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News from the Cavendish Laboratory

£85 million gift from the Dolby family

We are delighted and deeply grateful to the Dolby family for the truly magnificent gift of £85M. At the same time we received final confirmation of the Government's contribution of £75M to the New Cavendish project. As described below, these are wonderful boosts to the programme and things are now moving very fast. Planning permissions are going smoothly, we have completed RIBA Stage 3 and we are getting close to construction. The constructors for the new building have been appointed, the French firm Bouygues. There is every prospect that construction can begin this year.

It is a year since the last 'standard' CavMag and so there is a lot of catching up to do. Maybe one day we will not have an excess of matters to report, but it won't happen soon! Keep an eagle eye on this space.

MALCOLM LONGAIR

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COVER IMAGE:
A visualisation of the entrance to the New Cavendish Laboratory. Courtesy of Jestico + Whiles.

The University of Cambridge has received from the estate of Ray Dolby a gift of £85M, a very major contribution indeed to the construction of the new Cavendish Laboratory and the creation of a new research area under the direction of a new Professor, a chair which will bear the Dolby name. Ray Dolby was the founder of Dolby Laboratories and its world-renowned Dolby Noise Reduction, Dolby Surround, and succeeding audio signal processing technologies, which have revolutionised the audio quality of music, motion pictures, and television worldwide.

Cambridge University Vice-Chancellor Professor Stephen Toope stated:

'This unparalleled gift is a fitting tribute to Ray Dolby's legacy, who changed the way the world listened - his research paved the way for an entire industry. A century from now, we can only speculate on which discoveries will alter the way we live our lives, and which new industries will have been born in the Cavendish Laboratory, in large part thanks to this extraordinarily generous gift.'

The Dolby family gift is believed to be the largest philanthropic donation ever made to UK science, and will support the Cavendish Laboratory, where Ray Dolby received his PhD in 1961. In recognition of this gift, the flagship building of the new Cavendish Laboratory will be named the Ray Dolby Centre, and is expected to open in 2022. This is the second generous gift to Cambridge from the Dolby family, who donated £35 million to Pembroke College, Cambridge in 2015.

Dagmar, Dolby's widow, said:

'The University of Cambridge played a pivotal role in Ray's life, both personally and professionally. At Cambridge and at the Cavendish, he gained the formative education and insights that contributed greatly to his lifelong ground-breaking creativity, and enabled him to start his business.'

David, Dolby's son, stated:

'My father's time at the Cavendish provided him with an environment where he got a world-class education in physics, and many of his successful ideas about noise reduction were stimulated by his Cambridge experience. Our family is pleased to be able to support the future scientists and innovators who will benefit from the thoughtfully designed Ray Dolby Centre.'

ABOVE: A panorama of the New Cavendish Laboratory on the west side of J.J. Thomson Avenue from a visualisation courtesy of Jestico + Whiles.

A new Ray Dolby Research Group will be established at the Cavendish Laboratory, which will significantly expand research capability and expertise within the new building. The group, which will be led by a new endowed Ray Dolby Professorship, will build on and further strengthen the Cavendish Laboratory's status and impact as one of the greatest centres of physics research in the world.

Professor Andy Parker, Head of the Cavendish Laboratory, said:

'The Ray Dolby Centre will complete the development of the new Cavendish Laboratory. In addition to serving as a home for physics research at Cambridge, it will be a top-class facility for the nation. This extremely generous gift from the Dolby family is the most significant investment in physics research in generations, and a truly transformational gift in Cambridge's history.'

The construction of the new Cavendish Laboratory was first announced by the government in its 2015 Spending Review. It promised a £75 million investment in the Laboratory, which was confirmed at the same time as the announcement of the Dolby gift. The Government's Science Minister Jo Johnson announced:

'This generous £85 million donation from the Ray Dolby estate along with the £75 million government has already pledged are a testament to the importance of this facility and the UK's leadership in science. The UK is one of the

The entrance and reception area of the New Cavendish Laboratory, from a visualisation courtesy of Jestico + Whiles.

most innovative countries in the world, and through our Industrial Strategy and additional £2.3 billion investment for research and development we are ensuring our world-class research base goes from strength to strength for years to come.'

The Government funding will be delivered by the Engineering and Physical Sciences Research Council (EPSRC). Work on the new facility is expected to begin in 2019. Professor Philip Nelson, EPSRC's Chief Executive, stated:

'A successful nation invests in science, and this grant signals our intent to lead the world. The facilities will be open to researchers across the country and encourage collaborative working between academics and institutions. Clearly Ray Dolby valued the university that nurtured his talents and, in making his bequest, has made a truly generous contribution to future generations.'

All images courtesy of jestico + whiles the architects for the New Cavendish project.

Ray Dolby - the Cavendish Laboratory, X-ray microanalysis and noise reduction

The Dolby family have spoken highly of Ray Dolby's positive experience as a graduate student in Cambridge and the Cavendish Laboratory. It is intriguing to look at his PhD dissertation for the signs of things to come.

FIG1. Three pioneers of the many ways in which the unique capabilities of electron microscopy can be exploited. (left to right) Ray Dolby, Bill Nixon and Peter Duncumb. This is image is taken from the 1959 annual photograph of staff and research workers in the Laboratory.

In 1957, Ray Dolby received his B.S. degree in Electrical Engineering from Stanford University. He then won a prestigious Marshall Scholarship to study for a Ph.D. in physics at the Cavendish Laboratory. He became a member of Pembroke College and was awarded a Research Fellowship by the College. He was absolutely delighted by his Research Fellowship and, particularly, by his panelled rooms in Pembroke.

Through the period 1957 to 1961, he carried out research in the Cavendish Laboratory's Electron Microscope Group under the supervision of its leader, Ellis Cosslett. His PhD thesis concerned the X-ray spectroscopy of the light elements, particularly carbon, a material of great importance in materials science but it was very difficult to measure at that time because of the low energies of the characteristic X-rays. Under Cosslett's guidance and with friendly exchanges within the group, he found a solution, which depended upon extracting a tiny signal from the 'noise' from other X-rays. The summary of his PhD dissertation explains what he did:

This dissertation describes some new methods for discriminating between the light element characteristic wavelengths in an X-ray scanning microscope. For long wavelength microanalysis purposes, the classical methods of X-ray spectroscopy are impractical. The proportional counter, the best of several possibilities, has therefore been employed as a dispersive detector, the output pulses subsequently being analysed electronically to yield the necessary line intensity information.

Proportional counter operation with low energy X-rays is analysed and discussed, and the construction of a suitable counter described. Measurements of the quantum yields from carbon and aluminium, made with this counter are reported; these measurements, apart from their fundamental significance, provide an estimate of the performance to be expected from a light element analyser. Several methods of pulse height distribution analysis (deconvolution) are described practically and analysed theoretically. One of the methods, in which the outputs from several pulse analyser channels are treated as a set of linear equations, which can be solved simultaneously in an electrical network, is chosen for the development and incorporation into a scanning microanalyser. The design, construction and operation of this instrument are described; its use is demonstrated in several practical examples. The results are presented as pictures with resolution of 4-5 microns, showing the surface concentrations of elements as light as beryllium (Z = 4).

The wide range of skills needed to accomplish this research programme successfully is most impressive. Efficient proportional counters and electronic circuitry were built into the scanning electron microscope and theoretical analyses of the best way of extracting meaningful images from noisy data were carried out. These were then brought together to make a very significant advance in understanding the structure of metals and alloys. His proportional counter and the overall experimental set-up are shown in Figures 2 and 3.

The success of the programme is illustrated by Dolby's images of a magnesium specimen which included inclusions, previously thought to be some form of oxide. In fact, the images in Figure 4 show that the inclusions are of carbon, which is crucial in understanding the properties of metals and alloys. The result was six papers in the literature describing these research achievements. Particularly impressive is his 1959 sole author paper in the *Proceeding of the Physical Society of London,* which was actually submitted in July 1958, less than one year into his PhD programme. In 1960 he was elected to the Pembroke Fellowship as the then Drapers' Senior Research Student, and became the Drapers' Research Fellow after he received his PhD in 1961. He left the Fellowship in March 1963, founding Dolby Laboratories in 1965. He was elected an Honorary Fellow of Pembroke College in 1983.

Before his arrival in Cambridge, Dolby had already published in 1957 two single author papers on video tape recording amplifiers – he was clearly already an electronics expert, particularly in signal recording and reproduction. He continued his interest in audio reproduction while he was in Cambridge and demonstrated with pride his Quad loudspeakers in his rooms in Pembroke, another instance of a consuming passion for quality.

This interest in extracting weak signals from noise played a role in his theoretical analysis of Section 6.2.2, pages 95-99 of his dissertation entitled 'Time-reversal Deconvolution (Continuous Frequency)'. As he writes:

> **It has long been recognised that recording a signal on, for example, magnetic tape and playing it back in reverse gives an effective time reversal. The implications of this phenomenon have only recently been appreciated. Bogart (1957) has used this principle to correct the phase response of a long telephone cable by means of a magnetic tape record-reverse-reproduce system stationed at the half-way point.**

This procedure was then adapted to improve the deconvolution procedures needed to separate the light element signatures in the output of the proportional counter. The seeds of his innovations in what is now called the Dolby noise reduction system is present in his theoretical analysis of noise reduction by deconvolution. He was awarded his Ph.D in 1961.

From 1963 to 1965, he was United Nations Technical Advisor and helped set up the Central Scientific Instruments Organization in India. In 1965, he set up the Dolby Laboratories in London to develop noise reduction and signal processing systems for improving sound quality. The Dolby noise-reduction system works by increasing the volume of low-level, high-frequency sounds during recording and correspondingly reducing them during playback. This reduction in high-frequency volume reduces the audible level of tape hiss. The Dolby noise reduction technologies have become an essential part of the creative process for all recording artists and filmmakers. In 1976, he moved the company to San Francisco, where its headquarters has remained ever since. Ray Dolby was awarded the Honorary Degree of Doctor of Science by the University of Cambridge in 2000.

Reading his PhD shows clearly the remarkable effort and ingenuity Ray Dolby lavished on his research project with its superb combination of experimental and theoretical technique and insight. He grasped the opportunities in these burgeoning areas of electron microscopy and condensed matter physics and gained all the experience needed to carry out his future innovations in audio noise reduction.

MALCOLM LONGAIR

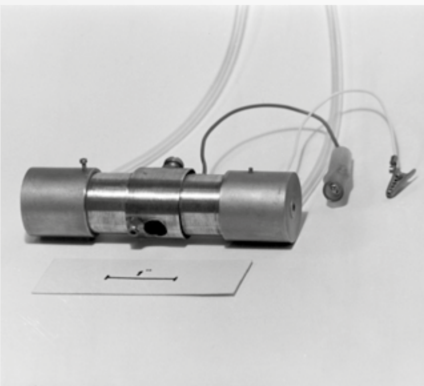


FIG 2. The proportional counter used to measure the X-ray spectrum of light elements such as oxygen and carbon.

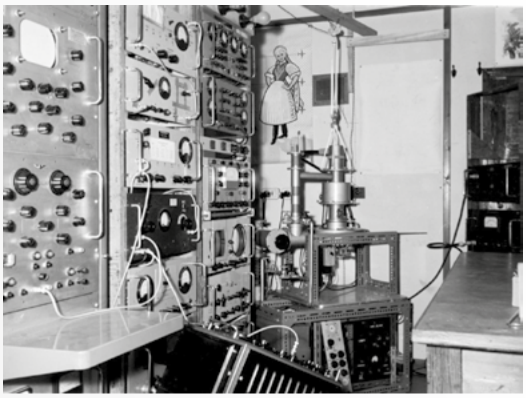


FIG 3. The apparatus used in Dolby's X-ray microanalysis project.

