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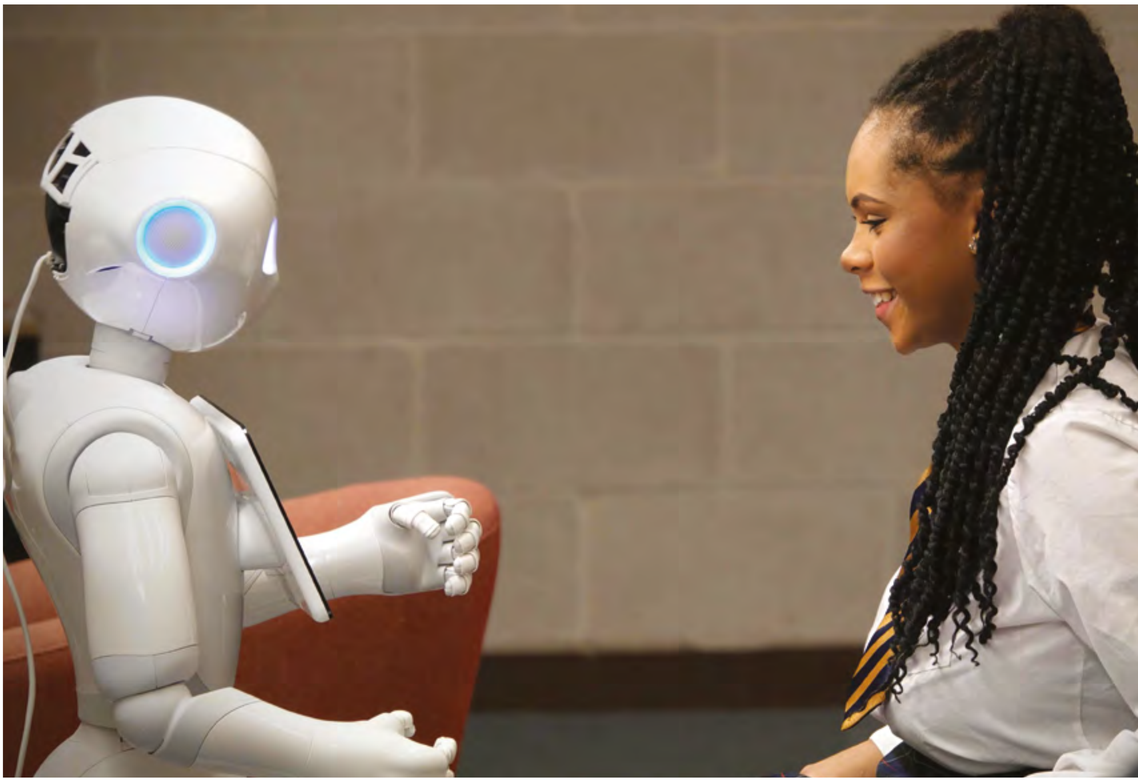
News from the Cavendish Laboratory



Physics at work – the next generation

INSIDE

IMAGES ON FRONT COVER: Physics at work 2023. Clockwise from top left: A firey lecture; interacting with a robot; magnetic levitation with superconducting magnets. Photography © Chris Brock.

The Changing of the Guard

We are delighted to welcome METE ATATÜRE as the new Head of the Cavendish Laboratory, succeeding Andy Parker – Mete took up this position on 1 October 2023.

In the last edition of CavMag, Mete described his vision for the future of the Laboratory and the challenging times ahead. As he commented on his new appointment,

“I am incredibly honoured to be trusted in this role and to follow in the footsteps of Andy Parker and everyone who made the Cavendish Laboratory what it is today - a great place of scientific discovery, driven by the urge to question and challenge.

"The Department is on a continuous journey. That is what excites me and my colleagues, and what attracts people to us: it’s the stimulation, the sense of possibility, the innovation, and I am proud to be taking an even more active part in this today. Our main resource is people, and I will do everything I can to support our community through the new era that is coming soon."

