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CAVMAG

News from the Cavendish Laboratory

A Time for Change

INSIDE

COVER PAGE:
The Ray Dolby Centre in April 2021. In the distance, the building with the orange panels is the Common Facilities Building for the West Cambridge Science and Technology Campus. In front of it are the four wings of the Ray Dolby Centre, with the addition of the building on JJ Thomson Avenue which contains the large 400-seater lecture theatre.

Special Guest Editorial

ANDY PARKER, Head of the Cavendish, reviews the challenges of the last year under Covid-19 restrictions.

This has been a difficult year for everybody, with the pandemic exposing some of the weaknesses of our modern lifestyles. The Cavendish was not spared, and on the 20th of March 2020, during the first UK national lockdown, we were forced to shut down our activities for the first time since the foundation of the Laboratory. That afternoon, I did a final safety inspection before leaving the buildings in the care of our facilities staff with a heavy heart. Fortunately, by the middle of June we were able to begin reopening our laboratories for experimental work to resume. During the shutdown, our facilities team faced the then uncertain risks of Covid to attend every day, keeping the buildings safe, and taking advantage of the situation to complete many maintenance projects in our absence. It was their hard work and dedication which allowed us to be among the first Departments in Cambridge to resume research activities.

Since then, we have adapted to the strange new world. Only about a quarter of our staff are in residence on a typical day. An enormous effort has been made by the staff to deliver lectures, practical classes and examinations online where needed, and in person where possible. Our students have faced the changes with the resilience we have come to expect of such talented individuals, and although their experience has been impacted, they will graduate with the skills and qualifications they will need for their futures. Our teaching was recognised with the award of the Pilkington Prize for Teaching Excellence to **Tina Potter** (see News Section).

Most of our staff work from home, some coping with loneliness, and others performing their duties in spite of cramped conditions with relatives and children. We owe them a great debt for their dedication. We are all now feeling the lack of human contact, and the limitations of social interactions via screens. With the vaccination programme now well advanced, we all look forward to seeing our colleagues again in person, before the end of this academic year. Both teaching and research rely on the free exchange of ideas, and informal discussion is

vital to that. While we are keeping the flame alive, the sparks of inspiration are not flying as far as they normally do!

During the year, we have welcomed some outstanding **new academic staff**. The Winton programme used some of the generous donation from David Harding to establish two lectureships which will carry forward the sustainability agenda into the future. We were delighted to welcome **Akshay Rao** and **Chiara Chiccarelli** to these positions, following their outstanding success as Winton Fellows. Sustainability will be an increasingly important driver for the research agenda as we face up to climate change. We were also fortunate to attract **Paula Álvarez Cartelle** to a lectureship in our High Energy Physics group. Many of you will have seen the recent news from CERN, where tantalising hints of new physics have been observed (see page 16). Paula has been central to these efforts, and has just been awarded the Institute of Physics HEPP Prize for her leadership.

We marked the end of an era in September, with the retirements of **Richard Friend**, Cavendish Professor since 1995, and **Athene Donald** who was appointed to our staff in 1983. Both founded their own fields of physics, organic electronics, and soft matter, and both have had huge impact on these fields and beyond. I am happy to report that Richard continues his research part-time, liberated from more mundane responsibilities, as a Director of Research, and Athene continues

FIGURE 1. The construction of the Ray Dolby Centre in March 2021.

FIGURE 2. (left) Wing 4 Central Utility Building (CUB). (top right) Wing 4 CUB North-West elevation. (bottom right) Wing 5, which will house the Large Lecture Room and entrance atrium.

to be an influential voice in policy, particularly in supporting women in science, in her role as Master of Churchill College.

We are now seeking to recruit two new senior staff, who will provide leadership in the Cavendish tradition, while striking out in new directions. The first will be a new **Cavendish Professor**, who will follow in the footsteps of Richard and his predecessors such as Maxwell, Rutherford and Mott - big shoes to fill! Thanks to the extraordinary generosity of the Dolby family, we are also seeking a **Dolby Professor**, who will be supported by endowed postdocs and students. In honour of Ray Dolby's career, we intend this appointment to have a focus on experiment and the practical applications of advanced physics technologies. For both of these Chairs we expect to attract interest from some of the best researchers in the world, and I look forward to announcing the appointments in due course.

At a more junior level, we have just advertised two lectureships in astrophysics. The first of these will work in the area of exoplanets, where our recent Nobel Laureate, **Didier Queloz** now our **Jacksonian Professor of Natural Philosophy**, aims to understand the origin of life in the Universe, by seeking signatures of biological processes in distant worlds (see page 6). He has built up an impressive interdisciplinary team, including geologists and biologists as well as those in the humanities and the Divinity School, to explore the complex issues this field raises. The new lecturer will complement the existing skills in Cambridge, giving us one of the strongest teams in the world. The second lecturer will work in the area of extragalactic astronomy. **Roberto Maiolino** has just won a Royal Society Research Professorship, recognising his leadership in the field (see page 10). He has a key role in MOONS, the next generation optical and near-infrared multi-object spectrograph for ESO's Very Large Telescope, as well as NIRSpec, the near-IR spectrograph on board the James Webb Space Telescope, and HIRES, the high resolution spectrograph for ESO's Extremely Large Telescope. The new lecturer will be able to participate in the development of these instruments and exploit the wealth of data that they will bring,. These will centre on exploring the evolution of galaxies and their central black holes from their epoch of formation in the early stages of the cosmos.

A measure of our success in research can be gauged by our winning prestigious grants. Our Hitachi Professor, **Henning Sirringhaus**, scored an extraordinary double, winning both a Royal Society Research Professorship and an ERC Advanced Investigator award for his work on thermoelectric materials and thermal energy harvesting (see CavMag24). These are the most difficult grants to obtain at UK and European levels. **Richard Friend** has been awarded an ERC Advanced Investigator award for his work on spin control in radical semiconductors, the SCORS project, which will explore the electronic properties of organic semiconductors that have an unpaired electron to give net magnetic spin. **Zoran Hadzibabic** has also received an ERC Advanced Investigator award to support his fundamental work on quantum mechanics, using ultra-cold atoms. He is also one of the winners of funding from the UK programme on **Quantum Sensors for Fundamental Physics**, along with **Stafford Withington**, working on superconducting quantum devices, and **Val Gibson** with **Ulrich Schneider**, who will use an atom interferometer to search for dark matter and black holes (see pages 18–19). We can look forward to a string of breakthroughs as these projects advance.

High quality research demands a high quality environment to make it possible - the complexity and precision of today's equipment means that we face tough requirements on vibration, electrical noise and thermal stability in order to make our experiments possible. Thanks to the generous support of our alumni, such as Humphrey Battcock, and external partners like the Kavli foundation, we have already been able to create an excellent astronomy campus. We also have excellent facilities for biophysics and industrial outreach from government support for our Physics of Medicine and Maxwell buildings. The **Ray Dolby Centre**, made possible by the legacy of Ray Dolby, will allow us to move all of our other researchers into state-of-the-art facilities. In spite of the pandemic, we aim to be able to start our move in 2023, and to have our teaching programme and most of our research active for the 2023–24 academic year.

I recently toured the building site of the new centre, where 500 construction workers are currently employed. The basement laboratories for our most sensitive quantum mechanical experiments are being fitted out with their complex services. Some of the research wings have the exterior facade and windows in place, and offices, workshops and laboratories are taking shape within. The public wing houses the impressive shell of the **Dolby auditorium**, capable of seating 400 people in lecture mode, and a decent-sized band when used for more social occasions! The steelwork which will suspend the smaller lecture theatre over the reception area will complete the building superstructure. It is a spectacular sight and bodes well for the future of the Laboratory.

The government has supported us with a grant of £75m, in return for which we will operate a **National Facility for Physics**, offering access to advanced equipment to researchers from other Universities and industry. This has triggered a reorganisation of our facilities and their operation. We will aim to provide the same excellence in technical areas as we aspire to in research and teaching. We will create a career structure progressing from apprenticeships to senior technical officers, with opportunities to work with the most cutting edge techniques at every level. This should attract the most ambitious and able practical individuals to work with us, in the tradition of JJ Thomson's brilliant assistant, Ebenezer Everett. Everett made and operated all of Thomson's apparatus, generally forbidding him from touching anything, saying that he was "exceptionally helpless with his hands". We hope our current researchers are less clumsy, and that they and their support staff will be as talented and as successful as Thomson and Everett were.

Moving the whole Department, securing the best researchers and supporting world-class research and teaching could not, and cannot, be achieved without the support of all of our friends and alumni. As we complete the building, there are numerous opportunities to name spaces. I would be particularly keen to hear from alumni who would like to honour inspirational teachers or supervisors, or unsung heroes who supported them during their time in Cambridge. We must move forward, but not forget our past, and the people who have made our lives richer.

Everyone has been extraordinarily supportive during one of the most difficult periods the laboratory has ever faced. We are confident that we will rise to the many complex physics and multi-disciplinary problems of key importance for society worldwide. We have done that more than once in the past and we will do it again.

Didier Queloz

Jacksonian Professor of Natural Philosophy

We are delighted that DIDIER QUELOZ has been appointed Jacksonian Professor of Natural Philosophy. He talks with your editor about this distinguished chair, his discovery of exoplanets with his PhD supervisor Michel Mayor and his plans for a future multidisciplinary attack on the problems of understanding exoplanets and the origins of life in the Universe.

MSL: Many congratulations on being appointed to the Jacksonian Professorship of Natural Philosophy! As a previous holder of the chair, I was delighted with the title 'Natural Philosophy' since it seems to me to reflect better my range of interests rather than 'physics and astrophysics'.

DQ: I too love the title 'Natural Philosophy'. I was delighted to learn that Jackson's will specified that preference should be given to candidates from Trinity and that any holder must search for a cure for gout! When I discussed this requirement with the Vice-Chancellor, he assured me that a cure for gout had been found and I need not worry about that! I agree that the title 'Natural Philosophy' is particularly apt for my research programme and future plans which span physics, chemistry, astrophysics, biochemistry, biology, geophysics and applied mathematics, to mention only the most obvious disciplines.