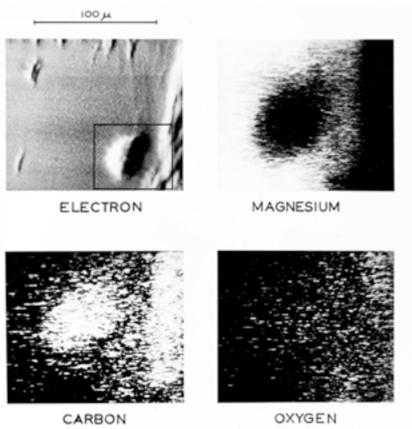


FIG 4. Images of a magnesium specimen with a carbon inclusion, previously thought to be an oxide inclusion.

Distinguished Prizes for Achievements in NanoScience

Many congratulations to JEREMY BAUMBERG and ALEX PATTO for recognition of their outstanding research in Nanoscience and its applications.

Jeremy Baumberg was the 2017 winner of the **Institute of Physics Michael Faraday Medal and Prize.** The citation reads: "For his investigations of many ingenious nanostructures supporting novel and precisely engineered plasmonic phenomena relevant to single molecule and atom dynamics, Raman spectroscopies and metamaterials applications."

Alex Patto received the University of Cambridge Vice-Chancellor's Impact Award from Sir Leszek Borysiewicz in July 2017. These Awards recognise and reward those whose research has led to excellent impact beyond academia, whether on the economy, society, culture, public policy or services, health, the environment or quality of life.

Alex and Jeremy describe the Waterscope project for which Alex was awarded the overall 2017 Impact Prize.

How Optics can help the Bottom Billion

Over 660 million people live without access to clean drinking water. Globally more than 2000 people die each day from a diarrheal related illness caused by bacteria. This is more than HIV and Malaria deaths combined.

Existing tests work by growing bacteria until they can be seen by eye, so they are complex, expensive, and take at least a day to give results. In emergency situations, waiting a day for an answer is often impossible; a faster answer would allow decisions to be made about water supply before people drink unsafe water. Current bacterial tests have to be performed by trained specialists but the reality is that over 80% of those without clean water live in extremely low resource communities.

WaterScope[1], led by Alex Patto, is a not-for-profit, impact driven company spun out of research conducted within the NanoPhotonics Centre in the Department of Physics. Using an open-source flexure microscope[2] developed by Richard Bowman in Jeremy Baumberg's group, WaterScope is developing rapid, automated water testing kits and affordable bacterial diagnostics to empower developing communities.

It works by 3D printing tiny 'leaf' springs that deliver a low-cost microscope with high enough performance to track individual bacteria as they grow. Their system allows identification of bacterial contamination from any liquid, giving a precise measurement, not dependent on user skillsets or the resources available. Using software they can automate bacterial growth detection, eliminating the requirement of trained professionals. They can also map the results and provide connections to purification companies and non-governmental organisations, allowing almost real-time intervention to those who need it most.

In August 2017 WaterScope went on their first field trial with Oxfam to Nyarugusu Refugee Camp, one of the largest refugee camps in the modern world. During this trip they obtained user feedback and comparative tests against current gold standards. The promising results have now led to a £0.9M Global-Challenge

Research Fund grant to explore the development of such low-cost 'open' instrumentation. Further, WaterScope is also using this open-source microscope to support local initiatives, with companies such as STIClab and JuakaliBox now making our microscopes from recycled plastic bottles.

In parallel, the microscopes are being used for education, to inspire future scientists: WaterScope currently have microscopes around the world, including India, Tanzania and Columbia.

WaterScope is 2 years old with a current team of Alex Patto, Richard Bowman, Nalin Patel, Tianheng Zhao and Sammy Mahdi. Alex is currently working in the NanoPhotonics Centre to develop the system further. To date WaterScope has won £130k of grants and competitions to build their technology. The coming year is crucial for WaterScope and the team is seeking further funding to take them to commercialisation.

If you are interested in this very important project or can help the WaterScope team, please contact Dr. Alexander Patto at alex.patto@waterscope.org.

1. www.waterscope.org
2. www.waterscope.org/3d-printing

OPPOSITE: Alex (left) and Sammy Madhi (right) with refugees at the Nyarugusu Refugee Camp during the field trials.

TOP CENTRE: Waterscope's Open flexure stage printed by Juakalibox empowers communities in Kenya. The microscope is capable of being made from recycled plastic.

BOTTOM LEFT: Alex Patto receiving the University of Cambridge Vice-Chancellor's Impact Award from Sir Leszek Borysiewicz in July 2017. These Awards recognise and reward those whose research has led to excellent impact beyond academia, whether on the economy, society, culture, public policy or services, health, the environment or quality of life. Each winner receives a prize of £1,000 and a trophy, with the overall winner for 2017, Alex Patto, receiving £2,000.

BOTTOM RIGHT: Jeremy Baumberg, Director of the NanoPhotonics Centre in the Cavendish Laboratory, receiving the Michael Faraday Medal and Prize from Dame Julia Higgins, President of the Institute of Physics.

Akshay Rao wins the 2017 IoP Henry Moseley Medal and Prize

We warmly congratulate AKSHAY RAO for the award of the 2017 Institute of Physics Henry Moseley Medal and Prize for his ground-breaking studies in the electronic properties of organic semiconductors, particularly the roles of electron spin in the operation of solar cells.

The citation includes the following description of Akshay's research.

His principal interest has been the fission of a spin-singlet photoexcitation in an organic semiconductor into a pair of spin-triplet excitons. He showed that this process can be very fast and efficient, that the triplet exciton can be ionised to an electron–hole pair at a suitable heterojunction, and that the triplet exciton can be rapidly tunnelled into an inorganic semiconductor. He further showed how this process of fission couples coherently with vibrational coordinates. This has demonstrated how the process of exciton doubling coupled to practical solar cells may be able to deliver tandem-cell performance in a cheap single-junction cell.

Akshay has also worked on the processes of electron-hole separation at the donor-acceptor heterojunctions used in organic solar cells. With Artem Bakulin he revealed the role of hot vibrational states in the process of charge separation. With Simon Gelinas he showed that the initial charge separation process can be extremely rapid, moving the electron and hole more than 5 nm apart within 40 fs and thereby escaping the electron–hole Coulomb attraction that would otherwise cause rapid recombination. These experiments indicate that there is quantum coherent electron motion at early times across multiple molecular units.

This body of research has brought real international recognition to the UK activity in this field.

Akshay has kindly described how he foresees this research developing in the future.

'Understanding and harnessing light-matter interaction in novel nanostructures and semiconductors materials has the potential to open a range of new device functionalities in areas ranging from solar energy harvesting and photocatalysis to spintronic and quantum information science. To understand fully these materials and the phenomena they host, it is important to understand the dynamics of the photo-excitations that dominate their physics such as electrons, excitons, polarons and polaritons. But for decades we have been stuck with a tradeoff between spatial and temporal information when studying these systems. While electron microscopy techniques can provide structural information with sub-nm spatial resolution and time-resolved optical spectroscopy techniques can provide sub 10 fs temporal information, no technique can provide a real-time picture of the dynamics of the photo-excitations in these systems at the nanoscale. This is because time-resolved spectroscopy is primarily performed at the ensemble level due to the diffraction limit, which is a few hundred nm for visible light.

FIG 1. Akshay receiving the 2017 IoP Henry Moseley Medal and Prize in the presence of the President of the IoP Dame Julia Higgins (seated) in December 2017.

'Another branch of science, biology has also wrestled with the diffraction limit for many decades, which limited the understating of structure and function of biological systems. Within the last decade the emergence of super-resolution fluorescence microscopy has brought about a revolution in biology, recognized by the award of the 2014 Nobel Prize in Chemistry to Hell, Moerner and Betzig.

'Inspired by these developments we have been working for the past year on a platform that can fuse high temporal and spatial resolution to tackle some of the most interesting problems in solid-state physics. Our Ultrafast Super-Resolution Microscopy setup now enables us to study the dynamics of electrons, excitons, polarons, polaritons and other quasiparticles with sub-10 fs temporal resolution and sub-10nm spatial resolution. We are using this unparalleled technique to study the dynamics of a range of systems including 2D semiconductors, quantum dots, molecular semiconductors, hybrid perovskites, organic-polaritons and polariton condensates. By providing a real-time picture of these photo-excitations at the nanoscale, we hope to gain new insights into their physics and pave the way to novel device functionalities.'

Didier Queloz wins the 2017 Wolf Prize

ABOVE: Didier Queloz (left) and Michel Mayor (centre) on the occasion of the presentation of the 2017 Wolf Prize in Tel Aviv.

Many congratulations indeed to Didier Queloz on winning the prestigious 2017 Wolf Prize jointly with his former supervisor Michel Mayor. In 1995, they published the first definitive detection of a planet orbiting a nearby star. This was a tribute to their vision and technical skill in being able to measure the tiny Doppler shifts associated with the oscillatory motion of the primary star because of the gravitational influence of the planet, in this case a Jupiter-sized planet orbiting very close to the star. This discovery led to a huge expansion of exoplanet research, one of the most exciting areas of modern astrophysics and one which has caught the public imagination.

Didier now leads a very dynamic group in the Laboratory and, in collaboration with colleagues in the Institute of Astronomy and elsewhere, they are producing a stunning stream of innovative exoplanet research. To celebrate one of their most recent successes, we publish a very nice summary of the discovery of the TRAPPIST-1 system, which contains seven Earth-like exoplanets. This was written by Ellie Kershenbaum, a student from Sawston Village College. For two weeks during the summer of 2017, Ellie was supervised by Aglae Kellerer, who asked her to write about this very remarkable discovery.

A first close look at another solar system

Searches for planetary systems like our own about other stars have concentrated on Sun-like planets. ELLIE KERSHENBAUM reports on how there great advantages and successes in studying much less luminous stars.

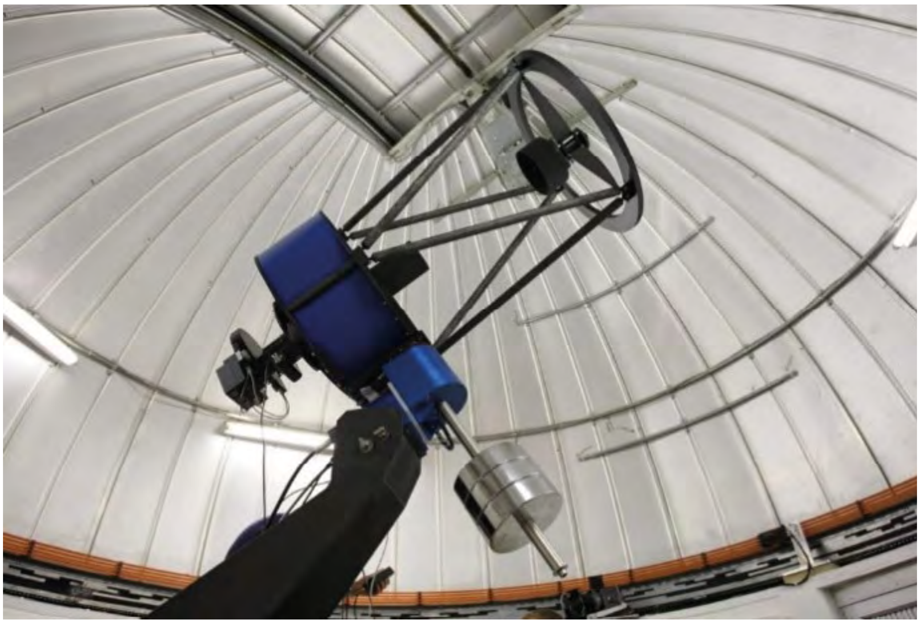


FIG.1. The 60-cm TRAPPIST telescope at the La Silla Observatory in Chile. The acronym stands for TRAnsiting Planets and Planetesimals Small Telescope.[1]

In February 2017, a team lead by Michaël Gillon of the University of Liège in collaboration with Laetitia Delrez, Amaury Triaud, and Didier Queloz of the Cavendish Laboratory announced the discovery of a system of seven roughly Earth-sized exoplanets about 39 light years away. These planets orbit an ultra-cool dwarf star not much bigger than Jupiter. The system is known as TRAPPIST-1, the acronym standing for TRAnsiting Planets and Planetesimals Small Telescope (Fig. 1). At least six of the seven planets are thought to be rocky. TRAPPIST-1 was discovered using the technique of transit photometry, which involves detecting a small periodic dip in the light from a star, which shows that a planet has crossed the face of the star, blocking a small fraction of the light from reaching us - this is known as a transit. The larger the dip in the light, the bigger the planet relative to the size of the star (Fig. 2).