Mete has been a highly successful head of the Quantum Optical Materials and Systems team (QOMS), investigating the quantum physics of light-matter interaction to implement quantum information networks and communication, as well as new applications in sensing. Articles by Mete and his colleagues have appeared regularly in CavMag, all testifying to the excitement and success of his programme. He is also a co-founder and Chief Scientific Officer of the quantum-tech spin out, Nu Quantum Ltd. He dedicates significant time to science communication and public engagement on the role of science in society, scientific integrity, and achieving diversity & equality in science.

We wish Mete all the best of luck in making a success of this demanding but exhilarating position.

Making way for new faces

The last seven years have been dominated by the implementation of the Cavendish 3 project, which is planned to culminate with the handing over of the Ray Dolby Centre (RDC) to the Laboratory at the end of March 2024. A whole new range of challenges present themselves to be taken forward by new colleagues in roles vacated by three academic staff members who have contributed to the success of the Cavendish 3 programme.

First of all, we must recognise Andy Parker's key role as Head of Department throughout the whole of the RDC project. The final go-ahead for the project took place during his tenure of the position as Head of the Cavendish and he was ultimately responsible for the implementation of the programme. This has been a terrific achievement. He retired as a Cavendish staff member on 30th September 2023.

On the same date, Richard Phillips retired. Richard has done a fantastic job in looking after all the complex technical details of building the new Cavendish we need for all aspects of our activity for the coming years. He has been looking after the interests of all staff members, ensuring that they will enjoy a stimulating and efficient new workplace. This required vision and foresight for what 'physics' as we know it will look like in the coming years. We all owe him a tremendous debt of gratitude for this unstinting efforts.

Finally, there is your editor whose long-overdue retirement also took place on 30th September 2023. To my embarrassment, Vanessa insisted upon paying tribute to me in this, my 30th edition of CavMag. This is a wonderful opportunity to record my gratitude to everyone in the Laboratory for the tremendous support I have had for achieving the goal I set in 2002 – we needed a new Laboratory for the 21st century and that is what we will begin to occupy next year.

What comes next?

2024 will not only be the year of our big move, it will also mark the 150th anniversary of the Laboratory and the 50th Anniversary of our occupation of the West Cambridge site. As we are writing these words, we are elaborating plans to commemorate this major milestone in style and of course, we will count on the support of all our alumni to make this year a truly exceptional one.

ABOVE: (Top) The entrance to the 1874 Cavendish Laboratory in Free School Lane. (Bottom) The entrance to the Ray Dolby Centre of the new Cavendish Laboratory ready for our arrival in 2024 (Photography by Paul Raftery).

We are already thinking about new ways to connect with you and to understand your preferences regarding CavMag and other ways to get involved in what promises to be an amazing future. We describe later in this issue how we plan to engage with all alumni and obtain interesting material from you. We hope many of you will take an active role in this next leg of the journey!

MALCOLM LONGAIR and **VANESSA BISMUTH**

Cavendish researchers exceptional success in the 2023 Institute of Physics awards

The Institute of Physics (IOP) awards celebrate physicists at every stage of their careers from those just starting out, through to physicists at the peak of their careers, and those with a distinguished career behind them. Four Cavendish colleagues have scored a brilliant success this year.

HANNAH STERN has received **the Henry Moseley Award** for her exceptional early career contributions to experimental physics. Hannah has made important advances in the understanding of electronic processes in molecular semiconductors and two-dimensional materials, including identification of a spin qubit in a two-dimensional material.

The Lise Meitner Medal & Prize, celebrating distinguished contributions to public engagement within physics, was awarded to **HARRY CLIFF**. His work on exhibitions, festivals, talks, magazine articles and a popular science book constitutes an exceptional record of growing the public understanding of physics.

ULRICH KEYSER has been awarded **the Sam Edwards Medal and Prize** for pioneering the study of transport of structured nucleic-acid molecules through nanopores and the quantification of out-of-equilibrium polymer dynamics at the single-molecule level. His research is enabling new applications in biotechnology including disease detection.

ULRICH SCHNEIDER has received **the Joseph Thomson Medal and Prize** in recognition for groundbreaking experiments on the collective dynamics of quantum gases in optical lattices, including fundamental studies of localization effects. These advances strengthen the development and application of new quantum technologies in the UK.