MSL: Your discovery of exoplanets with your research supervisor Michel Mayor at the Geneva Observatory took place during the final year of your PhD in 1995. It must have been a very exciting, but also a bit of a worrying time.

DQ: Yes, it was really scary. If I had got it wrong, that would have been the end of my career. Also, it was too big a discovery! As soon as I had refined the analysis of our data, I knew this was a huge discovery. Even immediately after the discovery, people were talking about this being a Nobel Prize level discovery. When I went to meetings, people would say, 'But how can it be? You are far too young!' I had a tough few years after the discovery because it took place long before I had become a properly trained professional research scientist - I could never make a more important discovery in my research career. So, I had to show that I could continue doing great research, despite having made such a big discovery so early. I think I managed to do this, but I confess that I really only began to enjoy the discovery after I moved to Cambridge in 2013.

MSL: I imagine Michel must have been delighted by the outcome of your joint work.

DQ: Yes, indeed. He is an outstanding scientist. During the last year of my PhD, he took a year's sabbatical leave in Hawaii and, when he came

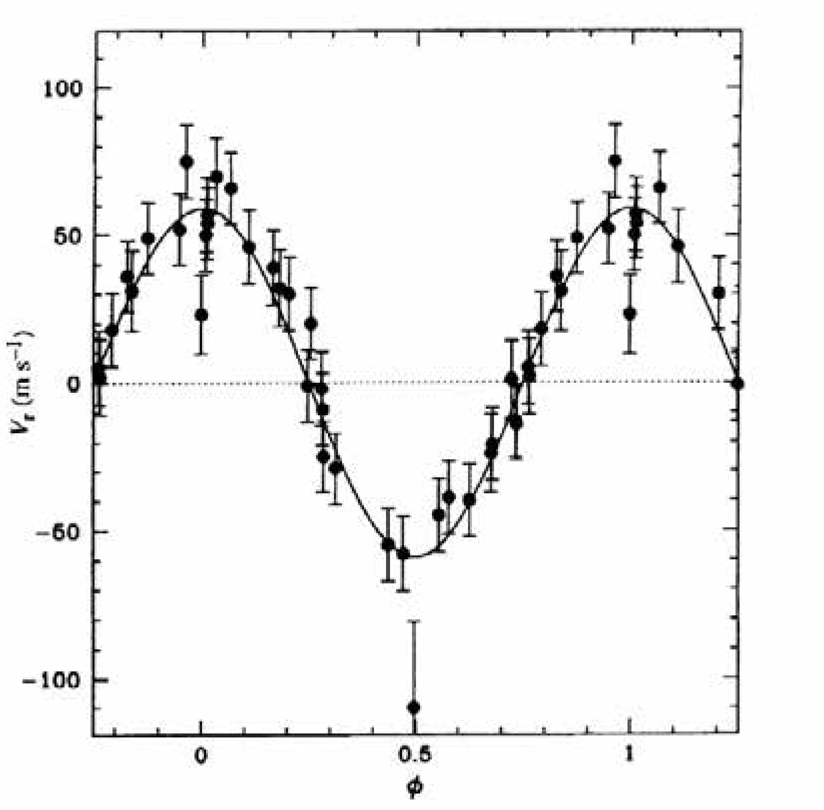


FIGURE 1. The discovery record of the velocity curve of the barycentre of the star 51 Peg with period of 4.32 days.

back, I was able to present him with a wonderful gift towards the end of his distinguished career. He had a wonderful ten years after the discovery before his retirement.

MSL: I imagine that Michel had no idea that the discovery of exoplanets might result from his concept of the ELODIE fibre-fed echelle spectrograph on the 1.93 m telescope at the Haute-Provence Observatory in France.

DQ: Yes. Michel's original intention was to build a spectrograph capable of measuring the radial velocities of stars at the level of 50 m s^{-1}, but I realised that one could do very much better than that. There were lots of tricks one could play to improve the performance of the spectrograph and reach the magic figure of 10 m s^{-1}. Once Michel realised the potential to do that, he suggested two programmes. We could survey 1000 stars looking for brown dwarfs, or a smaller sample of 100 stars looking for lower mass objects, possibly even planets. Michel went off to Hawaii, leaving me the key of the 1.93 m telescope at the Haute-Provence Observatory and letting me get on with it.

MSL: I have always assumed that the discovery really was a triumph of innovative technology and data analysis. Is that the case?

DQ: Well, yes and no. We had a lot of luck - Nature was very kind to us. The planet we found in 51 Pegasi (51 Peg) was not supposed to exist! No one had thought that planets with masses greater than that of Jupiter could exist in very close orbits about the primary star. The theories were all designed to account for the distribution of planets in our own solar system - the short-period orbits of exoplanets were not on anyone's agenda, nor were the subsequent results which showed that there is a huge range of orbits and masses among them. The diversity of the exoplanets we have now discovered is astonishing.

Without this bit of luck, it would have been a disaster for the NASA Kepler project, for example - they would have found no exoplanets. Instead, the Kepler project kick-started the American community in exoplanet research and discovered thousands of them. The connections with the problems of origins of life followed immediately

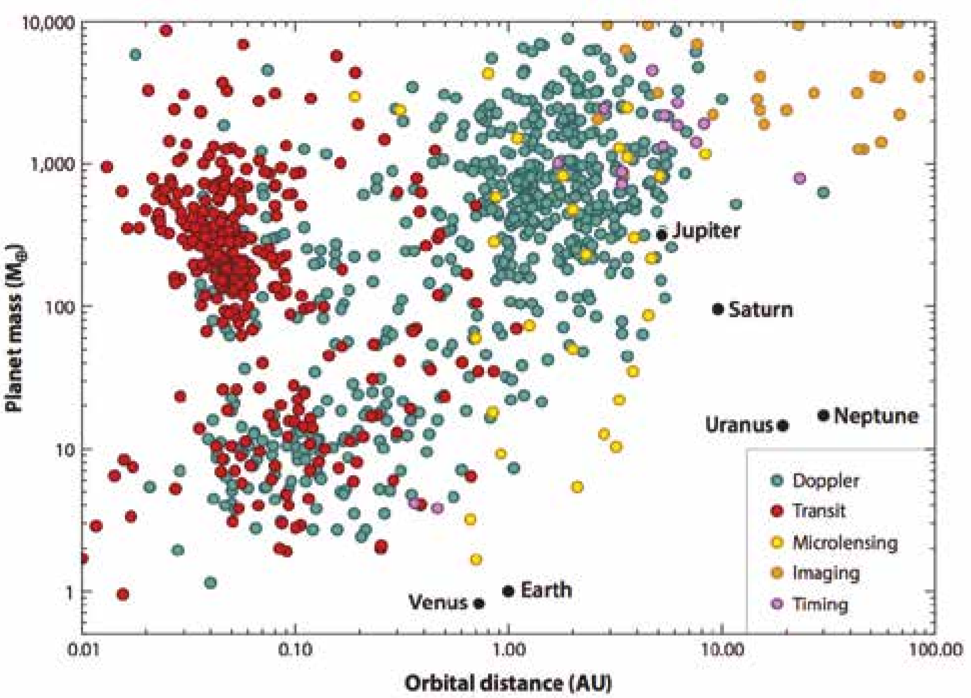


FIGURE 2. The diversity of planets illustrated by a plot of their masses against their mean orbital distances. The key shows the variety of different techniques Involved in their discovery (Courtesy of the Conversations in Science at Indiana University programme: post by Karna Desai 2018).

from the discovery of the enormous range of potentially habitable planetary systems.

MSL: One of the amazing things about your discovery paper is the huge amplitude of the velocity variations which made the discovery completely unambiguous (Figure 1). Is it surprising that others had not discovered this before?

DQ: We had a number of advantages. Among these was the fact that we were allocated generous amounts of observing time on the 1.93-m telescope, whereas our competitors in the USA and Canada were using much larger telescopes on which they were allocated only small amounts of time.

The spectrograph was excellent, but I also played a lot of attention to making sure we lost no information in converting the raw spectroscopic data into the final scientific products. This involved a lot of tricks. For example, we never re-binned the data and used computational cross-correlation techniques to obtain the best possible velocity information. We used the NAG library of computational procedures to optimize the near real-time analysis of the data. To speed up the data processing on our minicomputer, we obtained faster chips from the manufacturers. It was the combination of all these things and many others which contributed to our success. Michel was a superb supervisor but underestimated the amount of work needed to reach our goal. Eventually it took two years rather than 6 months.

MSL: With the thousands of exoplanets now identified, the diversity of the exoplanet population is truly amazing (Figure 2). How do you think some order will be put into this diversity? Will there be the equivalent of a Hertzsprung-Russell (colour-luminosity) diagram for exoplanets?

DQ: The diversity is fascinating. The equations are all known, but it is just too complicated and non-linear. Masses, radii and orbits are not enough - we need extra dimensions and the most important of these is the nature of the planetary atmospheres of the exoplanets, particularly if we want to address key issues related to the origins of life. This will become possible with the next generation of ground and space-based projects, but we also need the expertise of a new generation of cosmo-chemists who are able to analyse and understand the nature of the atmospheres of exoplanets. This

"I was attracted to Cambridge for the intellectual stimulation and diversity of people with whom I could interact on the very broad range of issues concerning exoplanets and life in the Universe."

is why the appointment of a new generation of chemical astrophysicists like Nikku Madhusudhan are so important, as are our links with geophysics through Oliver Shorttle. The James Webb Space Telescope and other dedicated projects will put us in an excellent position to add this new dimension to the search for life on exoplanets.

MSL: We were delighted when you accepted the offer of a Professorship in the Cavendish Laboratory in 2013. What are your reflections on how that has turned out and how do you see your programmes developing in the future?