The inner three planets (TRAPPIST-1b, TRAPPIST-1c, and TRAPPIST-1d) are so close to the star that the stellar radiation would evaporate any water on their surfaces. Similarly, the outermost planet (TRAPPIST-1h), is so far from the star that the water would turn to ice. TRAPPIST-1e, TRAPPIST-1f, and TRAPPIST-1g, are described as lying within the Habitable Zone, the range of distances from the star within which water can exist in liquid form (Fig. 3(a)). This is often called the Goldilocks Zone.

It may seem strange that a system with an ultra-cool dwarf star would be host to Earth-like planets, but this is not the case. Such low-mass stars have a number of advantages in the search for Earth-like planets. For instance, transits of planets in front of dwarf stars are easier to detect as the planet blocks a greater fraction of the star, making the dip in light more prominent. The dimensions of the Habitable Zone depend on the mass of the host star. The smaller the mass, the less luminous the star, since Luminosity $\propto$ Mass^3, and so the Habitable Zone moves closer to the star (Fig. 3(b). As a result, transit periods are shorter as the orbits are closer to the star, which means it is more likely that we will be able to detect a transit. Low-mass stars are also much more common than solar-mass stars and so there are many more candidates for low-mass planetary systems.

The planets in TRAPPIST-1 have similar masses to the Earth. The mass of a planet is not as simple to calculate as some other of its properties such as its diameter. Amaury Triaud, a Kavli Exoplanet fellow at the Institute of Astronomy, is a co-author of the key paper recently published about the TRAPPIST-1 system[3] in which the mass of an exoplanet is estimated by studying the effect it has on the other planets.

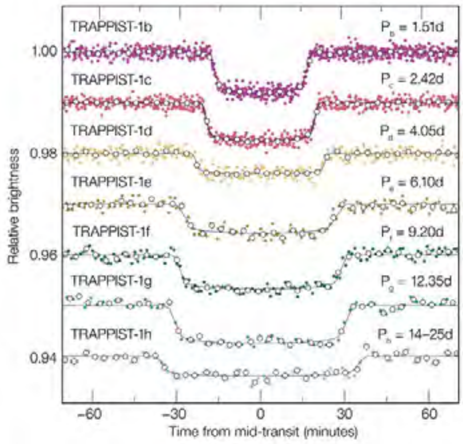


FIG.2. The transit light curves of all seven planets in TRAPPIST-1.

The gravitational force of a planet can accelerate or decelerate another planet's orbit which makes it transit slightly late or slightly early. This can be used to estimate a planet's mass.

One reason why we observe exoplanets is to look for signs of extra-terrestrial life. Sylvestre Lacour, a visiting astronomer at the Cavendish Astrophysics Group, works on a small satellite project called PicSat[4] that will detect exoplanets from space. As he says, observing exoplanets can improve our understanding of how planets form, by looking at different exoplanets and identifying different stages of a planet's life. He also suggests that observing exoplanets could predict what could happen to the Earth in the future, for instance, as a result of the effects of climate change.

The big question is, is there life on these planets? We need to expand our knowledge about life in the Universe as it could give us clues to how life began on Earth. Detecting certain gases and chemical compounds in the atmosphere, such as carbon monoxide, water, or oxygen, would tell us how habitable the planet is, and how likely it is for life to evolve there. It is possible that the planets (at least the inner ones) are tidally locked which could lead to one side of the planet being too hot to support life, and the other too cold, meaning life could only evolve at the rim that connects the dark and light side.

The James Webb Space Telescope, to be launched in 2019, and the Hubble Space Telescope will collect further observations on the TRAPPIST-1 system from space. There are also plans for finding more Earth-like exoplanets in dwarf planetary systems, including ultra-cool dwarf stars. Samantha Thompson, a research associate in the Cavendish Astrophysics Group, is developing new instruments and techniques to detect and characterise exoplanets. Her ultimate goal is to develop high-contrast imaging for the direct imaging method, taking images of planetary systems, which would enable us to see the planet's characteristics more clearly by suppressing starlight but preserving the light from the planet.

Amaury Triaud suggests that the discovery of TRAPPIST-1 could indicate how common life is in the Universe. We might be unique and rare, or surrounded by thriving alien life we just haven't detected yet. There has been increasing evidence to suggest that Earth-like planets are not so uncommon. If Earth-like planets in the Habitable Zone are not extremely rare, maybe life isn't either.

ELLIE KERSTENBAUM

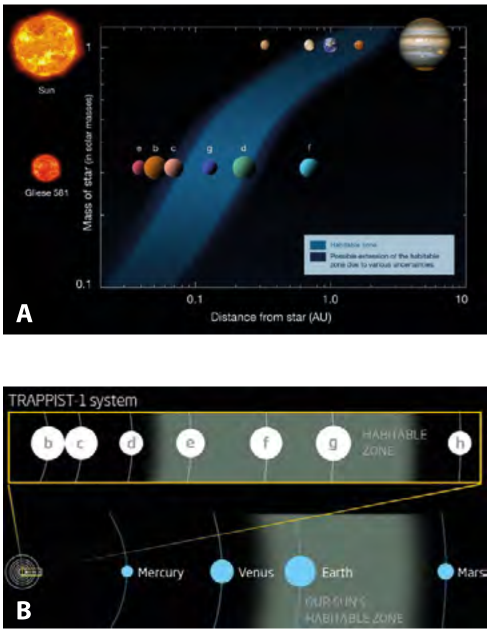


FIG.3. (a) The Habitable Zone of the Sun in comparison to the Habitable Zone of Gliese 581, a much smaller star. The Habitable Zone moves closer to the star as the star's mass decreases as indicated by the diagonal blue band.
(b) The planets in the TRAPPIST-1 system, three being in the habitable zone, compared with the scale of our solar system.[2]

1. www.manyworlds.space/index.php/tag/trappist-1/page/2
2. www.newscientist.com/article/mg23331155-100-how-were-already-seeking-life-on-trappist1s-rocky-planets
3. www.nature.com/nature/journal/v542/n7642/full/nature21360.html
4. picsat.obspm.fr/picsat

Interdisciplinary Lecturers

Interdisciplinarity is a powerful route to innovation and the School of Physical Sciences has reinforced its importance by creating a number of interdisciplinary lecturers who will belong to more than one department. Here we introduce and welcome BENJAMIN BÉRI, HUGO BRONSTEIN and LOUISE HIRST. We wish them all success in making the vision of interdisciplinary a reality.

Benjamin Béri – Interdisciplinary Lecturer between the Cavendish Laboratory and DAMTP

As a graduate student in Hungary, while working in the quite different field of mesoscopic quantum chaos, I grew fascinated by how the collective quantum behaviour of many electrons can lead to emergent exotic particles that not only make beautiful quantum field theories relevant to condensed matter physics but may also be harnessed for quantum computing purposes. Motivated by this, as a postdoc, first in Leiden, and then in Cambridge, I steered my research to so-called 'topological' quantum many-body systems, the field where most such particles emerge. This is the field my work has been revolving around as a faculty and Royal Society University Research Fellow in Birmingham, and now again in Cambridge.

The particle most often appearing in my research is called a *Majorana fermion*. It is predicted to arise in certain 'topological' superconducting devices (see the article by Nigel Cooper in *CavMag17*). In complete contrast to electrons, Majorana fermions are their own antiparticles. More dramatically, instead of the usual fermionic minus sign, slowly exchanging their positions imprints matrix operations on the wavefunction: they obey 'non-abelian' statistics. Remarkably, these exotic features are not only fascinating in their own right, but they also provide a promising route to quantum computing. The self-antiparticle character renders N distant Majoranas into N/2 - 1 robust topological qubits, on which robust quantum gates may be implemented using nonabelian statistics.

These prospects have attracted significant experimental activities, including industrial backing from companies such as Microsoft, which has made it increasingly important to find simple ways of demonstrating the existence of topological qubits. One of my key contributions has been the theoretical prediction of how this may be done – using just a few Majoranas, Coulomb energy, and leads of conduction electrons. The main insight is that in Majorana-probe hybrids based on these ingredients, topological qubits imply a 'topological Kondo effect', meaning fundamentally new forms of strong correlations with striking, non-locally controlled, transport characteristics.

ABOVE: The minimal setup to detect the topological Kondo effect. Majorana fermions (red dots) are envisioned here as emerging in spin-orbit nanowires (horizontal bars) coupled to a superconductor (central rectangle). The outermost wire segments form leads of conduction electrons, tunnel coupled to three of the four Majorana fermions.

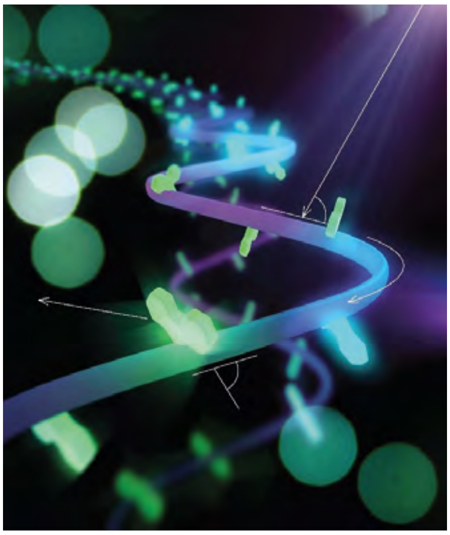
Of course, demonstrating topological qubits will just be one of the early milestones and Majorana fermions will continue to motivate new research, both in quantum computing, and in condensed matter physics. My joint appointment between the Cavendish and DAMTP provides an ideal setting for working in these fields and, as with the topological Kondo effect, for identifying exciting new problems which impact both disciplines.

References:
B. Béri and N. R. Cooper, 'Topological Kondo effect with Majorana fermions', Phys. Rev. Lett., **109**, 156803 (2012).
B. Béri, 'Majorana-Klein hybridization in topological superconductor junctions', Phys. Rev. Lett., **110**, 216803 (2013).
A. Altland, B. Béri, R. Egger, and A. M. Tsvelik, 'Multichannel Kondo impurity dynamics in a Majorana device', Phys. Rev. Lett., **113**, 076401 (2014).
B. Béri, 'Exact nonequilibrium transport in the topological Kondo effect', Phys. Rev. Lett., **119**, 027701 (2017).