We congratulate all four of them most warmly on these remarkable achievements in supporting so many aspects of our core physics activities.

Adam Brown
Championing the next Generation of Apprentices

We are delighted to congratulate ADAM BROWN who has been highly commended in the Champion of the Year category of the University's Apprenticeships Awards 2023. There is a desperate need for highly skilled technicians who are essential for the programmes of experimental physics research in the Laboratory. As Adam puts it, in this situation, 'we have to grow our own'.

Adam knows only too well how challenging and stimulating such apprenticeships can be, having experienced it himself at first hand. He started as a mechanical engineer apprentice at the Cavendish in 2007. He then progressed up through the apprenticeship training grades to the highest level, grade 6. During that time, he worked in the Laboratory workshop, reaching the grade of Senior Technician. I have very happy memories of working with him when we needed a replica of the Wilson Cloud Chamber of 1911. This was a major challenge which he thoroughly enjoyed, at the same time gaining an appreciation of the skill and genius of C.T.R. Wilson in inventing this instrument which was historically of the highest importance.

He joined Henning Sirringhaus's group to run the X-ray photoemission spectroscopy (XPS) facility with Roger Beedle and then became Laboratory Manager for the Cavendish's Maxwell Centre, which fosters collaboration between fundamental physics and industry. He next joined the Chemical Engineering and Biotechnology Department in charge of Technical Operations before returning to the Cavendish as Head of Scientific Laboratory Services, reporting directly to the Head of the Cavendish Estate, Peter Norman - Peter proved to be a wonderful mentor. Adam now faces the major challenges of the move to the Ray Dolby Centre next year and supporting Andy Jardine in providing services not only to the Department but to the whole UK community as the Laboratory takes on its National Facility role.

At the same time, Adam is working on creating a new apprenticeship scheme for the Department, and is mentoring two laboratory technician apprentices, Oliwia Zawadzka and Luke Cavill (Figure below). He will be hiring a further two new laboratory technician apprentices this year. As he states,

"I have always been committed to promoting, supporting, and developing apprenticeships in every way possible. By investing in the personal and professional development of our apprentices, I hope to inspire them to reach their full potential and to make meaningful contributions to our organisation."

Convinced that there is a need for more departments to be committed to apprenticeship training, Adam is strongly encouraging others on the West Cambridge site to take up this challenge. To demonstrate their value, some of the new Cavendish cohort will be spending periods of their training in these Departments.

We wish Adam every success in his ambitions to create the next generation of expert and imaginative technicians who will work with the researchers to their mutual benefit. This tradition stretches back to the brilliant technicians who supported successive Cavendish professors from the time of J.J Thomson to the present day – they are a crucial resource for the future programmes of the Laboatory..

For more details of the apprenticeship programme and interviews with the current apprentices, see www.phy.cam.ac.uk/jobs/apprenticeships

MALCOLM LONGAIR

BELOW: Oliwia Zawadzka and Luke Cavill with Adam.

Finding equilibrium in quantum chaos

New experiments on turbulence in a quantum gas reveal that key properties of notoriously complicated wave turbulence can be captured by an elegant universal equation.
LENA DOGRA and ZORAN HADZIBABIC explain.

Turbulence is ubiquitous, occurring everywhere from blood flow to airplane flights, and from interstellar plasmas to financial markets. Due to its chaotic nature, it is unpredictable and hard to control, but one thing that is established is that its key characteristic is that a flow breaks into smaller and smaller structures, until the energy injected at a large scale, for example by wind in the case of ocean waves, is dissipated at some small wavelength (Figure 1). Wave turbulence is challenging to treat either analytically or numerically, and also difficult to measure, due to the involvement of a large range of different wavelengths.

We obtained new insights by exploring wave turbulence in an atomic gas cooled close to zero absolute temperature, held in an 'optical box' made of laser light, an approach which was pioneered at the Cavendish (1), and shaken by an oscillating force (Figure 1). Our atomic clouds are no larger than the width of a human hair, but display a spectrum of turbulence similar to that observed on macroscopic scales. Moreover, and crucially, the precision tools of atomic physics allow us to study the cascade of wave excitations across all relevant length-scales, from the scale of the box size, at which the cloud is excited, to the smallest scale at which the energy is dissipated.