DQ: I greatly enjoyed working with my colleagues in Geneva and still devote 25% of my time working with them. But I felt I was missing something. I was attracted to Cambridge for the intellectual stimulation and diversity of people with whom I could interact on the very broad range of issues concerning exoplanets and life in the Universe. I had to move then or I would never have left Geneva. The range of colleagues and their genuine interest in my research areas here in Cambridge is amazing. It has been hard work, but it is all going well and I am thoroughly enjoying the challenges.

With the explosion of interest in the whole topic of Life in the Universe, we are developing new ways of tackling what is undoubtedly a highly multidisciplinary subject. We need a new generation of research scientists who are at home in working in a multidisciplinary environment. We have already set up the *Cambridge Exoplanet Research Centre* involving the three astrophysics groups in Cambridge, the Cavendish, the Institute of Astronomy and the Department of Applied Mathematics and Theoretical Physics. Just this year, this programme has been expanded to include many more Departments in the School of Physical Sciences to create the *Cambridge Initiative for Planetary Science and Life in the Universe**. But this is only the beginning. We have plans to become even broader and bolder in scope and ambition, involving our colleagues in the biological, molecular biological and biophysical sciences. We are even planning initiatives to include researchers working in the Arts and Humanities, including philosophers and members of the divinity school to deepen our appreciation of what we really mean by 'Life in the Universe'. Recent advances have been very dramatic across the complete spectrum of activities and that is what we plan to build upon.

The University has been fully supportive of this ambitious vision, but we also need the resources to bring about this new way of thinking about and doing science. These topics have the greatest public appeal and we will actively be pursuing support for this project as we move forward.

MALCOLM LONGAIR

* For more information about this initiative, see www.iplu.phy.cam.ac.uk

Roberto Maiolino
Royal Society Research Professor

Many congratulations to ROBERTO MAIOLINO on his appointment as Royal Society Research Professor, the Society's premier research award. It provides long term support to world-class researchers of outstanding achievement, releasing them from other responsibilities in order to concentrate upon their research programmes for five years. These will be crucial years for Roberto's major programmes on the evolution of galaxies in all their aspects over the last 10 billion years or more.

Roberto was appointed Professor of Experimental Astrophysics in the Cavendish Laboratory in 2012. He brought important new dimensions to the research of the Cavendish Astrophysics Group with his experience in optical-infrared studies of very distant galaxies and his involvement in the design and construction of instrumentation to carry out these programmes on world-leading large telescopes. These programmes will come to fruition over the next five years while he holds his Royal Society Research Professorship.
In his own words, here are his astrophysical and cosmological objectives.

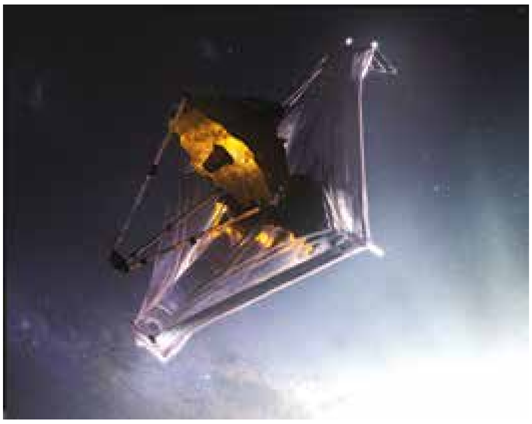
'Understanding the origin of the chemical elements in galaxies is one the primary challenges of modern astrophysics. Chemical elements heavier than helium, commonly referred to as 'metals' in astrophysics, are produced during stellar evolution within stellar interiors and associated explosive events. Metals are expelled and redistributed by galactic outflows and also diluted by the inflow of gas from the intergalactic medium. A fundamental milestone of any model of galaxy formation is that they must account for the content of metals as observed with cosmic epoch.

'The metal abundances in local galaxies have been well determined by extensive observing campaigns. In order to constrain the models properly, however, chemical enrichment processes have to be traced over cosmic time in distant galaxies. Currently, very little is known about chemical enrichment in distant galaxies, because it has been very challenging to obtain the high quality data for large samples of galaxies in the early Universe. I will use two new cutting edge facilities, the James Webb Space Telescope and MOONS, the next generation spectrograph for the Very Large Telescope, to measure the chemical enrichment of galaxies out to the earliest epochs of galaxy formation with unprecedented accuracy using samples containing hundreds of thousands of distant galaxies. The ultimate goal is to trace chemical enrichment all the way back to the very first galaxies, formed out of the primeval, pristine fog of hydrogen and helium.'

This concise description disguises the sheer complexity of the problem. The formation and evolution of the chemical elements involves many complex phenomena, such as star formation, outflows, inflows, galaxy mergers and interactions with central black holes. The roles each of these processes play change with cosmic epoch. Because the production of heavy elements results from nucleosynthesis during stellar evolution and associated explosive events, the 'metallicity' of galaxies provides uniquely important information about the integrated star formation history of galaxies. To complicate matters, different chemical elements are produced on different timescales and so their relative abundances also provide information on the star formation history in galaxies. Reproducing the content of heavy elements is nowadays regarded as a key milestone for any model of galaxy formation and of cosmological simulations.

Many of the advances over the next decade are expected to come from observations with the next generation of observing facilities. Roberto is fortunate in having privileged access to two of the most important of these.

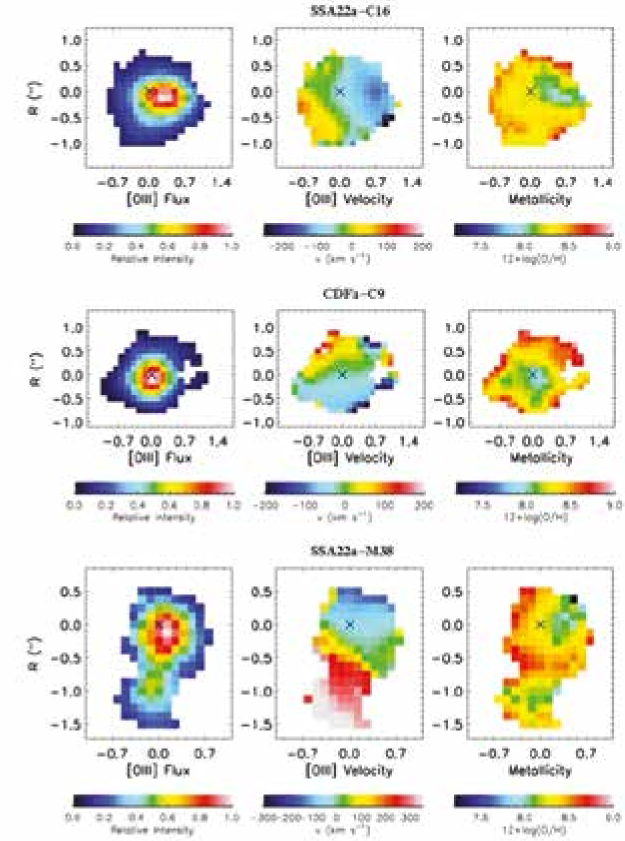
The **James Webb Space Telescope** (Figure 1) will be launched in 2021 and, with its 6.6m primary mirror, will be the largest telescope ever launched into space. Its large collecting area, together with the very low background emission and absence



of atmospheric absorption, will make the JWST far more sensitive than any previous facility. For spectroscopy, the leap in sensitivity will be up to a factor of 2,000 in some spectral bands. The largest and most complex of all JWST instruments is NIRSpec, operating in the 0.6-5mm spectral range. It will be the first multi-object spectrograph in space, enabling the spectra of a few hundred galaxies to be obtained simultaneously, as well as providing high sensitivity spatially resolved (3D) spectra by integral field spectroscopy with an angular resolution of about 0.1". An example of what is currently possible using integral field spectroscopy on the largest ground based telescopes is shown in Figure 2. As a member of the core Instrument Science Team of NIRSpec, Roberto will have access to 900 hours of guaranteed time observations (GTO), about 90% of which will be dedicated to deep observations of distant galaxies.

He is also the Project Scientist and Co-PI of **MOONS**, the next generation optical/near-IR multi-object spectrograph for **ESO's Very Large Telescope** (Figure 3). MOONS will be able to obtain spectra of 1,000 sources simultaneously across the 0.64-1.8mm spectral range, with high throughput and a spectral resolution high enough that the strong OH sky background lines can be isolated and removed. Within 5-10 years of operations, starting in mid-2023, MOONS will provide sensitive near-IR spectra of over a million distant galaxies, similar in sample size to the optical spectroscopic samples in the local Universe and more than three orders of magnitude larger than currently achievable at high redshift with current near-IR spectrographs.

These are crucial observations for astrophysical cosmology and we wish Roberto every success in carrying out these very challenging projects.



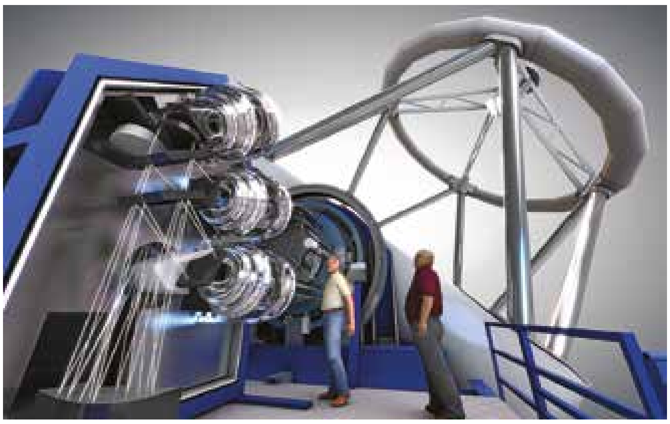


FIGURE 1 (top-left). A visualization of the James Webb Space Telescope in orbit, due to be launched in 2021.