Hugo Bronstein – Interdisciplinary Lecturer between Chemistry and Physics

I was born in Buenos Aires, Argentina in 1980 but grew up in London. I studied Chemistry at Oxford, before going on to a PhD at Imperial College. I then spent a year at the University of Washington in Seattle working as a postdoc and then returned to Imperial College for a second postdoc. I was appointed to a lecturership at University College London in 2013 and in 2015 was awarded an ERC starter grant. In 2017, I took up my present joint lectureship in Cambridge.

The research of my group involves the synthesis of novel conjugated materials for use in organic optoelectronic devices



ABOVE: Donor-orthogonal acceptor conjugated polymer capable of emitting light through thermally activated delayed fluorescence

such as solar cells, light emitting diodes and transistors. We are particularly interested in synthesizing materials that help understand and utilise triplet excited states - singlet fission, up-conversion, reverse intersystem crossing - due to their unique and fascinating properties. Our aim is to begin the research process from the "bottom up". I believe that by developing a true understanding of the fundamental properties of conjugated materials, simultaneous advances across all areas of conjugated polymer research and its relevant applications can be achieved.

Conjugated polymers have two types of excited states: singlets and triplets. Generation of singlet excited states are quantum mechanically allowed transitions responsible for light absorption and emission and typically have very short lifetimes. On the other hand, absorption and emission to and from triplet excited states is quantum mechanically forbidden and so they have much longer lifetimes. It has been speculated that the longer lifetime of the triplet excited state could be used to enhance the performance of organic solar cells by allowing more time to harness the power of this exciton. Due to the difficulty of generating and measuring the properties of the triplet excited state, however, not much is known about their fundamental properties.

We have recently synthesized a series of conjugated polymers which enabled measurements of the singlet-triplet energy gap and its diffusion length to be made. Both these parameters have long been discussed but rarely measured. By judicious incorporation of a small amount of a heavy-metal containing complex into the conjugated polymer backbone, we were able to generate exclusively triplet excited states along the polymer backbone. [1]

Going further, we then synthesized an entirely new class of conjugated polymer where we reduced the energy gap between the singlet and triplet excited states. This was achieved by introducing orthogonal electron accepting groups onto the polymer backbone reducing the overlap between the ground and excited states. The outcome was a new class of material that would rapidly generate triplet states, which were then able to be thermally populated back into the singlet state for light emission. This new class of materials is anticipated to have application in solar cells with drastically reduced loss mechanisms and organic photocatalysis. [2]

References:
[1] Synthesis and Exciton Dynamics of Triplet Sensitized Conjugated Polymers. R. Andernach et al., J. Am. Chem. Soc. 2015, 137, 10383-10390,
[2] Synthesis and Exciton Dynamics of Donor-Orthogonal Acceptor Conjugated Polymers: Reducing the Singlet-Triplet Energy Gap. D. M. E. Freeman, et al., J. Am. Chem. Soc., 2017, 139, 11073–11080

Louise Hirst – Interdisciplinary Lecturer with Materials Science

I will be joining the Cavendish Lab in January 2018 as a University Lecturer jointly with the Department of Materials Science and Metallurgy. I studied undergraduate Physics at Imperial College London and particularly enjoyed the applied aspects of the course, making connections between fundamental physics concepts and emerging new technologies. I stayed on at Imperial to study for a Masters in Optics and Photonics and then a PhD in Experimental Solid State Physics, specifically the design and characterization of high efficiency III-V photovoltaics. During my PhD I was able to collaborate internationally, spending time in spectroscopy laboratories in France, Australia and Japan.

These experiences opened my eyes to a world of opportunity and after completing my PhD I moved to Washington DC to work at the U.S. Naval Research Laboratory, where I have been based for the last five years as a National Academy of Sciences Research Associate, Karles Fellow and finally staff scientist.

My research focuses on the development of new photovoltaic technologies for applications including powering unmanned vehicles, remote communications and signalling, and satellites for imaging, communications, navigation and meteorological monitoring. The criteria for these systems is very different from standard domestic roof-top photovoltaics, with weight, flexibility, efficiency and tolerance to radiation exposure being important performance parameters. These innovations will benefit many aspects of modern life including agriculture, the emergency services and individual mobile connectivity. This work has involved the development of novel III-V alloys, the characterization of high E-field regimes of operation such as hot-carrier effects in quantum confined nanostructures and the advancement of III-V device fabrication and processing techniques for ultra-thin, flexible systems.

At the Naval Research Lab I have been able to collaborate with a variety of experts, ranging from early semiconductor pioneers through to space flight directors. The transition of technologies from concept, through laboratory development onto field implementation requires many different specialties and I believe my new joint appointment with Physics and Materials will enable this kind of translational research by bringing together strengths from both departments.

Unfolding Thinking – Nano Art-Science Exhibitions in the Cavendish Laboratory

LES BICKNELL is artist-in-residence at the Maxwell Centre EPSRC-funded Nano Doctoral Training Centre (NanoDTC). His work has been stimulated by living and working with members of the NanoDTC, now more than a hundred researchers strong. His imagination was caught by two areas of the Laboratory, the Maxwell display in the Administration Area and the old exhibition cabinets in the museum area. He explains how his thoughts developed in producing two wonderful exhibitions inspired by nanoscience.

Within a very short period of encountering the NanoDTC one is quickly divested of the notion that science is a fixed rigid occupation. Within the world of nanotechnology thinking is fast and fluid, creative connections are made which always lead to interesting conversations. It was this interdisciplinary, inclusive, outward thinking approach that attracted me to working in the Maxwell Centre.

In the initial phase of the residency, I attempted to assimilate the wide range of processes and activities with which the first year Nano PhD students engaged. I encountered many concepts initially beyond my understanding of the world but now realise that they very much underpin it. I slowly became preoccupied with a number of these issues.

One day whilst attending a practical demonstration I had the sensation of my mind drifting slightly as yet another truly extraordinary piece of information was imparted that I was unable to fully comprehend. In an attempt to grasp an understanding I started to watch the hands of the demonstrator, there was an urgency as they used every human muscle and articulation they had to communicate.

The space of not knowing occupied by an outsider created a revelatory moment. I saw that they were using subconscious hand gestures to explain complex scientific concepts and lab processes. I started to map these gestures in the lab; drawing and filming them. This generated a series of articulated bookworks and films that embody, reflect and have the potential to re-enact these extraordinary movements in time and space. The bookworks and films went on to be conceived as tools for thinking, a vehicle for meditation on ideas or a way to engage with the brain 'side-on'. Often the structures I created were connected to various research strands students were engaged in or represented chemical structures or concepts within nanotechnology.

I encountered a number of machines that map the topology of surfaces of material by firing electrons at them. The evidence of this activity is mapped, the space between surface and probe, or the interaction of electrons and material providing answers. The cast work follows a line of enquiry that looks at this phenomena. Science appears to be interested in the surface but what of the space between, the non or negative space, can this be mapped and made physical? I have been making physical something that cannot be seen by casting, the negative space of the folding structures that explored the hand gestures, fixing a moment in time.

What does science look like? Electron microscopy in combination with the imaging software create a science aesthetic which exudes trust. Working with software more familiar to the art world I have developed a number of images and films that mine this science aesthetic creating a dialogue around what information looks like. The affect on the individual of the materiality of the spaces in which science is enacted and the attire worn in those spaces, the lab, clean rooms, glove boxes, suits and gloves.

Thinking about making and making through thinking. For artists, the majority of the work they create is invisible to a public outside their studio. This work often takes the form of sketches, notes and material tests existing in notebooks and discarded objects in the studio on its way to becoming something 'finished'.

OPPOSITE: The Maxwell exhibition area showing the juxtaposition of artefacts from Maxwell's time with the nano-inspired three-dimensional structures reflecting the perception of the nanoworld.

LEFT: The museum area contains the beautiful old display cases for scientific instruments with forty eight drawers underneath. This was the inspiration for Les Bicknell's cabinet of curiosities, displaying sketches for works in progress, which become artworks in their own right. The visitor is invited into the workshop of the artist's imagination. Examples of the contents of the drawers are shown below.

The collection of double page spreads are a form of visual note book. The pages act as a repository for some of the pieces or 'props' that were created for and used within finished film pieces. The spreads are full of ideas, possible starting points and contain many elements of the finished works - they are in effect a sort 'look book' or 'mood board' of the project.

The idea of revelation is at the core of my history with the book. Here the action has been recreated by literally opening drawers to reveal the inner space where ideas are stored. The placing of the pieces reference the late 19th century practice of displaying objects within cabinets of wonder or curiosity.

Much of my work has been about exploring space, the space between and the space of making, the idea of negative space and ignored space. The articulated structures have become contemplative tool for thinking, objects that heighten an awareness of the hand movements used whilst demonstrating scientific processes. They are starting points to consider actions in space.

When working within science one is confronted by the phenomena that is the laboratory, it is a controlled, managed environment. Every aspect is monitored, every action is considered and in some way constricted, a place where one becomes conscious of body. But the mind is free to wander. The space attempts to be a 'non space' that is neutral and repeatable, in which the controlled factors enable the focus of activity to be on the samples, the actual science one is working on.

The glove box and the laboratory are very specific spaces which have their parallel in the art world. The artist studio is traditionally a space of making and the gallery of displaying conclusions, so the laboratory/ gallery correlation is not an exact match, but I started to think about the parallels that these spaces have.

The white box of the gallery is a physical and conceptual space that attempts to enable viewers to see art without restrictions or connections. Its function is to neutralise the materiality of the space, to enable the focus to be on the work, to place art at the centre. Obviously no space is neutral and each have their meanings which can be read but the aspiration to create a static continuum brings to mind Heraclitus 'No man ever steps in the same river twice, for it's not the same river and he's not the same man.' It appears that science and art are constantly trying to create a time and space where the river is still.

LES BICKNELL

Other examples of Les's works are on display in the Maxwell Centre and in the Department of Materials Science and Metallurgy.

Les Bicknell is Course Tutor, Book Arts MA, UAL Camberwell College of Art, Senior Lecturer in Textile Design BA, Norwich University of the Arts and Visiting Tutor; Fine Art MA, Open College of the Arts.

See also: https://unfoldingthinking.blogspot.co.uk

Using the Gaia satellite to detect low frequency gravitational waves

ANTHONY LASENBY has been investigating the use of data from the Gaia astrometry satellite to detect very low frequency gravitational waves in the universe with colleagues from the Institute of Astronomy and the Department of Applied Mathematics and Theoretical Physics. He describes this work, which has recently been published and highlighted in Physical Review Letters.[1]

When the Advanced LIGO Observatory in the United States made the first detection of gravitational waves in September 2015, they observed the signal from the final stages of the coalescence of two black holes, each of mass about 30 times that of our sun. It was not previously known that black holes existed in this mass range and this was, in a sense, a 'double first' for this remarkable discovery. We know, however, that in the nuclei of galaxies, much larger black holes exist, with that at the centre of our own Milky Way galaxy known to have a mass of about 4 x 10^6 $M_\odot$. This is relatively modest compared with the supermassive black holes in the centres of massive galaxies, which span the range up to about 10^{10} $M_\odot$.