The main finding of our study is that the key properties of wave turbulence in our gas can be related by a universal 'equation of state' (EoS) (2). Such equations have been cornerstones of equilibrium thermodynamics ever since Robert Boyle observed in 1662 that the volume of a gas is, at constant temperature, inversely proportional to pressure. The beauty and power of such equations lie in the fact that they capture key properties of macroscopic equilibrium systems without the need for a detailed microscopic description. In comparison, far-from-equilibrium systems are generally less amenable to such succinct descriptions and harder to understand. For decades, theorists have speculated if, and under what conditions, one can describe them in a systematic way analogous to equilibrium thermodynamics (Figure. 2). Our experiments show that an EoS-like description is possible for steady wave turbulence. This important step towards extending a thermodynamic-like approach to non-equilibrium situations could also be relevant for other far-from-equilibrium systems, such as glasses or active matter.

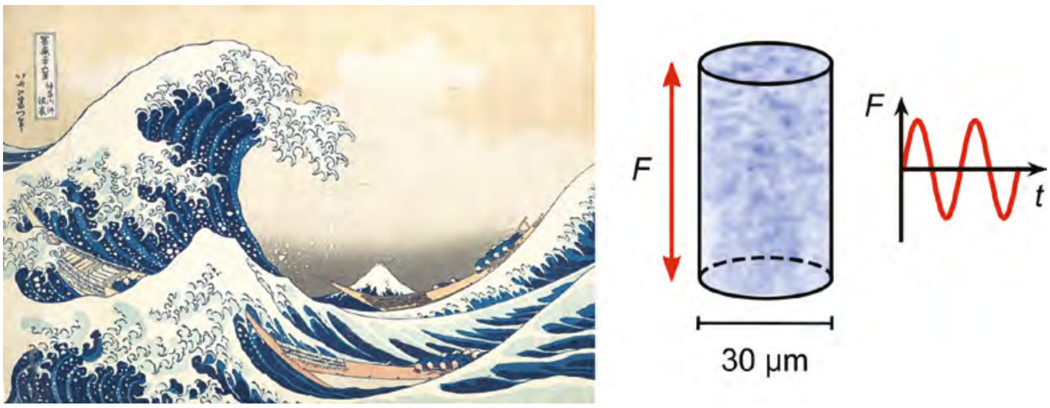


FIG 1. (left) The Great Wave off Kanagawa print from 1831 shows a classic example of turbulence, a far-from-equilibrium phenomenon that has fascinated scientists for centuries but is still not fully understood (credit: Wikimedia Commons). (right) Our new experiments shed light on wave turbulence by studying it in a tiny quantum gas, cooled close to zero absolute temperature and held in a box made of laser light. The cartoon portrays our cylindrical optical box holding a quantum cloud (blue) and the oscillating force that drives the gas into a turbulent state.

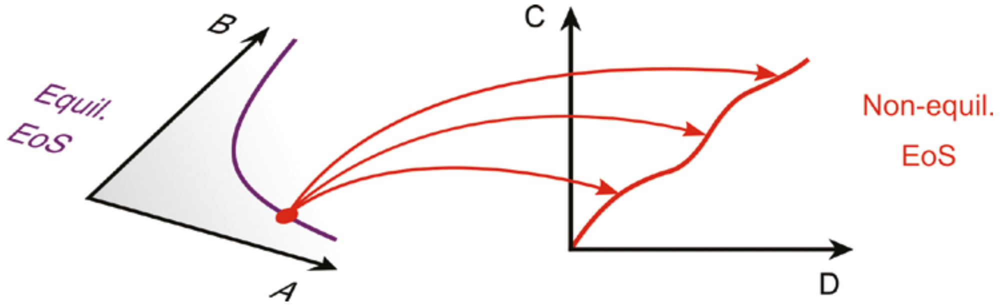


FIG.2. Concept of a far-from-equilibrium equation of state (EoS). An EoS describes possible states of a macroscopic system by relating state variables such as pressure or temperature. Here, A and B are some generic equilibrium state variables, all equilibrium states lying in the A−B plane, and out of each of them one can create countless far-from-equilibrium ones, shown by the arrows. If the latter are stationary, they might still obey an EoS with new state variables C and D.

