panel STFC (**O'Brien**), the Chair of their Exoplanet Science Review Panel (**O'Brien**), *ad hoc* member of their Science Board (**Lester**), a member of their Balance of Programmes Committee (**Fletcher**), the External expert on PPRP's review of the LSST-UK project (**Wilkinson**), the Chair of their Oversight Committee

for LSST-UK (**Wilkinson**), members of their Particle Astrophysics Advisory Panel (**Lapington**), and their UK SKA Oversight Panel (**Blain**).

We provide the current Chair (**Barstow**) and former member (**Lester**) of UKSA's Science Programme Advisory Committee and two Chairs of their Space Exploration Advisory Committee, (**Ambrosi**, **Bridges**), a member of both the Space Technology Advisory Committee (STAC) (and the separate Space Standards Advisory Board (SSAB) (**Sims**). We provided an Observer to the ESA Science Programme Committee, (**Barstow**), a member of ESA's Space Science Advisory Committee (**Lester**) and of ESA's Human and Space Exploration Advisory Committee (**Sims**), as well as a member of the ESA/ExoMars Rover Landing Site Selection Working Group and Science Operations Working Group (**Bridges**), and the SMILE SXI Science Advisory Panel (**Milan**). We have also played leading roles as Chair of the Space Telescope Institute Council (**Barstow**) and of the SuperDARN Executive Council (**Lester**).

Staff also advise international Universities and Research institutes. Examples include a member of the Visiting Committee, Dublin Institute for Advanced Study (**King**), an Advisory panel member for the Australian National Institute of Theoretical Astrophysics (**King**), Research Review, University College Cork (**King**), a Member, University of Sharjah Board of Trustees (**Barstow**),

We have contributed to other areas such as membership of the Newton Agritech Governance Board (**Barstow**) and the Europlanet Board and Vice-Chair of the COSPAR outer planets commission (**Fletcher**). We have strong links with the NSC and several staff are actively involved in the administration and running of the NSC (**Barstow, Bunce, Sims**).

Participation on Grant Committees

We contribute to the grants process at STFC through a variety of roles, including membership of STFC's Astronomy Grants Panel (Bannister, **Bridges**), Chair of the assessment panel for the UKRI ExCALIBUR Exsascale software development call (**Wilkinson**). **Lester**, Wright and **Imber** are on the NERC Peer Review College, leading to membership of several grants panels, while **Lester** chaired the panel to assess the proposals for a 'Wave 2' programme of the UKRI Strategic Priorities Fund on Space Weather Innovation, Measurement, Modelling and Risk.

We play a full role in assessment of Royal Society proposals through membership of Research Professorships Panel (**King**) and the University Research Fellowship Panel (**Bunce**)

Our staff contribute to a variety of international funding bodies, such as NASA assessment panels (**Casewell, Nichols** as Chair, **Imber**, **Lester, Nixon, Nyakshin**), Hubble Space Telescope time allocation committee (TAC), (**King**), e-ESO TAC, (**Fletcher**), LOFAR TAC (**Nichols**). JAXA assessment panel – 2016 for SPICA (**Blain**), NASA NPP (NASA Center Postdoc Scheme) Panel member and Chair (**Blain**), VLA extragalactic TAG panel membership (**Blain**).

Conference Chair Roles

We have played a major role in leading and contributing to the science organisation and local organisation of many different conferences, symposia, and workshops, and highlight a selection. **Wilkinson** organised the first UK conference of the HPC-AI Advisory Council, at Leicester in September 2019. **Fletcher** organised a Royal Society meeting on the Ice Giants in 2020. **Barstow** led and organised IAU Symposium 357 in 2019.

Journal Editorship

Our staff play active roles in Journal Editorship and as members of Journal Editorial Boards. These include membership of the Springer-Praxis Astronomy & Astrophysics Library editorial board and Associate Editor for Springer's Experimental Astronomy (**Barstow**), Editorial advisory committee Earth and Planetary Science Letters (**Bridges**), Deputy Chief Editor, Monthly Notices of the Royal Astronomical Society (**King**), editorial board of Journal of Solar Terrestrial Physics of the Russian Academy of Sciences (**Lester**), associate editors for JGR:Planets (**Fletcher**, PDRA Sanchez-Cano), member of the CUP editorial board for planetary science series (**Fletcher**), lead and Topical editor for Annales Geophysicae (**Milan**).

Refereeing Academic Publications or Research proposals

All research staff contribute to the peer review process for both refereed journals and for grant proposals, with the latter being anything from small awards to mission proposals. This is both expected of all our staff including ECRs and the norm for the discipline.

Honorary Positions Elsewhere

Several staff had honorary or visiting positions, including at the University of Bergen (**Milan**), Paul Sabatier University, Toulouse (**Lester**), IRAP, Toulouse (**Lester**), University of Michigan (**Imber**), University of Dayton, Ohio (**Ambrosi**), University of Amsterdam (**King**), University of Leiden (**King**), Institut d'Astrophysique, Paris (**King**), Chiang Mai University (**Nichols**).

Summary

The REF2021 period has been extremely successful in all areas of our research and impact work. We have maintained and expanded high-quality research and enterprise programmes in Astrophysics, Planetary Science, and Space Science Instrumentation. We have attracted new high-quality staff, our ECRs have been recognised through the award of Fellowships and Prizes, and we are building novel new instruments for new missions. Space Park Leicester has received significant investment from Government and the University leading to new research and impact activity. The next REF period will include results from a variety of new missions and facilities, JWST, CTA, BepiColombo, ExoMars, SMILE, SVOM. We look forward to this exciting and successful future.