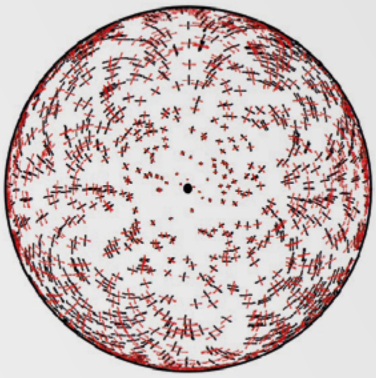
Mergers and collisions between galaxies are quite frequent (Fig. 1), and when they occur the black holes in their centres may end up in orbit about each other, forming a supermassive binary pair. These will gradually lose energy by gravitational radiation, very much like a scaled up, and slowed down, version of the binary pair of black holes which led to the first detection. We don't have to wait however until they finally merge in order to have a chance of detecting such pairs. The frequency of gravitational waves emitted before the final stages is likely to be in the range 10^{-9} to 10^{-6} Hz, for which there is no chance of detection from the ground, but two other methods show promise for detecting such waves using current astronomical observations.

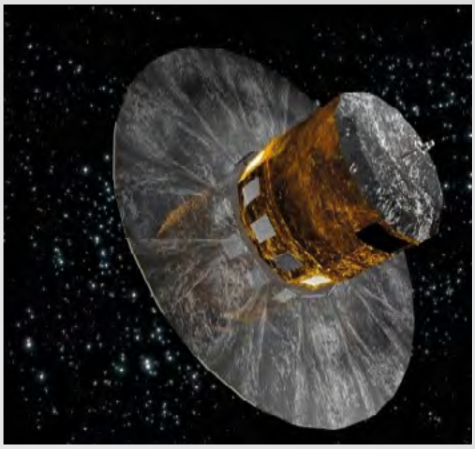
The first uses a 'pulsar timing array', which is a collection of a number of pulsars. These rapidly rotating neutron stars are monitored continuously to search for correlated changes in their frequency as a gravitational wave sweeps over them and the Earth. The Astrophysics Group at the Cavendish is already strongly involved in such efforts, and in the future the Square Kilometre Array will provide a big increase in the number of such pulsars and the accuracy of the timing available to study this effect.

The second method is the subject of the recent paper by my colleagues and myself and involves not looking for frequency changes as the GW passes by, but for changes in the apparent positions of celestial objects. According to general relativity, a gravitational wave is responsible for changing the proper distance between objects as it passes by. For a given polarisation of the wave, distances in one direction are compressed, whilst distances in the orthogonal direction are expanded, and then vice versa as the wave progresses. This is how the LIGO interferometer works, in which the lengths of the two perpendicular arms are compared.

A gravitational wave also changes the directions that light waves appear to come from. If the star lies at several gravitational wavelengths from the Earth, all objects in a given direction in the sky will appear to execute a sinusoidal motion, back and forth along a line tangential to the sky. This effect is illustrated in Fig. 2, in which a gravitational wave travels from one pole of the celestial sphere - the black and red lines indicate the induced apparent motions of the stars within a hemisphere, exaggerated by a large factor to make them visible, and corresponding to the two possible polarisations of the wave.[2] The wavelength of gravitational waves with frequency 10^{-8} Hz say, is about 1 parsec, hence the 'far-field' approximation which leads to this pattern is likely to be well-justified for nearly all stars in the sky.

We need an instrument which can give us exquisite sensitivity to changes in apparent stellar positions, for a large number of stars, covering the whole sky, and which ideally can make many repeated measurements for a given star over a timescale of a few years (10^{-8} Hz corresponds to a period of about 3 years). The Gaia satellite, launched in 2013, is ideal for this purpose (Fig.3). It will take up to 70 measurements of the position of a star over a period of about 5 years, the current mission lifetime, for at least 1 billion stars in the Galaxy, as well as of order ½ million quasars. The measurement accuracy per star, in terms of how well its position can be determined, is very impressive, amounting to the angle subtended by a human hair at a distance of about 1000 km for the brightest stars, but this is orders of magnitude greater than the values needed to detect a plausible gravitational wave. We can make this factor up, however, by the fact that Gaia is able to carry out this measurement for at least a billion stars around the sky. This





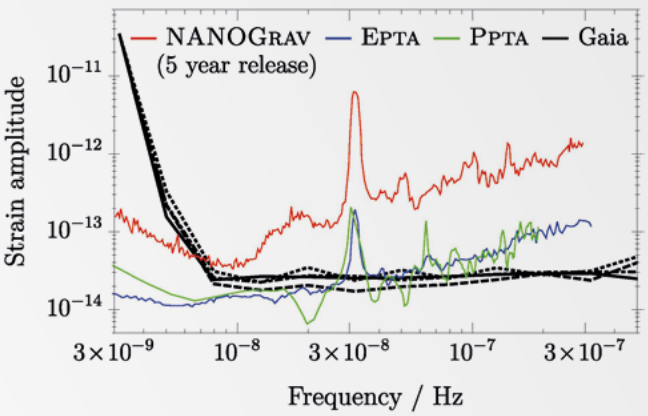


FIG. 1. (top left) The colliding galaxy pair NGC 5426 and NGC 5427, jointly known as Arp 271. It is thought the Milky Way will collide with our own nearest large neighbour, the Andromeda Galaxy, in about 4 billion years time. (Credit: Gemini Observatory)

FIG. 2. (top centre) A projection of the Northern hemisphere of the sky in which a GW is coming from the North pole (marked with a black dot) and the black and red lines show the apparent stellar motions

FIG. 3. (top right) Artist's impression of the Gaia spacecraft. (Credit: European Space Agency)

FIG. 4. (bottom) The black curves show the strain sensitivity of the final Gaia data release using different time samplings. The coloured lines show 95% upper limits from various current PTAs

brings its own problems in terms of data fitting to a sinusoidal component for so many objects, and one of the main features of the work in our paper is to show how the enormous dataset can be compressed by a large factor.

This is accomplished by a Voronoi tessellation of the celestial sphere, in each cell of which the coherent motions over the cell means that results for individual stars can be represented by a single 'virtual star' at the cell centre. For each star we assume its individual mean proper motion, represented by linear and quadratic terms, has been determined already, before this averaging – it is the sinusoidal 'wobbles' in position, with a coherent spatial pattern in the sky at a given frequency in time, that we are looking for. Using these methods, Fig. 4 shows the projected sensitivity of Gaia for the detection of very low frequency gravitational waves. It can be seen that Gaia's full mission sensitivity is comparable to that from current and near-future pulsar timing arrays, and improves slightly on these at frequencies greater than about 10^{-7} Hz. This provides a totally independent method to that provided by pulsars.

A further interesting possibility is provided by the fact that within *modified gravity* theories, the possible polarisation states of a gravitational wave can depart from those in general relativity. These polarisation states can be quite difficult to detect via laboratory-based detectors, but they give rise to quite *different* patterns on the sky compared with those shown in Fig. 2, and thus to the possibility of quite stringent tests of alternative gravity theories. This study will be the subject of a further paper.

Anthony Lasenby is Professor of Astrophysics and Cosmology at the Cavendish Laboratory and the Kavli Institute for Cosmology. The paper by Moore et al. was selected as Editor's Choice and featured on the front cover of a recent issue of Physical Review Letters.

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1. Moore, C.J., Mihaylov, D., Lasenby, A. & Gilmore, G. , Phys. Rev. Lett., 119, 261102 (2017).
2. For those familiar with the idea of spin in particle physics, the four-fold rotational symmetry of the effect visible in this plot is a good illustration of the spin-2 nature of the graviton!

Winton Symposium on Energy Storage and Distribution

The Winton Annual Symposium is one of the highlights of the academic year. Remarkably, the 2017 event was the sixth symposium, all of which have explored different aspects of the sustainability agenda. The 2017 Symposium concerned Energy Storage and Distribution.

Richard Friend, Director of the Winton Programme, welcomed the large and diverse audience to the Cavendish and to the sixth Winton Symposium. There is now optimism that we can produce renewable energies at costs that are comparable to or lower than fossil fuels. In favourable locations, this is now realised. We can expect efficiencies to improve and costs to continue to fall, because in many cases we are still far from the limits set by thermodynamics. The challenge of approaching these limits requires new science, the goal of the Winton Programme.

The 2016 Symposium explored the rapidly advancing science and technology of solar cells. However, the sun does not always shine (or the wind blow), and energy is not usually generated where we want to use it. So we need to move and store energy. We also include a presentation on the state-of-the-art of hydrogen fusion reactors, as this field moves towards sustained fusion at the ITER reactor.

Howard Wilson, Programme Director of the UK Atomic Energy Authority, described the 'Path to Delivering Fusion Power'. Our local fusion reactor is the sun, but for fusion to be viable on earth we need an interdisciplinary collaboration of the physical sciences, engineering and technology to tackle some major scientific and engineering challenges. Nuclear fusion is very attractive; there is plenty of fuel, no greenhouse gas emissions and the process is inherently safe in that there is no chain reaction.

The most accessible reaction is the fusion of deuterium and tritium, generating energetic alpha particles, later to become helium atoms, and neutrons, but this process requires temperatures above 10^9 K, 10 times that at the centre of the sun. These temperatures were achieved over 25 years ago. The bigger challenge is to control the density and to confine the particles in the complex plasma state at these temperatures. Other issues include the management of damage from the high-energy neutrons to the heat absorbing 'blanket' and the exhausting of the extremely hot gases from the fusion chamber.

The JET (Joint European Torus), built at Culham in the 1980s, advanced magnetic confinement using the tokamak design. Advances in the 1990s were in understanding the plasma physics and creating longer confinement times. In pulsed mode, JET is now able to produce as much energy output through fusion as the energy used to generate the plasma. The next breakthroughs will be enabled by the \$15 billion ITER (International Thermonuclear Experimental Reactor) global project, due to be operational in 2025. ITER has 8 times the volume of JET and is designed to demonstrate 10 times as much output as input power.

Katsuhiko Hirose (above), Visiting Professor at the International Institute for Carbon Neutral Energy Research, Kyushu University, joined the Toyota Motor Corporation 35 years ago. He has been involved in two major innovation projects; the Prius electric hybrid vehicle and the Mirai hydrogen fuel cell vehicle. The ethos at Toyota is that to 'do nothing' would be a greater risk. His presentation 'Hydrogen as a vector toward the sustainable society' focused on the latter project and the broader implications of moving towards a hydrogen based economy.

Hydrogen fuel cell cars were not thought to be viable 10 years ago because of concerns about the high usage of platinum, high costs and storage. Since then, fuel cell prices have decreased markedly, with the volume power density improved by a factor of 20 and a correspondingly reduced requirement for materials. Storage with compressed hydrogen has become the most effective and simplest approach. These advances and the benefits offered of high recharge rates of only 3 minutes, long range of 600 km and zero emissions at the point of use make hydrogen vehicles commercially attractive.

Hydrogen is also viable for grid networks, with upfront costs recoverable in 20 years. The price also remains stable, as opposed to fossil fuels, which vary significantly, making this an attractive investment. In addition, hydrogen can be a feedstock for making methanol, making it a valuable asset. The future for hydrogen is promising with estimates that it will provide 13% of the total energy requirement by 2050.

David Larbalestier, Director of the Applied Superconductivity Center at Florida State University, reviewed the 'Prospects for the Use of Superconductors for Energy Storage and Distribution'. Low (LTS) and high (HTS) temperature superconductors are at the technical level at which they could be used for 'green' energy applications. There are designs for energy storage in large volumes of high magnetic field, up to football stadium sized systems for energy storage on the GWh scale, but these are far from commercial viability. The missing link has been making the conductors cost competitive with copper and iron.