In Figure 3 we outline our quantitative results. A continuously shaken gas reaches a steady state characterized by a power-law momentum distribution, which gives the relative amplitudes of waves with different wavelengths. This far-from-equilibrium state is sustained by continuous energy injection; a constant energy flux ϵ flows in momentum space from large to small wavelengths. Intuitively, the two key properties of this turbulent state should be the amplitude n_0 of the power-law spectrum and the energy flux ϵ. However, both n_0 and ϵ are 'emergent' - individually, they depend in complicated and hard-to-calculate ways on the amplitude and frequency of the shaking force, the gas density, and the strength of the interactions between the atoms. What our study shows is that, despite this complexity, the relationship between the emergent n_0 and ϵ is universal for a wide range of microscopic parameters, echoing the universality of the equilibrium equations of state, such as the ideal-gas law empirically discovered by Boyle.

These results are the culmination of 7 years of our work on turbulence starting with the paper by Navon and our colleagues (3). The key advantage of our experiment was that we can directly measure the energy flux ϵ, also covered in the article in CavMag 23, which is notoriously hard in other turbulent systems (4). Our experiments empirically show that an EoS for wave turbulence exists, but also challenge leading theories, based on the so-called Gross-Pitaevskii equation, which cannot explain it fully. We thus expect further exciting studies, both experimental and theoretical, to come in the future.

References

(1) Gaunt et al., Phys. Rev. Lett. **110**, 200406 (2013).
(2) Dogra et al., Nature **620**, 521 (2023).
(3) Navon et al., Nature **539**, 72 (2016).
(4) Navon et al., Science **366**, 382 (2019).

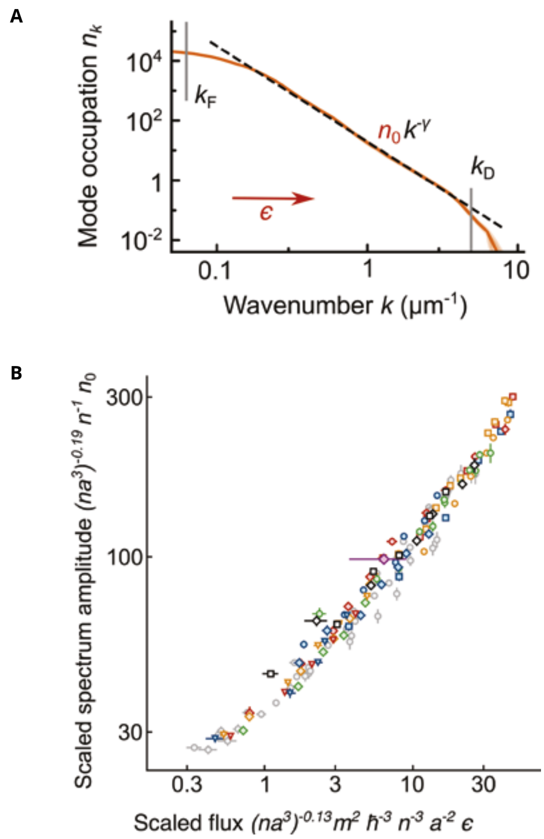


FIG.3. The universal equation of state for wave turbulence in a quantum gas. (a) In the steady state, a turbulent gas has a highly non-equilibrium, but stationary, power-law momentum distribution, with fixed γ = 3.2 and variable spectrum amplitude n_0. This steady state is sustained by the energy flux ϵ, which is injected at a large length-scale $1/k_F$, set by the box size, and flows through momentum space to the small energy-dissipation length-scale $1/k_D$. Both n_0 and ϵ depend in complex ways on the amplitude and frequency of the shaking force, the gas density n, and the strength of interatomic interactions a. (b) However, we show that for various microscopic parameters, the relationship between the emergent n_0 and ϵ can be cast in a universal form, the colours indicating measurements with different n and a, and m is the atom mass, much like the relationship between the volume and pressure in an equilibrium gas.