FIGURE 2 (top-right). Near-infrared spectroscopic observations of three galaxies with redshifts just greater than three obtained with the integral field spectrometer SINFONI 14 on the Very Large Telescope of the European Southern Observatory. The first column shows the surface brightness distribution of the three galaxies. The second column shows the velocity distribution of the redshifted [OIII] λ 5007 line of the three galaxies and the third column metallicity maps (Courtesy of Roberto Mailino).

FIGURE 3 (bottom). A conceptual engineering drawing shows MOONS mounted on ESO's Very Large Telescope (VLT). (Courtesy of the ESO/MOONS Consortium)

Val Gibson OBE

We are delighted that Val Gibson, Head of the High Energy Physics Group, has been awarded an OBE in the Queen's New Years Honours List 2021 for her 'services to Science, Women in Science and to Public Engagement.'

Besides her leading role in the LHCb experiment at the Large Hadron Collider at CERN, which continues to produce ground-breaking science (see page 16), Val is a major player in the recently UKRI-funded AION project, a state-of-the art initiative to search for ultra-light dark matter and detect gravitational waves using large-scale atom interferometry (see page 18). She has played a leading role in promoting Women in Science for many years. As we were able to report recently,

'Cavendish academics lead the Equalities, Diversity and Inclusion (EDI) agenda within the University, nationally and internationally. Val Gibson chaired the Institute of Physics (IoP) Juno Panel and is the University's Gender Equality Champion for STEMM subjects. She works with the VC and Pro-VCs on the University's EDI agenda.

'Some measure of the positive results of these efforts is that, under her leadership, the Cavendish was the first Department in the University and the first Physics department in the UK to attain Athena SWAN Gold status in 2014, which has been renewed twice. The Cavendish has also held IoP Juno Champion status since 2013. There has been a 64% increase in the number of women academic staff. Of 25 academic appointments during the last eight years, eight are women. Current lectureships are now more gender balanced with seven women and ten men, while among current Readers there are four women and eight men. From 2014, all women academics eligible for promotion have been promoted at least once. '

Val is also passionate about the communication of science, giving numerous lectures at events locally and across the UK. She has appeared on the BBC Radio 4 'In Our Time' programme four times and the 2020 Christmas University Challenge. She is Patron of the Gravity Fields Festival, a biennial science and arts festival held in celebration of Sir Isaac Newton at his school-town of Grantham and his home at Woolsthorpe Manor, Lincolnshire.

We congratulate Val most warmly on a very much deserved award and wish her all success with the new projects in which she is involved.

Quantum, quantum everywhere…

We are delighted to report the success of a number of our Cavendish colleagues in winning substantial support under the UK Research and Innovation (UKRI) **Quantum Technologies for Fundamental Physics programme**, involving £31 million investment to demonstrate how quantum technologies can lead to advances in many unsolved problems in fundamental physics. Of seven projects funded by the scheme, four involve Cavendish Physicists. These are:

- **AION:** A UK **Atom Interferometer Observatory and Network** has been awarded £7.2 million in funding and will be led by Imperial College London. The Cambridge AION team is led by Val Gibson and Ulrich Schneider, along with researchers from the Kavli Institute for Cosmology, the Institute of Astronomy and the Department of Applied Mathematics and Theoretical Physics.
- **QSHS** The **Quantum Sensors for the Hidden Sector** (QSHS) project, led by the University of Sheffield, has been awarded £4.8 million in funding. The project aims to contribute to the search for axions, low-mass 'hidden' particles that are candidates to solve the mystery of dark matter. These particles are predicted to exist theoretically, but have not yet been discovered experimentally. Stafford Withington is co-Investigator and senior project scientist on QSHS.
- Stafford is also involved in the **Determination of Absolute Neutrino Mass** using Quantum Technologies, which will be led by UCL. The project aims to harness recent breakthroughs in quantum technologies to solve one of the most important outstanding challenges in particle physics – determining the absolute mass of neutrinos.
- The **Quantum Simulators for Fundamental Physics** project is led by the University of Nottingham, the Cambridge effort being led by Zoran Hadzibabic. The project aims to develop quantum simulators capable of providing insights into the physics of the very early universe and black holes.

We congratulate all those involved in these successes and recognize the many challenges our colleagues face. More details of the AION project are included in the accompanying article (page 18).

Vanessa Bismuth

Cavendish Laboratory Communications Manager

We are delighted to welcome VANESSA BISMUTH, the Laboratory's first Communications Manager. It is a major and important challenge to manage these key activities given the size of the Laboratory and the move to the new buildings in the increasingly near future. Here is her story and vision for her new role.

I am originally from France, but I have been living in the UK for 11 years - first in Edinburgh and now in Cambridge for the past five years. I studied communications and media relations at La Sorbonne Université in Paris, with a detour via the University of California at Davis, before diving straight into a junior role at the press office of the French Minister for Higher Education and Research.

After these formative years, my peregrinations and personal life choices led me to a variety of communications roles, from the Museum of Natural History in Paris to the Institut français in Edinburgh, and most recently Cambridgeshire County Council. While widely diverse in organisational culture and fields of activity, all these places have been remarkable in their own rights and have prepared me well for what is the biggest 'culture shock' of my career so far: joining the University!

With the construction of the new Ray Dolby Centre well underway and an array of excellent research activities that keep coming out of our labs, there is no better time to develop the Department's communications, both for our internal and external audiences. There is so much to celebrate, so much to showcase and so much to shout about. But also, a lot to do to put the tools in place to ensure that all of this is visible and that we can reach our extended community, starting with our current staff and students, but also anyone interested in learning about physics at the Cavendish. These include all those potential future students and researchers, our alumni all around the world and of course, the general public.

This means for instance developing a website that truly reflects our journey as we develop a new Cavendish Laboratory for the 21st Century, and extending our social media presence to share compelling stories of science brought to life and to portrait the people behind the physics. Internally, this is about looking at ways to build a sense of ownership, belonging and pride to be part of the Cavendish Community.

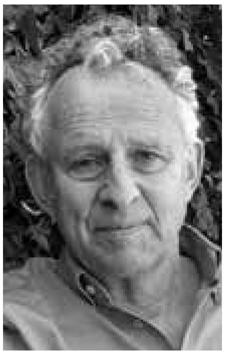
These are no small feats by any means, but an exciting challenge at such an important time in the history of the Laboratory. And while I am still learning the ropes of the University world, I have deep-dived into the world of Physics and focused on getting to know the labs and their people, as well as all the professional staff that support the department operations.

I have been overwhelmed by the warm welcome I have received from everyone and to see such an appetite for good and effective communications. As I continue to shape the new function and think about how it can support everyone in the department and beyond, I look forward to being able (Covid permitting) to meet more people in person, to visit the labs, and to see the Ray Dolby Centre site with my own eyes!

If you would like to say hello, bonjour, or send me any comment and suggestion, please write me an email at **communications@phy.cam.ac.uk**

"With the construction of the new Ray Dolby Centre well underway and an array of excellent research activities that keep coming out of our labs, there is no better time to develop the Departments' communications..."

Three European Research Council Advanced Grants awarded to Cavendish researchers


We congratulate most warmly ZORAN HADZIBABIC, RICHARD FRIEND and HENNING SIRRINGHAUS (left to right above) on winning major ERC Advanced Grants, the total funding amounting to just over €7.1 million.

In the recent round, the Cavendish has the most grant winners within the University. ERC Advanced Grants support excellent scientists in any field with a recognised track record of research achievements in the last ten years. As remarked by Andy Parker, Head of the Department:

'This is a fierce competition and only 8% of candidates were successful in this last ERC call so seeing three of our top researchers amongst the 12 Cambridge grantees is a colossal and fantastic achievement. All three of them are proposing greatly ambitious projects and I look forward to seeing what major insights will spring from this European funding.'

Zoran was awarded funding for his UNIFLAT project. As he explains, one of the great successes of the last-century physics was recognising that complex and seemingly disparate systems are fundamentally alike. This allowed the classification of the equilibrium states of matter into classes based on their basic properties. At the heart of this classification is universal collective behaviour, insensitive to the microscopic details, displayed by systems close to phase transitions.

A grand challenge for modern physics is to achieve the same feat for the far richer world of nonequilibrium collective phenomena. In his own words,

'Our ambition is to make a leading contribution to this worldwide effort, through a series of coordinated experiments on homogeneous atomic gases in two-dimensional (2D) geometry. Specifically, we will study in parallel three problems – the dynamics of the topological Berezinskii-Kosterlitz-Thouless phase transition, turbulence in driven systems, and the universal spatio-temporal scaling behaviour in isolated quantum systems far from equilibrium. Each of these topics is fascinating and of fundamental importance in its own right, but beyond that we will experimentally establish an emerging picture that connects them.'

Richard has been awarded funding for his Spin Control in Radical Semiconductors (SCORS) project, which will explore the electronic properties of organic semiconductors that have an unpaired electron to give net magnetic spin. The project is based on a recent discovery that this unpaired electron can couple strongly to light, allowing very efficient luminescence in LEDs. His group will explore new combinations of optical excited states with magnetic spin states. This will allow new designs for LEDs and solar cells, and opportunities to control the ground-state spin polarisation in spintronic devices.

Henning received funding for his NANO-DECTET project, for the development of next-generation energy materials. Following on from his article in CavMag24, he explained:

'Worldwide, only about a third of primary energy is converted into useful energy services: the other two thirds are wasted as heat in the various industrial, transportation, residential energy conversion and electricity generation processes. Given the urgent need to mitigate the dangerous consequences of climate change, a waste of energy on this scale needs to be addressed immediately. Thermoelectric waste-heat-to-electricity conversion could offer a potential solution, but the performance of thermoelectric materials is currently insufficient. In this project we will use the unique physics of molecular organic semiconductors, as well as hybrid organic-inorganic semiconductors, to make efficient, low-temperature thermoelectric materials.'