Superconductors were discovered in 1911 by Kammerling Onnes and the means for generating high fields identified early on. The technology was spurred by two major breakthroughs. The first took place in the 1960s at Bell Labs where high current densities were demonstrated; the second occurred in the 1980s when HTS materials were discovered. The majority of applications still use LTS such as Nb-Ti and Nb_3Sn which need cooling with liquid helium. HTS materials that can be cooled by liquid Nitrogen are needed for larger scale applications.

The 'killer app' for superconductors is the ability to generate very high magnetic fields or low fields in large volumes. His group at the National High Magnetic Field Laboratory is producing world leading high field systems with 32 Tesla in production and 40 Tesla under development. An example where fields in large volumes are needed is the Large Hadron Collider at CERN which uses 1500 tonnes of LTS cables and thousands of HTS leads, storing 15 GJ of magnetic energy.

A challenge is making the materials more homogeneous and less sensitive to crystallite grain boundaries. Current materials science research is progressing with systems that are 'single crystal' on the km scale for energy distribution. Wider HTS adoption requires the costs to be reduced by a factor of 10, which will be possible through clever materials engineering.

Munaf Rahimo gave a prospective review of 'Power semiconductors for grid system power electronics applications', based on his experience at Asea Brown Boveri (ABB) where he is Corporate Executive Engineer in the Grid System Division. ABB employs over 130,000 people globally and is enabling stronger and greener grids.

One of the key technology enablers is the shift to ultra-high DC (UHDC) systems that are more efficient than AC systems for power transmission across distances greater than 300-400 km. An area that has seen considerable development at ABB is based on voltage source converters. These are able to operate at voltages up to 500 kV, handling up to 3GW with an efficiency loss of less than 1% over distances of 1,000 km. The cables can be over-head or land- or sea-based and so have many applications.

To modulate the power at these high voltages, large numbers of power electronic devices are connected in series. A High Voltage DC line has typically 7000 stack packs of devices per converter with the whole system using about 100m^2 of silicon area. The performance of these power devices in the past has been driven by size and power, with efficiency and reliability now becoming more important. Research is focusing on high bandgap alternatives to silicon with SiC and GaN the forerunners. The main benefit is that devices can be made thinner and so operate at higher voltages with less inductance and thereby reducing switching losses. Devices operating at 3.3 kV are already available and in principle devices operating at 20-30 kV could be constructed.

Rosa Palacín (overleaf) of the Institut de Ciència de Materials de Barcelona provided a brief history of battery technologies; from the early work of Volta in the late 1700's to the lead-acid and nickel-based batteries

of the 1800's, still in use today. The current battery technology of choice is the lithium (Li)-ion battery. This was based on scientific studies of Li intercalation in the 1970's and 80's and commercialised by Sony in 1991. In her talk 'Battery energy storage beyond Li-ion' she described some future options for batteries.

The performance metrics are application dependent, with portable devices driven by energy density, vehicles by safety and cost and grid storage by cost and reliability. Sustainability factors such as water-energy footprint, recycling and abundance of materials are also becoming more important as more batteries are produced.

Sodium(Na)-ion batteries are interesting as Na is more abundant than Li, and does not alloy with Al, enabling low cost Al current collectors to be produced. Although there are some chemical similarities between Li and Na there are significant differences and new ion-insertion electrodes have had to be developed. Na prototype devices have now been made with comparable performance to Li, but these will not be available in products commercially for a number of years.

Another approach is to move to divalent ions such as magnesium (Mg) and calcium (Ca) to increase the energy density. The former has attracted considerable interest since 2000, but many issues still remain, including finding a suitable electrolyte. Rosa's research has focused on Ca for metal anode devices; it has been shown that Ca can be plated and stripped and electrodes from $CaMn_2O_4$ have promising performance.

A number of challenges remain in several areas, but there is optimism that these will be overcome.

Professor David Greenwood, leads the Advanced Propulsions Systems Group at the Warwick Manufacturing Group. In his talk on 'The future for zero emissions transport', he discussed how transport is strongly linked to economic growth, but how can we reduce emissions? We can manage demand or use technology to be more efficient, but the only way to reach zero emissions is by reducing the carbon content in fuel.

Liquid fuels based on bioethanol and biodiesel are one option, but these result in local emissions and often compete with crops - another is hydrogen, reviewed earlier. The best solution is to switch to electric propulsion, although this depends on how the electricity is sourced; nuclear and wind energy produce lifecycle emissions of 5gm CO_2/kWh and at the other extreme, brown coal produces up to 1000gm CO_2/kWh. The good news is that the carbon intensity of electricity is reducing in the UK with the shift to renewables and the phasing out of coal.

For electric vehicles, the battery has an energy density that is relatively low compared to fossil fuels. This means the size of the battery is very large - the car has to be designed around the battery. An even bigger challenge is the cost of the battery; for a fully electric vehicle this is around €10,000, an order of magnitude more than a conventional engine. The promising news is that the cost has dropped from $1,000/kWh to < $250/kWh in 8 years. The energy density has doubled in the same period.

Battery performance will continue to improve, through the developments discussed above by Rosa Palacín, and batteries are expected to be produced that are factors of two smaller, cheaper and longer lived over the next 20 years. These batteries will need to meet high safety standards and effective procedures developed for recycling. These activities are aligned with the Faraday Challenge, a £250M government research programme for developing batteries in the UK.

David concluded that the transition to zero emission passenger electric vehicles will take place in the next 20-30 years as research leads to performance and price improvements and the electricity source de-carbonised.

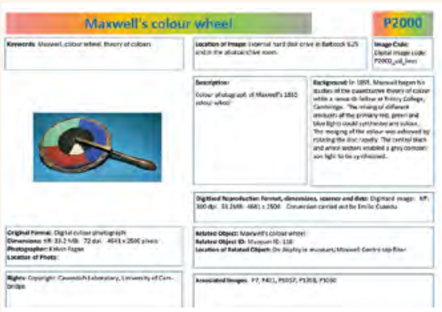
RICHARD FRIEND AND NALIN PATEL

Undergraduate Summer Research Projects – A Real Win-Win Development

The competition for places on Masters and PhD programmes is now very intense, and outstandingly accomplished students are challenging each other to carry out their graduate research with us and at other top institutions worldwide. Most undergraduate courses contain some element of research nowadays, but it is becoming apparent that, in winning selection competitions for PhD study, it is an enormous advantage if students have been able to undertake one or more independent research placements during their undergraduate careers. This is a familiar experience for many students who have studied abroad, but is much less commonplace for a large fraction of our own undergraduate class. In fact, it is now almost mandatory to have done this, if our students wish to be accepted on the most prestigious PhD programmes.

For the past three years the Laboratory has been making a new substantial contribution to support our high-performing class through its **Long Vacation Bursaries Scheme.** This allows Cambridge undergraduates in their current Part IA, IB and II years to work in research teams in the Laboratory as significant contributors to real research projects. Last year Departmental funds were able support 10 bursaries, but with a headcount of over 350 in Parts IB and II alone, these opportunities are hugely oversubscribed. This year the Head of Department has agreed to an increase in funding of 30%, and so we are offering around 16 places, three of which have been leveraged from the School of Physical Sciences EPSRC studentship award on the basis of our Departmental support.

The bursaries cover student maintenance costs for up to 10 weeks and up to £500 of hardware or consumable costs associated with each student's research. Typically, the total costs are around £3000 per candidate.


Maxwell's colour wheel
P2000

The bursaries are proving of great value to the students and to our research programme. For example, last year Matthew Le Maître worked with my colleague Dr John Young on a study investigating the potential of modern astronomical infrared synthesis telescope arrays for imaging geosynchronous satellites. These expensive assets are completely unresolved by any ground-based telescope, and so even a rudimentary imaging capability may have significant commercial potential (Top. Upper figure).

We are also very happy to take on students from other Universities for summer positions. Thanks to the generosity of one benefactor we have been able to take on summer students from non-Oxbridge universities. These have proved to be very valuable experiences for the students, all of whom have been inspired by their summer research opportunities. They have gone on to obtain first class degrees and a determination to carry on to PhD studies. Not all the placements offered have involved pure research projects, but they are all invaluable in deepening the students' understanding of physics. For example, your editor took on a summer student two years ago to redesign completely the Cavendish museum signage, making the stories behind the artefacts much more accessible. And last summer, a student did a wonderful job in helping create a digital PhotoArchive of the many historical images of life and research in the Laboratory. In the process, the student had to understand how the apparatus worked and the background to the discoveries which followed.

This programme costs the same as the Long Vacation Bursaries Scheme and both types of scheme are splendid targets for philanthropic funding. Sponsoring undergraduate student placements on summer projects is an extraordinarily valuable contribution to enhancing the prospects of our most talented scholars and also for developing the trained research pool of bright young people for the benefit of the UK as a whole.

CHRIS HANIFF

Chris is Professor of Physics in the Astrophysics Group, the Director of Graduate Education, and Deputy Head of Department (Education).

TOP: A "true" and near-infrared reconstructed image of DirectTV-9S assuming a state-of-the-art 10-element synthesis telescope. The reconstruction is not perfect, but can be compared with the best possible conventional ground-based image which would contain a single featureless pixel approximately 2 times larger than the fields shown above.

BOTTOM: An example of the PhotoArchive Catalogue 'file card' for Maxwell's colour wheel developed by Emilio Cuandu. The items in the Cavendish PhotoArchive will be going on-line in 2018.

Many congratulations to Lisa Jardine-Wright on the award of a 2017 Pilkington Teaching Award

ABOVE: Lisa receiving her award from Pro-Vice-Chancellor for Education Graham Virgo QC

The citation reads as follows:

'Dr Lisa Jardine-Wright has made an outstanding and sustained contribution to excellent teaching in Physics and Mathematics, both within the University and beyond, for many years. Lisa previously taught mathematics in the Natural Sciences Tripos but currently teaches undergraduate physics, for which she receives high student praise. Students commend her high quality notes, use of visual aids, and well placed interludes to keep her sessions engaging. One student wrote, in all caps, that she provides 'THE BEST NOTES EVER!'

Lisa is also the founding co-director of the incredibly successful **Isaac Physics project,** which offers support and activities in physics problems solving to help with the transition from GCSE though A Level to University. It includes online study tools, videos and live-streamed tutorials. The project currently has over 100,000 subscribed users, and through helping to address the skills gap students are experiencing, is educating the next generation of university physicists from all over the world.

Further to this, Lisa has made many other vital contributions to Physics teaching including sitting on the Physics Teaching Committee, taking a lead role in the development of the new admissions test, acting as a Director of Studies and taking part in many outreach projects in her role as Educational Outreach Officer of the Cavendish Laboratory.'

Mastering GCSE Physics

Lisa introduces a new Isaac initiative to help students studying GCSE Physics

Launched at the start of the new school year 2017, *Mastering GCSE Physics* from the Isaac Physics Project has prompted nearly 10,000 users a week from 1,000 different schools to engage with problem solving in physics online. Lisa, co-director of the Isaac Physics project, stated:

"After our success with Mastering Pre-University Physics, we were excited to launch the new GCSE book and waited in anticipation for the impact. We are delighted with yet another September upsurge in the numbers of students and teachers engaging with Isaac."

The GCSE and A-level books are available at a cost price of £1 each from the Isaac website at: www.isaacbooks.org.

Isaac Physics is a national project funded by the Department for Education to provide access to resources, events and physics specialist expertise to all students, irrespective of location or school, with or without their teachers' involvement. We also support teachers and reduce their workload by providing online marking and report generation as well as free continuing professional development events across the country.

Students' comments from a recent survey:

"Thank you very much! I really enjoy Isaac physics and I love doing a couple of questions for homework each night. The book is amazing to make sure you understand concepts from class fully."