The Greening of the Andes

In 2017, **CRISPIN BARNES** created an Environmental Physics Group in collaboration with four Peruvian universities; Moquegua UNAM, Barranca UNAB, Canete UNDC and Huanta UNAH. Here, **HUGO LEPAGE** and Crispin describe the remarkable results of their studies of the greening of the Andes.

The Pacific slope of the Andes in Peru and northern Chile is an area of particular interest for studying the effects of climate change on vegetation. The arid region is geographically separated by rapidly rising mountains, with each valley supporting high levels of biological endemism, meaning species only found in a single defined geographic location. Furthermore, water scarcity in the region leads major cities, such as Lima and Arequipa, to rely on a small number of rivers to support their large populations and agricultural demands. A study of the changing conditions in this vulnerable region is therefore critical to forecast the impacts of climate change on ecosystems and biological water management services.

We have used multispectral satellite imagery to monitor the vegetative response to changing climate factors across the entire western slope of the Andes. We found that an area of over 80,000 km^2, about 1/3 the size of the UK, along the west flank of the Andes has been undergoing significant greening in the past 20 years. We define greening as an increase in a vegetation index calculated using blue, red and infrared bands of light reflected off the surface of the Earth and detected by satellites. Figure 1 shows an exaggerated three dimensional rendering of the Andes with a false colour overlay. Green regions on this image represent areas where the vegetation has increased by 30-60% in a statistically significant way. We call this continuous region of vegetation increase the 'greening strip'.

This strip roughly follows climate zones as defined by the Köppen-Geiger classification system, lying mostly across the hot arid desert, the cold arid desert and the cold