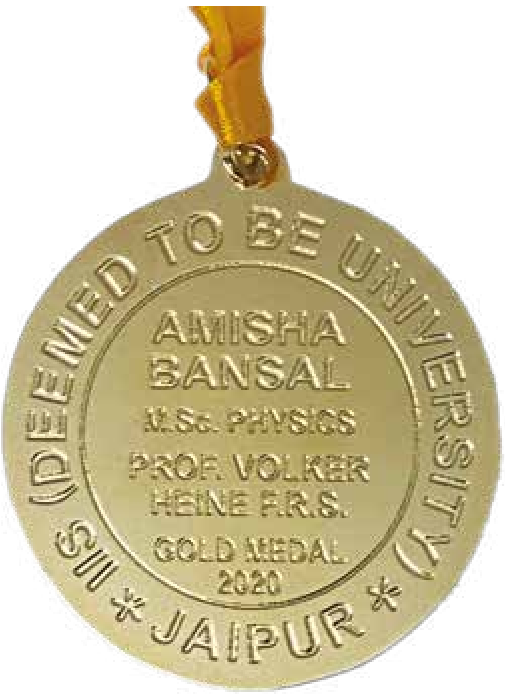
Heine Gold Medal

VOLKER HEINE, professor emeritus of theoretical physics and a founder member of the TCM Group, describes in his own words how his actions resulted in the dedication of a gold medal in his name for excellence in Physics at a University in Jaipur, India.

'Prof. K.S. Sharma of the IIS Deemed to be University in Jaipur India with two colleagues have arranged the publication of a Hindi edition of my book *Group Theory in Quantum Mechanics,* first published in 1960. The translation originated many years ago when they were teaching the subject using it as the course textbook. They thought it was nice and clearly written, with lots of examples from various branches of physics.

'The present Prime Minister of India, Mr Modi, is very keen to promote Hindi culture, and I expect that money for publishing academic books in Hindi may have come about in that way. I agree that Indian students should be able to study physics in their own language. I also suggested that my fraction of the royalties should go towards an annual prize for the top student in the M.Sc. exam in Physics, and the university proposed that it should be a gold medal. They suggested that my gift should fund an annual gold medal in my name at the University.

'The first recipient at the end of 2020 is Miss Amisha Bansal (see below) and comes with a congratulatory note from me. I hope it will make her feel that she has joined the world community of physicists.'



Eloy de Lera Acedo wins STFC Ernest Rutherford Fellowship

We congratulate ELOY DE LERA ACEDO on winning one of the prestigious STFC Ernest Rutherford Fellowships. These are awarded yearly to 10 promising researchers *'with clear leadership potential to establish a strong, independent research programme'* from all around the World to work in UK universities.

Eloy's research focuses on the study of the early epochs of our Universe through observations of the hyperfine 21-cm line of primordial neutral hydrogen. He leads the international collaborative REACH experiment and the centimetre-wave experimental radio cosmology team in the Cavendish Astrophysics Group. His project is entitled 'Probing the Cosmic Dawn and the Epoch of Re-ionization with REACH'.

With this fellowship, he will focus for the next five years on observations of radio signals emitted at the time when the very first stars were formed from primordial neutral hydrogen, subsequently shaping the Universe we observe today. His team aim at unravel the mysteries of these key unexplored early cosmic epochs. 21-cm cosmology is a particularly challenging field because the extremely faint radio signals are buried deep within strong background noise signals, up to 100,000 times brighter than the cosmic signal in the case of the Galactic radio emission. Furthermore, both signals, cosmological and foreground noise, are contaminated by the radio telescope itself.

Eloy's multidisciplinary skills in engineering and radio astronomy, with a background in precision radio instrumentation development for the HERA and SKA telescopes, will be fundamental to this quest.

Beautiful rare decays and lepton-flavour universality

We congratulate PAULA ÁLVAREZ CARTELLE most warmly on her recent appointment as a University Lecturer. In addition, she hit the headlines in March 2021 with a potentially very important result concerning the asymmetry of decay of the beauty quark. She explains what the excitement is all about.

The Standard Model of particle physics currently provides our best description of fundamental particles and their interactions. The theory predicts that the different charged leptons, meaning the electron, muon and tau, have identical electroweak interaction strengths. Previous measurements have shown that a wide range of particle decays are consistent with this principle of *lepton-flavour universality.*

The recent result involves the decay of the beauty (or bottom) quark, an exotic fundamental particle not usually found in nature, but produced in huge numbers at the LHC. It has been shown to have a slight preference to decay to electrons rather than muons, a result in conflict with lepton-flavour universality, if confirmed by future experiments. Paula is one of the leading analysts who discovered this new result. She describes in more detail the result in her own words:

'My research has been focused on rare decays of the beauty quark. I have spent the last few years studying the $b \to s\ell\ell$ transition, the decay of the beauty quark b to a strange quark s and two leptons, ℓ: the leptons can be either muons or electrons (Figure 1). This turns out to be very sensitive to the existence of *new physics*, that is, forces that might exist in nature but that have yet to be discovered.

The new result is one of a string of measurements which suggest that the Standard Model, containing all the quantum particles we know about, might not be able to account for what we observe.

The challenge of studying rare beauty decays is largely that they are very rare indeed. So you need an energetic collider running for a long time to produce enough of them to have the statistics to make a strong statement. Other experiments have studied these processes but never to this precision – we are at the forefront of knowledge (Figure 2).'

This latest result is presented as the ratio of rates for the two decays proceeding through a $b \to s\ell\ell$ transition. The ratio of these rates is predicted to be 1.000 in the Standard Model. Carrying out absolute calculations in quantum mechanics can be a messy business, but many of

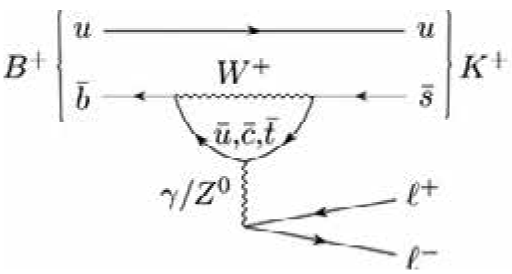


FIGURE 1.
The Standard model process for the decay of a beauty meson into a kaon and two leptons (ℓ). The Standard Model does not prefer any lepton flavour and the predicted rates of decay should be the same for electrons and muons.

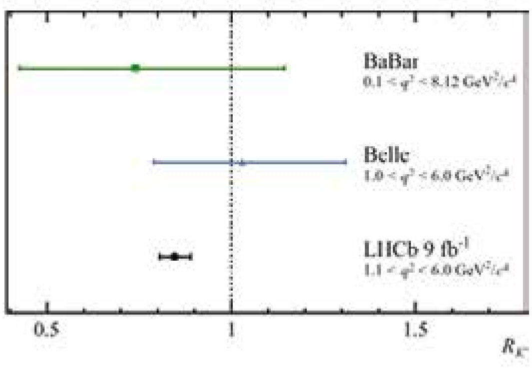


FIGURE 2.
The ratio of the decay rate to muons to that to electrons, so-called "R_K". The Standard Model predicts a value of 1.000. The latest LHCb analysis finds a number slightly different from 1. Also shown are other measurements from the BaBar and Belle experiments.

the problematic effects that come up cancel out by using this ratio, a much better test of the core principles of the theory. We measure a number that is not 1.000, but 0.846 ± 0.044, meaning just over three standard deviations from the value 1.000.

In particle physics, the gold standard for discovery is five standard deviations – which means there is a 1 in 3.5 million chance of the result being a fluke. This three standard deviation result means there is a 1 in 1000 chance that the measurement is a statistical fluctuation. It is too soon to come to any definite conclusion. While they are still cautious, the physics community is nevertheless excited by this apparent deviation and its potentially far-reaching implications.'

A BRIEF BIOGRAPHY:

Paula studied experimental particle physics at the University of Santiago de Compostela in Galicia. In 2016 she was awarded a five-year Junior Research Fellowship at Imperial College, London. She had a short stint as a CERN senior research fellow before joining Cambridge as a University Lecturer in the High Energy Physics Group in March 2020. She has been a collaborator on the LHCb experiment at the Large Hadron Collider at CERN since the very first data-acquisition in 2009, and she was an author of one of the resulting very first physics publications (Figure 3). Since then she has worked on amplitude modelling, deuteron identification, and rare leptonic decays of the beauty quark. She has held convenerships of two physics working groups.

FIGURE 3.
The LHCb experiment at CERN, searching for the origin of the asymmetry of matter and antimatter in the Universe.

AION

A UK Atom Interferometry Observatory and Network


VAL GIBSON and ULRICH SCHNEIDER of the High Energy Physics and Atomic, Mesoscopic and Optical Physics Groups respectively describe the AION project, which involves a consortium of the University of Cambridge, STFC and 5 other UK Universities, in partnership with the National Quantum Technology Hub in Sensors and Timing at the University of Birmingham.

Atom interferometry opens up new possibilities for precise measurement of extremely small masses and very small phase differences. This can best be understood through a comparison between optical and atom interferometry. Once the wave nature of light was established, it was soon appreciated that by splitting the beam into two parts and then recombining them, the differences in path length result in the characteristic interferometer pattern. If some physical phenomena changes the path length along one of the arms of the interferometer, there is a small change in phase in the interference pattern which allows very precise measurements to be made. A historic example of the power of this technique is the famous Michelson-Morley experiment which could measure path differences of one part in 10^8 in the late 19th century.

According to the wave-particle duality, waves can behave like particles and particles like waves under different circumstances. In atom interferometry, the wavelength associated with the atom is its De Broglie wavelength $\lambda = h/p$, where p is the momentum of the particle. However, the experiment has to be carried out at ultra-low temperatures at which the bosonic nature of the atoms might enable them to form coherent Bose-Einstein condensates. This opens up the possibility of detecting extremely small masses. As Ulrich Schneider expresses it:

'Every physical effect, known or unknown, leaves its fingerprint on the phase evolution of a coherent quantum system such as cold atoms; it only requires sufficiently sensitive detectors. We are excited to contribute our cold-atom technology (Figure 1) to this interdisciplinary endeavour and to develop atom interferometry into a powerful detector for fundamental physics.'