"Isaac Physics has helped me to understand concepts (e.g. series in circuit and parallel) by working on 10 or more questions on the same circuit. Sticking with the same problem for a whole piece of homework has ensured that I am confident with it before moving on. Isaac Physics is helpful in checking my answers as I work through the questions, meaning I won't carry mistakes. Submitting answers as I work through each question boosts my confidence on-the-go."

"I have seen massive improvements in physics A level past papers and

tests and I feel more enthusiastically about the subject. It's a great website, thank you :)"

"It's improved my scores in tests by around 25%"

Teachers' are reporting the following observations:

"The automatic feedback to students and the ability to have automatic results by question for each student is really valuable. It saves some marking time, which can be better used in planning, while still allowing teachers to get the assessment data needed to plan effectively."

"Confidence and aspiration improve after achieving mastery in a topic."

"Better return rate to homeworks. The students know that I am checking on their progress. They appreciate the instant feedback scores."

"Test scores are higher following Isaac work"

"Hard to do direct comparisons, but I'd estimate that pupils are about 1 grade up on equivalent pupils pre-Isaac."

Isaac shows students that physics is not just something that you can either do or not do. Physics, like playing football or the piano, takes practice and Isaac's thousands of online problems, graded from GCSE through to first year university level, provide the opportunity to practise wherever or whoever you are. And if users do not have specialist physics support or have questions they want to ask, the Isaac team are there to help through free online tutorials, our mentoring scheme and events across the country.

If you would like more information about this topic, please contact Lisa Jardine-Wright at 01223 337042 or email lisa@isaacphysics.org

Please note that the statistics shown below change daily.

Number of question attempts since launch:	**15,081,098**
Daily question attempt max:	**99,000**
Registered Users:	**104,817**
(56,038 active in the last 6 months)	**34% female**
(compared with 21% at A-level)	
Registered Teachers:	**4,864**
Number of Schools:	**2,878**
State Schools:	**78%**

How you can contribute

Online Giving

The University's Office for Development and Alumni Relations (CUDAR) has made it easier to make donations online to the Department and to two of our special programmes. If you wish to make a donation to the Department, please go to:

campaign.cam.ac.uk/giving/physics

If you wish to support the graduate student programme, please go to:

campaign.cam.ac.uk/giving/physics/graduate-support

If you wish to support our outreach activities, please go to:

campaign.cam.ac.uk/giving/physics/outreach

If you would like your gift to be applied to some other specific aspect of the Development Programme, please contact Andy Parker or Malcolm Longair. The Development portfolio is at:

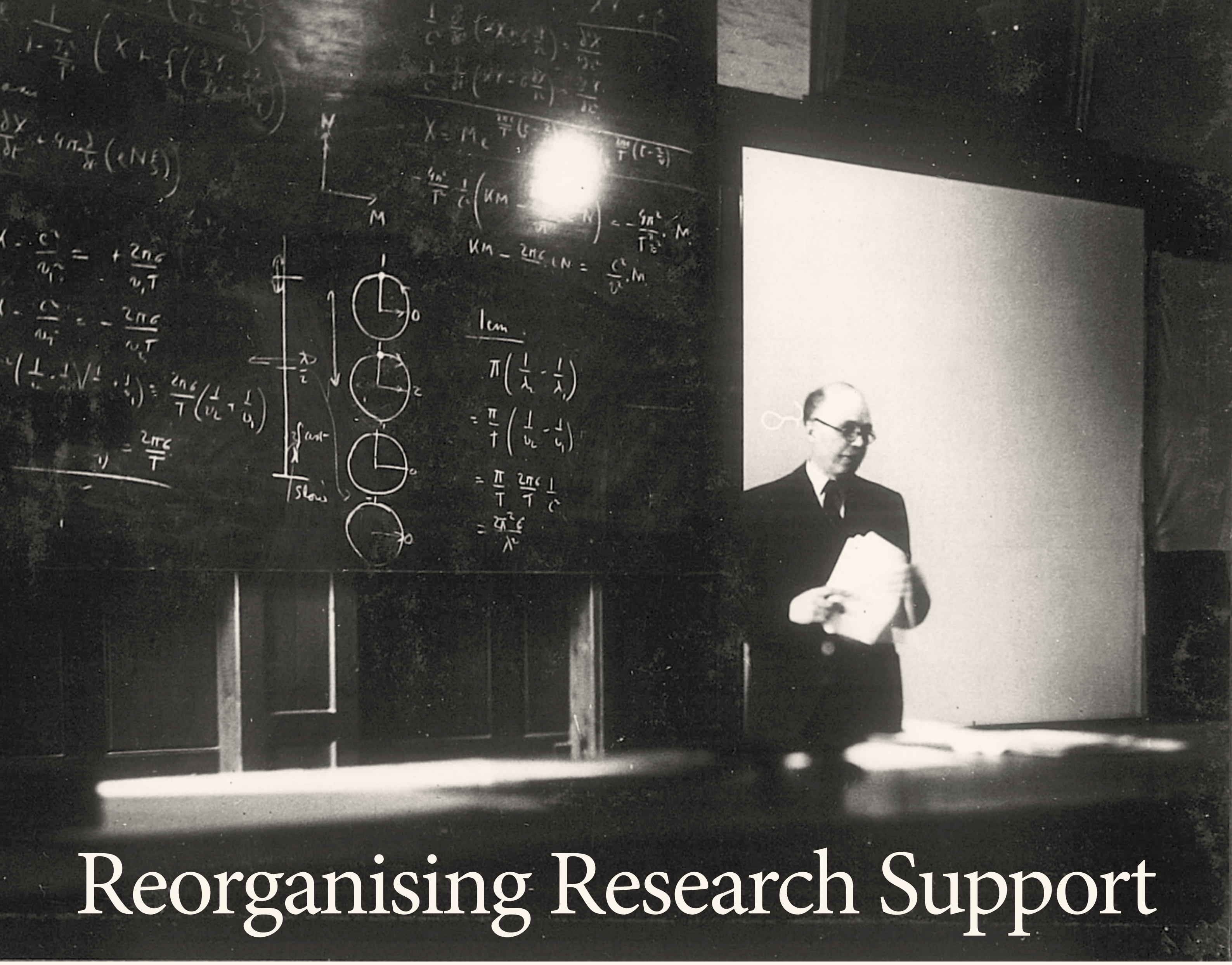
www.phy.cam.ac.uk/development

A Gift in Your Will

One very effective way of contributing to the long-term development of the Laboratory's programme is through the provision of a legacy in one's will. This has the beneficial effect that legacies are exempt from tax and so reduce liability for inheritance tax. The University provides advice about how legacies can be written into one's will. Go to: **campaign.cam.ac.uk/how-to-give** and at the bottom of the page there is a pdf file entitled **A Gift in Your Will**.

It is important that, if you wish to support the Cavendish, or some specific aspect of our development programme, your intentions should be spelled out explicitly in your will. We can suggest suitable forms of words to match your intentions. Please contact either Malcolm Longair (**msl1000@cam.ac.uk**) or Gillian Weale (**departmental.administrator@phy.cam.ac.uk**) who can provide confidential advice.

If you would like to discuss how you might contribute to the Cavendish's Development Programme, please contact either **Malcolm Longair** **(msl1000@cam.ac.uk)** or **Andy Parker** **(hod@phy.cam.ac.uk)**, who will be very pleased to talk to you confidentially.



Reorganising Research Support

ABOVE: Lawrence Bragg lecturing on optics in the Maxwell Lecture Theatre in about 1940. Snapshot by J.F. Fletcher, copyright Cavendish Laboratory. This image will be available in the forthcoming Cavendish PhotoArchive.

In CavMag18, a new vision for the development of the Laboratory's research programme was described, the result of a long process of consultation and discussion within the Department. The aim of this thematic approach is to encourage inter-disciplinarity, which has always been present in the Department's programme, but not as explicitly as it needs to be in the coming years. There is huge discovery space at the interfaces between the traditional physics disciplines and with cognate subjects such as chemistry, materials science, biology, the life sciences and so on. This is where we need to be, particularly as we plan the research ethos of the new Cavendish Laboratory in a few years' time.

The group structure for research was initiated by Lawrence Bragg in the immediate post-World War II years to cope with the greatly increasing size of the Laboratory and the need to provide many more trained physicists for the needs of society at large. The pre-War dominant research area had been nuclear physics and the understanding of the structures of atoms and nuclei under the magisterial direction of Ernest Rutherford. At the same time, new disciplines were on the horizon, the seeds of which were present before the War, but which now began to develop into major research areas in their own right. These included Radio Science (to become Radio Astronomy), Crystallography, Low Temperature Physics, Metal Physics, Fluid Dynamics, Theoretical Physics, Electron Microscopy, Meteorological Physics, as well as smaller activities such as Lubrication and Friction.

Bragg had pondered the issues of research support during the War Years and published two articles in *Nature* about what he considered to be necessary reforms. He wrote:

'… the ideal research unit is one of six to twelve scientists and a few assistants, together with one or more first-class mechanics and a workshop in which the general run of apparatus can be constructed.'

The Mott Hub

The Mott Hub, supporting the Molecular Electronics (ME), Quantum Matter (QM), Semiconductor Physics (SP), Surfaces, Microstructure and Fracture (SMF), Theory of Condensed Matter (TCM) and Thin Film Magnetism (TFM) Groups.

From left to right: Romy Hall (Administrative Assistant), Richard Lidstone (Human Resources and Events), Diana Eddy (Hub Administrator), Gillian Burrows (Finance Administrator).

The Kapitza Hub

The Kapitza Hub, supporting the Optoelectronics (OE), Microelectronics (ME) and NanoPhotonics (NP) Groups.

From left to right: Jennie Nelson (Hub Administrator), Janette Roberts (Human Resources and Events Administrator) and William Mortimer (Finance Administrator). An Administrative Assistant will be appointed in the near future.

The Rutherford Hub

The Rutherford Hub, supporting the Astrophysics (AP), Atomic, Mesoscopic and Optical Physics (AMOP), Biological and Soft Systems (BSS), High Energy Physics (HEP) and Quantum Sensors (QS) Groups.

From left to right: Kayleigh Dunn (Administration Assistant) , Amelia Bloomfield (Human Resources and Events Administrator), Steve Day (Finance Administrator) , Viv Chou (Human Resources and Events Administrator), Sarah Hedger (Hub Administrator). A further Administrative Assistant will be appointed in the near future.

This model proved its value in the subsequent years, each group ultimately containing about 50-100 group members, each group with its own secretary, while central support was provided by the Central Administration under the leadership of the Departmental Secretary, a quite new concept. Bragg's reforms included the academic staff having their own offices and even their own telephones!

As part of the recent review of the Department's scientific programme, the opportunity was taken to determine whether or not the Bragg model was really appropriate for the coming years. The Group Secretaries and Central Administration had done a truly sterling job in supporting the very large programme of teaching and research, but it was progressively becoming unsustainable into the future. The great problem was the huge increase in the requirements for reporting, scrutiny of the research and teaching programmes, accountability and human resource management, all of which were requiring a high level of professional expertise in these disparate areas.

The model which has been developed is one in which the traditional research groups are supported by three 'hubs', each containing professional, experienced administrators in the areas of general administration, human resources, events management, research grants and finance. The personnel in the hubs interact with all the research groups within their defined areas and provide immediate advice on the many complexities of administering and managing an organisation of 1200 people, with the forthcoming challenge of acting as a national support facility for all the physics departments in the UK. The hubs have now been set up and we warmly welcome the numerous new appointees to their roles. The personnel working in the three hubs are introduced in the three boxes above. We wish them good luck in their new roles, which will all present new challenges and opportunities for advancing the work of the Laboratory, as well as their own careers.