Putting this together, the primary objectives of the AION science programme are as follows:

- To explore well-motivated ultra-light dark matter candidates with sensitivities orders of magnitude beyond current bounds;
- To explore mid-frequency gravitational waves from astrophysical sources and from the very early universe;
- To operate the successive stages of AION in a network with the MAGIS detector, a partner experiment situated at the Fermi National Laboratory in the USA, and potentially other atom interferometers. It will also operate alongside approved laser interferometers such as LIGO, Virgo, KAGRA, INDIGO and LISA, and other proposed detectors.

FIGURE 1. The vacuum system required to produce ultracold atoms.

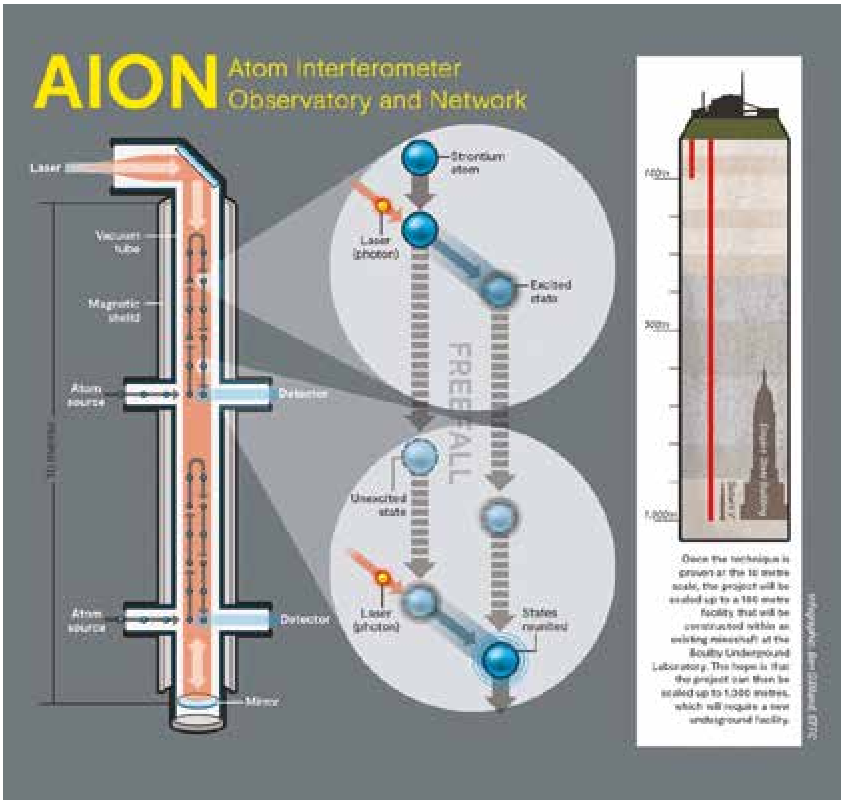


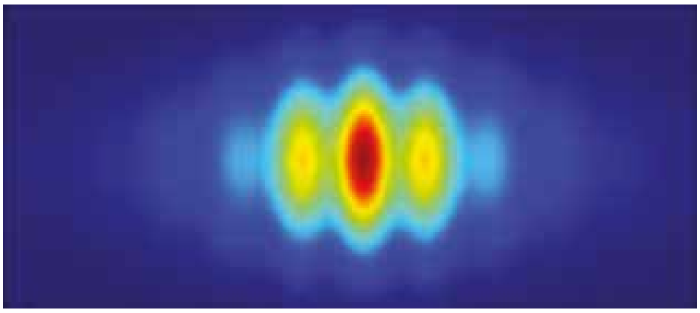
FIGURE 2 (left). A schematic diagram showing how the interferometer will operate. Because of the extreme sensitivity of the detector system, the local effects of gravity need to be eliminated, so that both detectors are in 'free-fall' in the local gravitational field. Interrogating two atomic ensembles with the same laser beam enables differential measurements to be made which are immune to laser noise which is normally the limiting factor. The expected interference pattern of the coherent atomic beams is shown in Figure 3.

FIGURE 3 (below). Expected atomic interference pattern.

The Cambridge effort, which also involves researchers from the Kavli Institute for Cosmology, the Institute of Astronomy and the Department of Applied Mathematics and Theoretical Physics, will develop the cold atom transport and final cooling sequences for AION, the data readout and network capabilities for AION and MAGIS, and undertake data analysis and theoretical interpretation.

The interdisciplinary team of researchers, engineers and PhD students from the particle physics, ultra-cold atom and astronomy communities will develop the technology to build and reap the scientific rewards from the first large-scale atom interferometer in the UK.

The UKRI funding will support the design of a 10m atom interferometer, leading towards the construction of the instrument, and paving the way for larger-scale experiments in the UK in the future. Members of the consortium will also contribute to MAGIS, networking the two instruments together.



Val Gibson enthused about this important development:

'We are delighted with the announcement from STFC to fund the AION project, which alongside some seed corn funding from the Kavli Foundation and support from the School of Physical Sciences, will allow us to target key open questions in fundamental physics and bring novel interdisciplinary research to the University for the foreseeable future.'

The new funding will also establish a leading role for Cambridge in large-scale atom interferometry for fundamental physics research, as the AION consortium looks towards possible 100m- and km-scale terrestrial detectors as well as a future space mission.

On LEGO and elephants

We are delighted to welcome OLEG BRANDT who has taken up a lectureship in the High Energy Physics Group. Here he writes about his main research focus, the search for dark matter particles at colliders.

What is the main driving factor for my fascination with particle physics and with Dark Matter (DM) searches? LEGO and elephants. As a kid, I was obsessed with LEGO. I was fascinated with the idea that, with only a few basic building blocks, complex structures could be assembled. When I learned that Mendeleev's table of the elements can be understood following few basic concepts from atomic physics, I fell in love with chemistry. The moment I learned that - in principle - one can understand the clockwork of the Universe with only 12 LEGO building blocks of the Standard Model (SM) and four fundamental interactions between them (Figure 1), that was the beginning of my passion for particle physics.

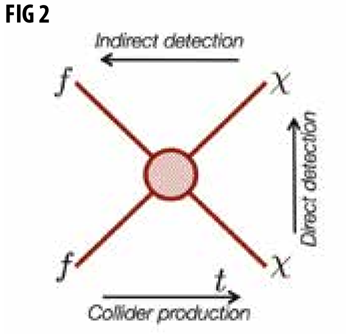
FIG 1

The big questions fascinate me the most. One of these is the particle nature of the Dark Matter (DM), the proverbial elephant in the room, accounting for 85% of matter in the Universe. Imagine viewing the overwhelming presence of an elephant, and not having any idea what kind of LEGO blocks it is made of! We know DM is there and yet we have no idea about its particle nature.

DM search strategies

The search strategies for DM can be characterised into three types, all depicted in the Feynman diagram of Figure 2. (i) Direct detection is when the time arrow in this Feynman diagram points upwards: a DM particle comes in and scatters off a SM fermion. The recoil energy of the SM fermion is detected using precision ultracold calorimetry as in CRESST III or dual-phase noble gas time projection chambers such as

FIG 2



XENON 1T. (ii) Indirect detection has time running to the left: two DM particles annihilate, producing SM fermions, or other SM particles, that can be observed by the AMS on the ISS. Such annihilations may occur in active galactic nuclei, where the DM density may be the highest. (iii) collider production is the inverse process: two SM fermions, for example quarks at the LHC, annihilate producing DM particles. The smoking gun signature of such events is missing momentum, abbreviated to *pmiss*, since the DM particles escape detection.

Each of the three approaches involves specific assumptions. My personal passion lies in the third category, as this arguably makes a minimal set of assumptions: a production mechanism and that DM particles can be kinematically produced or at least their presence inferred at the LHC. I am particularly fascinated by new signatures that have not received attention yet, even after 10 years of LHC operations.

Landscape of searches for vanilla WIMP dark matter

In the past few years, we have seen a rapid evolution of searches for *WIMP DM*, meaning weakly interacting massive particles, with DM *weakly* coupled to the SM sector. *The LHC Dark Matter Working Group*, which I chaired from 2018-20, successfully coordinated these efforts, bringing together the theory and experimental parts of the community. The result was many new interesting theoretical models for potential DM signals (1, 2, 3), novel high-precision calculations (4) of the main SM backgrounds, and new experimental efforts that flourished as a result of this cross-fertilisation. As a consequence of this effort and the growing dataset of *pp* collisions at the LHC, the sensitivity of flagship searches using *generic* signatures, for example, a jet from a gluon or a quark recoiling against missing transverse momentum *pTmiss* from DM particles escaping detection, as shown in Figure 3, could be dramatically improved.

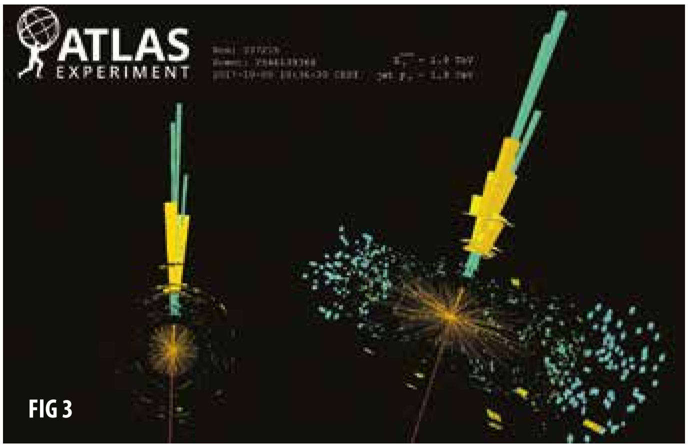
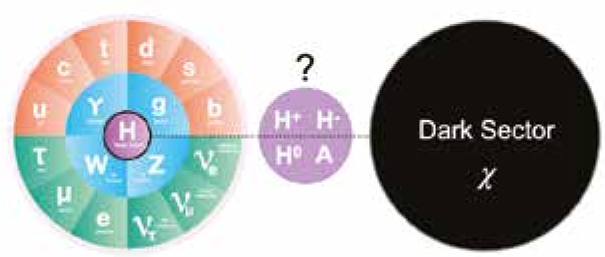


FIG 3

The palette of signatures to search for DM events was significantly extended during my co-leadership of the *ATLAS Common Dark Matter Group* in 2018–20. Additional focus was placed on scenarios where the Higgs boson plays a special role (Figure 4). Such scenarios result in final states involving Higgs (*H*) bosons, *W* and *Z* bosons, as well as top quarks, in addition to the *pTmiss* from DM particles. A few recent examples that my team has significantly contributed to are the searches for H+DM (5), W/Z+DM (6), invisibly decaying H (7), and, most recently, DM production in association with dark Higgs bosons (8), which involved a hitherto uncovered signature at the LHC: resonantly produced *WW* or *ZZ* pairs with *pTmiss* from DM particles.

FIG 4

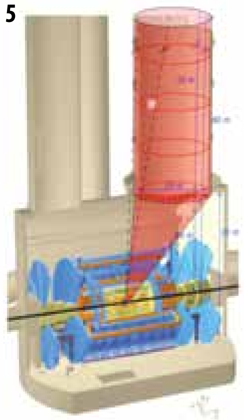


Dark Matter beyond the vanilla WIMP paradigm

My attention has recently transitioned to alternative DM scenarios that require orthogonal search strategies at the LHC. From a theory perspective, a compelling assumption is a *complex* dark sector containing not just one DM particle, but several particles that may reflect an additional symmetry. A fascinating example could be dark quarks and an SU(3) non-Abelian symmetry, which mirror the quark sector and the strong interaction of the SM.

The experimental signature typically present in models with complex dark sectors is striking - particles with macroscopic lifetimes - but searching experimentally for such signatures is inherently challenging. One limitation is the ability to efficiently identify candidate events , both online, that is, at the trigger level, and offline. We are currently working to improve the sensitivity of the ATLAS detector to long-lived particles with lifetimes less than 1 s. Another limitation for large decay lengths is simply the geometrical acceptance of the detector. To close the sensitivity gap spanning several orders of magnitude of particle lifetimes, we recently proposed ANUBIS — AN Underground Belayed In-Shaft experiment.

FIG 5



Our idea is to instrument the *existing* 18 m wide PX14 service shaft above the ATLAS detector with a series of tracking stations, as shown in Figure 5. ANUBIS is expected to dramatically improve the sensitivity to lifetimes in the currently unexplored range from 1 µs to the Big Bang nucleosynthesis bound of 1 s. With the generous support of the Issac Newton Trust, we are working towards firmly establishing the physics case for ANUBIS with detailed simulations and a prototype detector.

Biography

Oleg studied physics at the Universities of Bonn and Amsterdam and received his PhD from Oxford University in 2009, devising the first strategy to search for supersymmetry and dark matter at the LHC, and commissioning the Si tracking detector of ATLAS. As a post-doc at Göttingen and simultaneously a Fermi International Fellow at Fermilab, this work culminated in the most precise measurement of the top quark mass at the Tevatron. Back in Heidelberg in 2013, Oleg returned to the ATLAS experiment at the LHC and continues his DM searches after joining the Cavendish Laboratory in 2019. Oleg's other passions involve outdoor activities like open water swimming, free diving, hiking, or running as well as education, history of science, and philosophical implications of physics and technology.

1. https://doi.org/10.1016/j.dark.2019.100371
2. https://doi.org/10.1016/j.dark.2019.100365
3. https://doi.org/10.1016/j.dark.2019.100377
4. https://doi.org/10.1140/epjc/s10052-017-5389-1
5. https://doi.org/10.1103/PhysRevLett.119.181804
6. https://doi.org/10.1007/JHEP10(2018)180
7. https://doi.org/10.1103/PhysRevLett.122.231801
8. https://doi.org/10.1103/PhysRevLett.126.121802

Ray Dolby Centre News

Construction of the new Ray Dolby Centre continues to make good progress with the average number of people on site reaching 540 during April 2021. We anticipate these numbers to increase over the coming months with the commencement of new subcontractors on internal architectural trades and the push to completion of the Shared Facilities Hub.

We continue to face continued pressures due to the COVID pandemic but these have been managed carefully on site with full protective measures implemented in April last year still in place. We have had limited numbers of cases on site and the workforce have embraced the measures the project has taken to help keep everyone safe. In addition to the existing measures, we are also undertaking Lateral Flow testing of everyone on the project every 2 to 3 weeks which takes a tremendous amount of effort from the team organising over 500 people to be tested over a 3 day period!

The structural works have reached several important milestones over the last six months with the completion of the concrete frames for each of the 4 main wings and the Central Utilities Buildings (CUBs). The main focus now is the completion of the steel structure to Wing 5 which involves careful sequencing of the pre-cast columns and steelwork. This part of the project requires extensive temporary works and around 16 different phases of the construction sequence. The first area of this frame is complete, which forms the main central atrium, and shortly we will be installing the main steel trusses for the 'hanging small lecture theatre'.

The building envelope continues to progress sequentially around the site with the majority of the building watertight for the main wings. Works are now focusing on the CUBs and the link buildings, with the last main area to commence with the curtain wall to wing 5.

Internally the building is progressing in all areas with Internal trades and Mechanical and Electrical works ramping up resources progressively. Wing 4, the workshops and teaching laboratories, is the most advanced area of the project with painting, preparation for floor finishes, glazed partitions and ceiling grids starting to progress. The main plantroom areas are progressing well with the Ground Source Heat Pump room well advanced. The main Electrical Supply which will feed the main building has been energised with permanent power now feeding the Shared Facilities Hub as part of this energisation.

Wing 2 and 3 office areas are being worked on sequentially with the most advanced areas now having glazed partitions and grids for the acoustic rafts being installed. The mock-up office

has been completed and is under a review process with the retained team.

The clean room areas on Wings 2 and 3 have seen significant progress with the majority of all the high level M & E works substantially complete. Cleanroom partitions and plenums are in construction and, with the perimeter walls shortly due to be closed, these areas will move to the next phase in which the works will be completed in a controlled environment.

The Cryostat Hall in Wing 1 now has all the main steelwork and lifting beams installed allowing the high level M & E works to progress. The construction of the timber grey spaces will commence in the coming weeks.

With the structure and form of Wing 5 now taking shape you can now start to get a good impression of how these spaces will feel when completed .

ABOVE: (top left) Wing 5, steelwork. (top right) Wing 4, East elevation. (bottom left) Wing 4 North-East elevation. (bottom right) Courtyard link between wings 1 and 2.

On the Shared Facilities Hub, the façade is substantially complete with the orange cladding progressively being covered with the veil cladding. Internally the building fitting out is progressing with finishing trades now fully mobilised. The M & E works are reaching the final stages with Testing and Commissioning starting in the next few weeks.

There have also been some changes to the roads around the campus with the speed bumps now replaced with alternative traffic calming measures on Charles Babbage road. These works have been completed to reduce the risk of vibration impacts on the Ray Dolby Centre.

NEIL PIXSLEY

Outreach during the Pandemic

Though things may, thankfully, be starting to return to some form of normality, we are still a long way from being able to welcome schools and the wider public back into the lab. Luckily, our online catalogue of events has been very well received and allowed us to connect with larger numbers of more distant students than usual. So far this year, 1730 students from around the UK have made use of our online resources including a collection of novel Physics activities using common school equipment, videos on higher education, and a remote Q&A session with Steve Martin (right) and myself (left) in the screengrab above.

These aim to dispel misconceptions about Physics, and inspire students to pursue Physics in further and higher education. Adapting a very practical programme to a remote, online model has been challenging but has been well received by our attendees. Some Y12 attendees commented; 'Before I thought going to university may have been a huge challenge, but now I understand if you put the correct effort of work in, it is quite achievable.' 'I'm now considering it for further study at University' and 'Its amazing! Especially kinematics.'

Two sessions remain in this year's programme, for Y7/8 and Y9. To begin with, next year's programme will be online only but we hope to be back with face-to-face events as soon as the situation allows, though our success with remote events mean that we will be moving to a blended approach. For more information, please visit **http://outreach.phy.cam.ac.uk/cpe**

TOP: Jacob and Steve in full flight during their online Q and A session. The leader from King's Maths School commented, 'Such an animated Q&A between our Year 12s and Steve and Jacob. Ranging from uni life to the future of physics. Felt great pride hearing our students' breadth of questions.'

Physics at Work 2020

Last September, Physics at Work (PaW) took place online for the first time in its 36-year history. Over the course of the event, we had 2951 unique visitors to the Physics at Work pages and hundreds of views of the exhibitors' recorded content. In line with university guidance, PaW 2021 will be online again and, with the benefit of a year of online working, we hope to have a much more dynamic and interactive event. If any Physics-related academics or professionals wish to become involved, please contact the Outreach Office.

Cambridge Festival 2021

The Cambridge Festival (previously Science Festival) took place last month, both online, via a socially-distanced walking tour around the West Cambridge Site, and at home with our "make-and-do" activities. *The Making of a Physicist*, a screening of four short films on female Cavendish researchers and a Q&A with each of them, is available, along with the SciArt Soiree, an evening event featuring three renowned Sci-artists talking about their work, and four short presentations from early-career Physicists explaining their research. These can all be viewed at **https://outreach.phy.cam.ac.uk/festival**

JACOB BUTLER

ABOVE: Researchers from the Cavendish who produced short films for the Cambridge Festival. Clockwise from top-left: Amita Ummadisingu, Denis Tihon, Paolo Molignini, and Angela Harper

Isaac Physics: Update and New Faces

ANTON MACHACEK brings this success story up to date and introduces some new faces

Ingrid Murray (left) in full flow with young teachers. Nicki Humphrey-Baker (right) making creative use of the hands in solving physics problems.