GILLIAN WEALE and MALCOLM LONGAIR

The Cambridge Colleges' Physics Experience (CCPE)

The CCPE is a free one day event organised by the Cavendish Laboratory in collaboration with many Cambridge Colleges that has been running for over five years. The one day programme consists of:

- A morning spent at a Cambridge College, with a tour of the college, information and advice about Higher Education and applying to Cambridge.
- An afternoon at the Cavendish Laboratory, including:
    - 1:15-1:45 History of physics in Cambridge
    - 1:45-3:30 Practical physics session and curriculum Physics problem solving
    - 3:30-4:00 Conclusions and final talk

CCPE events aim to increase participation in physics and challenge misconceptions about Physics and studying at Cambridge University. The programme is thoroughly enjoyed by students and teachers alike. For more information, please visit outreach.phy.cam.ac.uk/ccpe

Dates and Year Groups

- 5th-9th February Year 12: Evaluating local gravity
- 19th-24th February Year 12: Evaluating local gravity
- 19th-24th March Year 10/11: Lenses and Optics
- 16th-20th April Year 7/8: Mars Rover Mission
- 7th-11th May Year 9: Forces Challenge

SciArt at the Cavendish Laboratory - 'Making Sense of the World'

SciArt in Cambridge is excited to present the first Cambridge SciArt Exhibition at the Cavendish Laboratory as part of the Cambridge Science Festival. The exhibition will be open during the Cambridge Science Festival, March 2018 and is being sponsored by ZEISS and the Institute of Physics.

The SciArt movement aims to engage a wider audience with Science through Art, reaching people who perhaps would not normally react to, or be interested in, Science. We believe Art can communicate emotionally to people in a way that Science rarely does.

SciArt in Cambridge is a fast growing community of creative people, including artists and scientists, aiming to make the secrets of the world we live in more intelligible and engaging to the human imagination. We are building accessible, friendly and open-minded platforms - meetups, discussions, debates, events and exhibitions - in order to foster and promote collaborations between artists and scientists.

Exhibition Opening Times and Events:

Monday 19th - Friday 23rd March 2018: open daily 10:00 - 16:00

Saturday 24th March: 14:00 - 17:00

Special Events:

Monday 19th March 18:00: Drinks and opening speeches - all welcome

Tuesday 20th March 18.00: Artists event-presentations by exhibiting artist & the science behind their work - booking required

Saturday 24th March: 14.00-17.00 Families workshop with Neural Knitworks (booking required)

Saturday 24th March: 19.00-late. SciArt Soirée - speed-meets, refreshments, music, short presentations designed to get the art and science communities talking and foster collaboration. Booking required.

JACOB BUTLER

The Maxwell Centre – an Update

Photo credit: Robert J. Foster

The Maxwell Centre programme has been growing steadily since the opening in April 2016 (see CavMag 16). We now have a community of over 200 scientists, mostly physicists within the Cavendish Laboratory, but also chemists, material scientists, engineers from around the university and industrial partners from nearly 20 companies. Besides the full time residents and part-time hot-deskers, we are glad to see a steady stream of day visitors and event participants come through the Centre each week, forming a much broader Maxwell Centre community.

One of our resident companies is the National Physical Laboratory (NPL). The Maxwell Centre hosts the NPL's East of England hub and we are growing the relationship between the NPL and the University of Cambridge. The NPL has recently launched a new strategy with four key focus areas: advanced manufacturing, digital, energy and environment, and life science and health. These themes help contextualising directions for future collaborative work. A new call for joint NPL-Cambridge PhD student projects was successfully trialled, and it closed its second intake in December 2017 – we look forward to even more excellent science enabled though this scheme.

Among several new research directions established since the NPL took up residence at the Maxwell Centre, we highlight a new collaboration between NPL and Ulrich Keyser. Jointly, they are developing a rapid opto-fluidic screening platform to quantify the activity and safety of novel polypeptide antimicrobials synthesised by Max Ryadnov. Antimicrobial resistance has severely compromised global health, with the rates of antibiotic discovery falling far behind the development of resistant pathogens. These drugs are a promising new pipeline of antibiotics to treat multi-drug resistant Gram-negative pathogens. This project combines physical methods used in Ulrich's laboratory to create a platform for quantifying the active and minimal doses of promising candidate antimicrobials.

Among other exciting developments at the Centre, we are preparing for the official launch of the Cambridge spoke of the Henry Royce Institute for Advanced Materials Research, which will serve academic and industrial researchers with access to cutting-edge equipment, largely' based at the Maxwell Centre.

We look forward to the upcoming second Maxwell Centre Annual Research Showcase on the 22 March 2018, where the Annual Report for 2017/18 will also be released. The full agenda and registration links will appear on our website in early 2018 – please save the date and join us there!

AGA IWASIEWICZ-WABNIG

Further details of ongoing activities at the Maxwell Centre can be found at: www.maxwell.cam.ac.uk
Contact: Aga Iwasiewicz-Wabnig, Maxwell Centre Programme Manager
ai261@cam.ac.uk

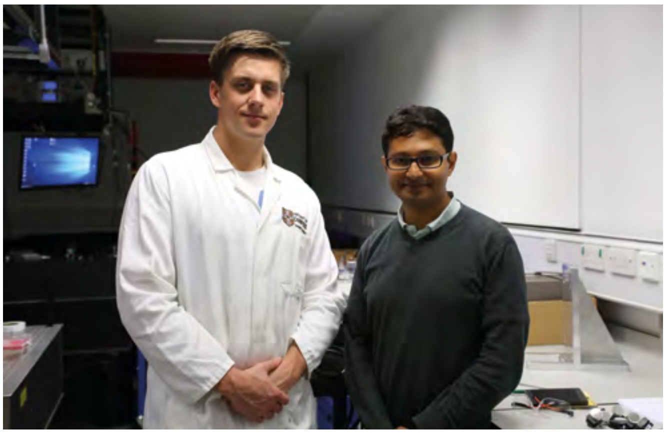
With CavMag 18 being devoted to the future research programme of the Laboratory, we have fallen seriously behind in recording highlights of Cavendish News. In addition, with the changes in the Administration arrangement, there are many new welcomes to be made and new faces to recognise. We cannot include everyone here, but we do extend the warmest of welcomes to all newcomers.

Academic Promotions

We are delighted to report a number of successes in the 2017 promotion round. Many congratulations to:
Professorship: **Ben Grapaios**
Readerships: **Suchitra Sebastian, David Buscher, Alex Mitov, Sarak Bohndiek**

Other Promotions

Many congratulations to:
Senior Technician: **Jim Greenwood**
Senior Mechanical Engineering Technician: **Tom Sharp.** Tom joined the Laboratory as an apprentice in 2012.



Tom Sharp (left) and Akshay Rao (right) in the Akshay's new Laboratory in the Maxwell Centre. Akshay's 2017 IoP award is described on pages 10–11.

Awards:

Many congratulation to:
Didier Queloz on winning the 2017 Wolf Prize (page 11)
Jeremy Baumberg on winning the 2017 Institute of Physics Michael Faraday Medal and Prize (pages 8–9).
Akshay Rao on winning the 2017 IoP Henry Moseley Medal and Prize (pages 10–11).
Nigel Cooper on winning a Simons Foundation Investigator Award.

New Interdisciplinary Lecturers:

Benjamin Béri, Hugo Bronstein and **Louise Hirst.** They describe their careers and research activities on pages 14–15.

Distinguished Fellowship Awards:

Royal Society University Research Fellowships**: Sam Stranks, Lorenzo Di Michele, Chiara Cicarelli.**
Winton Advanced Research Fellow**: Alpha Lee**
Royal Astronomical Society Norman Lockyer Fellowship**: Vinesh Rajpaul**
Herchel Smith Fellowship**: Nadav Avidor**
Royal Society Newton International Fellowship: **Bart Roose, Gerald Delport, Maite Goiriana, Ian Jacobs**
EU Marie Curie Fellowship: **Mark Nikolka, Yuelong Li, Sachin Dev Verma**
Leverhulme Early Career Fellowship: **Guillaume Schweicher**
Gruber Foundation Fellowship: **Laetitia Delrez**

Retirements

Nigel Palfrey retired at the end of 2017. Nigel has been in the Laboratory for 29 years. He is fondly remembered for pioneering the very successful student workshop training programme which he devised and which has had well over 100 graduate students introduced to the arts of workshop techniques and skills. The picture (above left) shows former Workshop Apprentice, Oliver (Ollie) Wadsworth, receiving the Endeavour Award from CRC, accompanied by his rightly proud parents and a very pleased Nigel (right). Ollie has since gained promotion in the Department of Engineering. We will miss Nigel, as will all the grateful graduate students. We all wish Nigel the happiest of retirements.

Two other long standing members of the Laboratory retired earlier this year. **Roger Beadle**, Chief Research Laboratory Technician in the Optoelectronics Group retired after 36 years' of outstanding service to the Department. At his retirement party, Richard Friend said that Roger was mentioned in the acknowledgements of more PhD degree theses than most Professors. **Brian Camps**, Chief Mechanical Workshop Technician, retired after 28 years' of outstanding service to the Department. We wish them both very happy and fruitful retirements.

Departures

We were very sorry to lose some of our long-serving and much appreciated assistant staff as a result of the changes to the administrative support structure of the Laboratory. We thank **Karen Scrivener** (AP), **Pam Smith** (AMOP), **Helen Verrachia** (QM), **Gilly Walker** (OE), **Alison Barker** (OE) and **Angela Campbell** (NP) for all their excellent support over the years and wish them well in their future careers.

We were sorry to report that **Renata McLeod,** Financial Advisor, has moved on to a more senior post outside the University.

New Administration Staff

The **three Administrative hubs** have now been established and the staff members and their roles are described in a separate article (pages 26–27).
Niall Taylor Purchasing Supervisor
Mike Moriarty Head of IT Transformation
Erica Pramauro Administrator for the EPSRC CDT in the Centre for Scientific Computing
Robbie Yuan Departmental Financial Advisor
Katarzyna Targonska-Hadzibabic Library Assistant (now on maternity leave). During her absence, her post is being filled by **Veronika Flaskorova.**
Luciana Bonatto Caldiz and **Benjamin Hanson** have joined the Isaac project as content developers.
Woon Suan Loo Administrative Assistant.
Abbie Lowe has joined the department as an apprentice, primarily associated with the work of the Semiconductor Physics Group.
Kiala Lazula Cleaner

Distinctions

Rachel Padman (above) has been awarded the Barbara Burford Excellence Award, the inaugural Gay Times honour for having a profound impact on the lives of LGBT+ people. Every honour was given to an individual who lives only as LGBT+ and whose work had a profound – and often unrecognised – impact on the lives of LGBT+ people.
Lisa Jardine-Wright has won the 2017 Pilkington Teaching Award in Physics (see page 24).
Oliver (Ollie) Wadsworth, who carried out an apprenticeship in the Department, received the Endeavour Award from CRC. He has since been promoted to an engineering post in the Department of Engineering (see image with Nigel Palfrey above left).
Your editor, seen properly dressed, receiving the degree of Honorary Doctor of Science of St. Andrews University from the Chancellor, Baron (Ming) Campbell of Pittenweem (right) accompanied by Professor Sally Mapstone, Principal and Vice-Chancellor of St. Andrews University (left).

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