Since its inception in 2013 thanks to the vision of Lisa Jardine-Wright and Mark Warner, the Isaac Physics project has enabled school-age students to develop problem solving skills with online and face-to-face support. The project, based at the Cavendish Laboratory, is funded by the UK Government's Department for Education with support from The Ogden Trust. This has enabled the team to create an Online Platform for Active Learning (OPAL) which enables students to access a bank of over 6000 questions together with support and teaching materials at **http://isaacphysics.org**. Over 71 000 000 questions have been answered online in the last seven years - over 340 000 students and 10 000 teachers registered.

The material was developed to enable students to practise using their mathematical knowledge in practical contexts, bridging the gap between two disciplines taught separately at school. Our conviction is that Physics is best learned by doing it, leading to better understanding of the concepts and how they can be applied.

To enable the material to be used more readily in schools, questions targeted at improving mastery of the concepts needed at A-level are also made available in workbook form. These books are sold to schools at cost price (£1 each). While students can use the site on their own, teachers in schools may set up groups on the site for their classes, set particular questions to those classes, and then monitor the students' progress. There is no charge to schools or students for these facilities. The scope of the project subsequently expanded into the Physical Chemistry aspects of A-level Chemistry, supporting A-level Mathematics and Further Mathematics teaching and also to GCSE Physics. All of these are covered by an extensive question bank and printed workbooks. We intend developing resources for younger students too and have commissioned questions and a workbook for GCSE Mathematics as well.

With the wide-reaching effects of the pandemic on school learning, the OPAL is relied upon by teachers to support their students in remote learning, and concept and revision lessons are available. The Isaac Team has also increased the frequency of support events. These have moved online as meetings and webinars, and have enabled over 2200 students to meet, solve problems together, and receive guidance since August 2020. The feedback from students who attended the events has made it clear that these have played a vital role in helping students understand and apply their Physics during a period of school closure.

Comments from masterclass participants

- This masterclass did meet my learning needs, I found it really helpful to go over questions that I struggled with in the practice beforehand. I found it especially useful that we were set work before so I knew which questions I struggled with. I can't think of anything to improve it, I found it was perfect for what I needed.
- I really enjoyed it and it has made me sure that I want to do it [Physics] at A-level and possibly in the future because it went deeper into the subject than GCSE.
- It was really helpful in building my confidence
- That was an absolutely amazing session – one of the best ones I have ever been part of.

Part of our remit is to support teachers. Teachers who responded to a recent survey indicated that, on average, Isaac Physics saved them nearly four hours each week, thereby fitting in with recent Government targets to reduce teacher workload and aid teacher

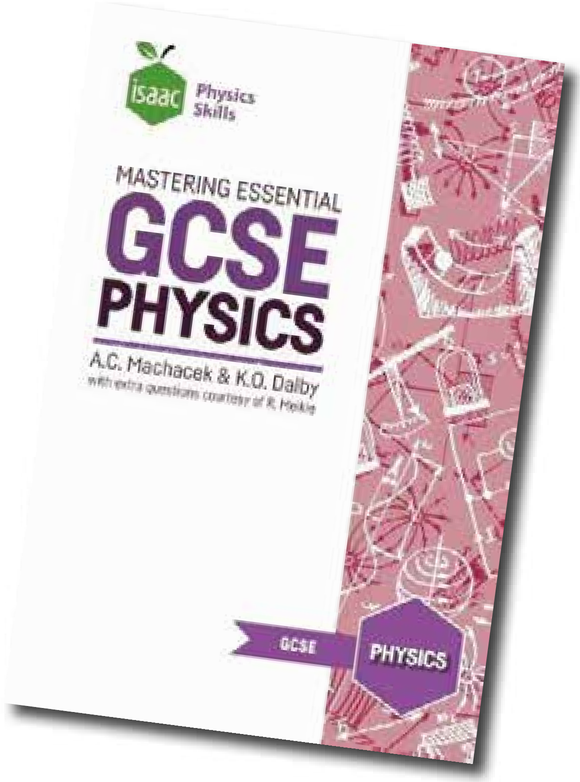
retention. We now have a dedicated Teacher Support Manager, **Ingrid Murray**, who is a highly experienced and accomplished teacher with experience of Special Educational Needs support as well as Departmental leadership. She has organized training events online and sessions for trainee teachers too. Teachers' comments after sessions include:

- Very grateful for the program – helps me understand Isaac Physics, great to learn problem solving skills and hearing your tips about teaching – also good to hear issues, tips from other teachers.
- Amazingly helpful session. Thank you so much.

To assist with the expanding remit of Isaac Physics, and to support Lisa Jardine-Wright, the Project's Director, the team has expanded, including **Nicki Humphry-Baker** as Assistant Director. She has been involved with the project from the beginning and supervises the OPAL and content development, as well as overseeing aspects of the Physics Department's Outreach programme. She is assisted in this by **Lee Phillips**, the Senior Content Developer, who manages the day to day quality assurance and editing of new material as well providing guidance and direction to those adding to our resource bank. He brings commercial and academic experience to his role. In addition, **Anton Machacek**, who contributed to Isaac questions and books during his time as a Physics teacher and Assistant Head, has joined the project as Associate Director. He has responsibility for the delivery of remote lessons, online and in person events, and for developing resources for new audiences.

The Department for Education has just renewed the Isaac Physics grant for a further three years and it is no surprise that the team is keen to demonstrate that it can build on the terrific success to date, and support the education of young scientists, mathematicians and engineers further.

ABOVE: Lee Phillips (left) with his apparatus. Anton Machacek (right) in lecture mode.



Isaac Physics: FREE GCSE Physics workbooks to 8000 students

Isaac Physics is offering to provide FREE GCSE Physics workbooks to 8000 students who have difficulty accessing online resources. These 182 page books, which contain notes, worked examples and practice questions, are normally sold for £1 + P&P but the Isaac project will provide them free and pay the postage required for students to receive them at their homes. The workbooks cover core topics in GCSE syllabuses.

Students or their teachers and supporters (such as family members or community leaders) can request one of these books at the following link: **https://tinyurl.com/physgcsebook**.

Any student is eligible to apply, but the 8000 free copies will be prioritised for students who live in one of the Department for Education's opportunity areas. Teachers may also use the link above to order a box of free books for their school to use in the classroom and for homework. The funding for these free books is provided in collaboration with a generous legacy to the Cavendish Laboratory from physics teacher and teacher trainer, the late Brenda Jennison.

Cambridge Centre for Physical Biology Awards to Diana Fusco and Alexander Ohmann

We congratulate warmly Diana Fusco and Alexander Ohmann for their Cambridge Centre for Physical Biology Awards.

Diana Fusco, recently appointed a lecturer in the Biological & Soft Systems sector, has been awarded a Pump Priming Grant, jointly with Somenath Bakshi (Engineering) for research into 'Super-resolution imaging of microbial biofilms using tunable synthetic genetic oscillators'. The **Cambridge Centre for Physical Biology - Pump Priming Grants** is an annual scheme aimed at generating new collaborations between early career research teams with complementary expertise, promoting multidisciplinary research in the field of physical biology in the University.

Alexander Ohmann, a research associate in the Nanophotonics Centre, has been awarded a 2020 PhD Prize for 'innovative research at the intersection between biological, physical and/or mathematical sciences' for his research in 'Outperforming nature with a lipid-flipping enzyme built from DNA'.

Tina Potter: Pilkington Prize Winner

Many congratulations to **Tina Potter** who has been awarded a Pilkington Prize for her teaching. The Pilkington Prizes are awarded annually to members of staff in recognition of their contributions to teaching excellence. The awards were initiated by Sir Alastair Pilkington, who believed that the quality of teaching was crucial to the University's success. A virtual ceremony is planned for Tuesday 29 June, at which thirteen Pilkington Prizes will be presented to the 2020-21 prize winners.

Jacqui Cole awarded the ACA 2021 B E Warren Diffraction Physics Award

Many congratulations to **Jacqui Cole**, Head of the Molecular Engineering Group, on the award of the American Crystallographic Association's 2021 B E Warren Diffraction Physics Award in recognition of her 'important recent contribution to the physics of solids or liquids using X-ray, neutron or electron diffraction techniques'.

Welcome

We welcome the following new staff members to the Laboratory:

Vanessa Bismuth
Communications Manager (see page 13)

Chris Brock
Audiovisual Specialist in the IT Services Team

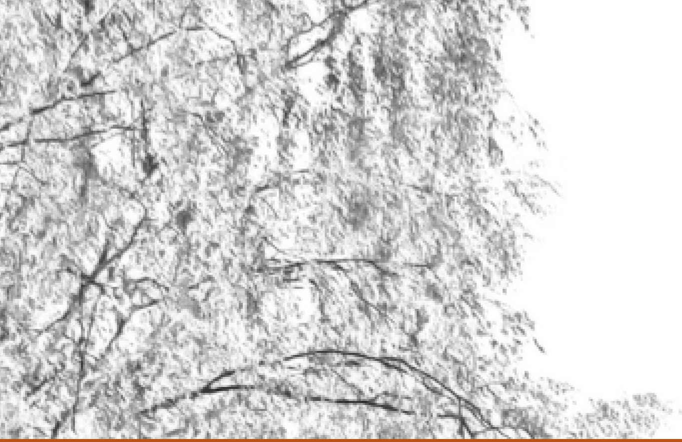
Fiona Egan
Rutherford HR Coordinator

Anthea Messent
Cavendish Laboratory National Facility Development Manager

Roberta Verlini
Rutherford Hub Administrator (Secondment cover)

Sam Stokes has been seconded to the role of Departmental Administrator during **Gillian Weale's** secondment to manage the University's response to the Covid-19 emergency.

Sarah Hedger has been seconded to the role of Deputy Departmental Administrator to support **Sam Stokes**.



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 described in CavMag 18 and can be viewed online at: **www.phy.cam.ac.uk/alumni/files/Cavmag18Aug2017online.pdf**

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.

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