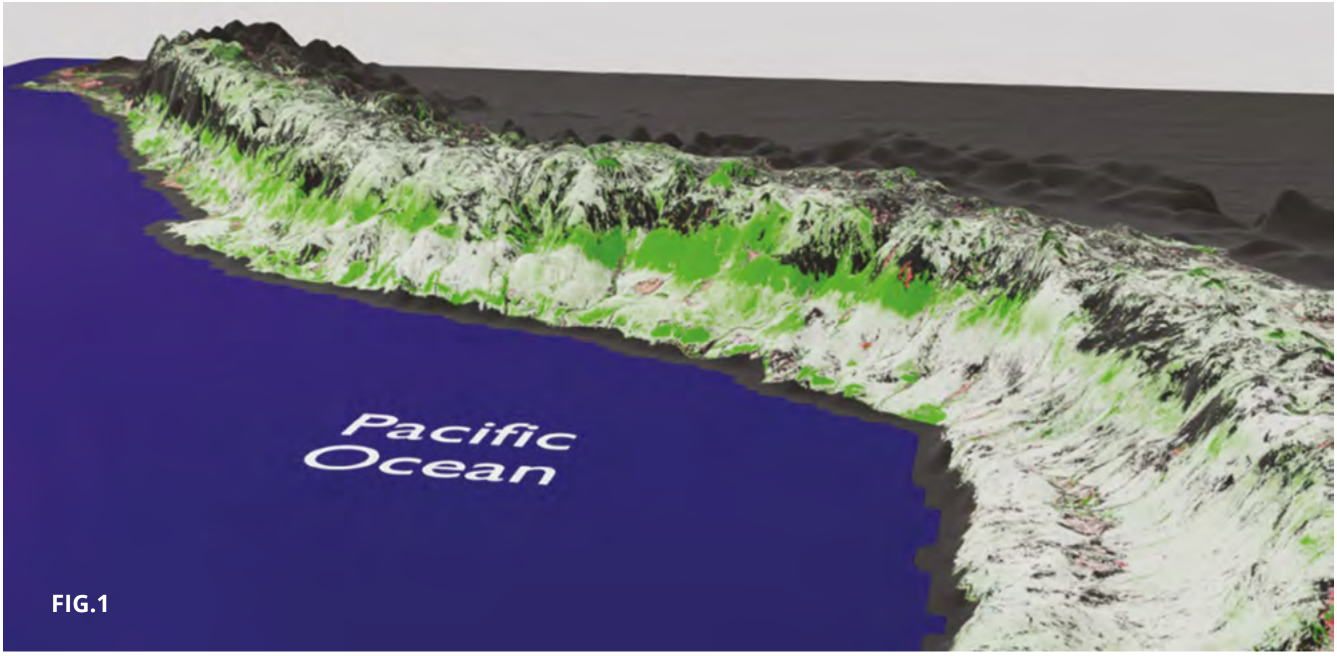


FIG.1

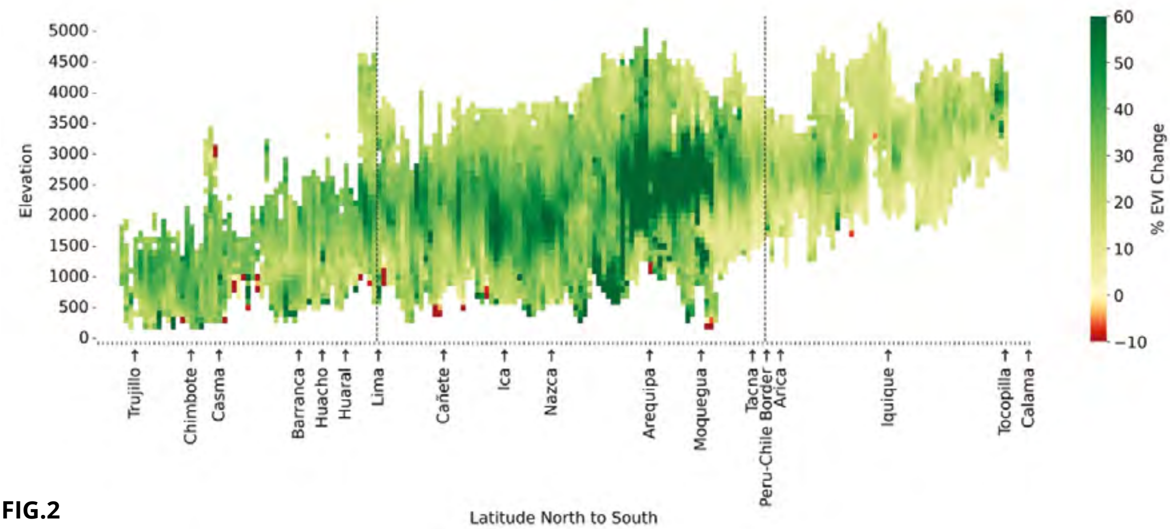


FIG.2

arid steppe regions. An interesting observation is that the greening strip does not follow the climate zones fully. In northern Peru, the strip lies almost entirely in the hot arid desert, ranging from a few hundred meters to 2000 meters in altitude. As we travel further south, the climate zones climb in altitude and so does the greening strip.

However, the strip climbs faster than the climate zones, crossing the cold arid desert to cover the cold arid steppe. This climb is counterintuitive since one would expect that as we look further south in the southern hemisphere, temperatures get lower and ascending in altitude would have a similar effect. Figure 2 illustrates the ascent of the greening strip as we go from North to South, starting from Northern Peru all the way to Northern Chile.

We compared the twenty-year time series of the greening strip with climate factors that would influence plant growth such as the amount of precipitation, the temperature at the surface of the sea along the western flank of the Andes and the concentration of atmospheric CO_2 at ground level. These results can be seen on Figure 3 alongside the El Niño (orange) and La Niña (blue) climate events. From this figure, we can see that vegetation responds to changes in precipitation with a delay of approximately two weeks. Using cross correlation functions, we determine that the biggest driver of this vegetation change is atmospheric CO_2, where a steady increase in airborne carbon has provided some plants with a greater material supply for photosynthesis.

This research highlights a significant change in an area defined by a fragile ecosystem. Rapid changes such as this can lead to unpredictable consequences, which in turn could affect biodiversity, water availability and soil composition in the area, thus impacting local populations.

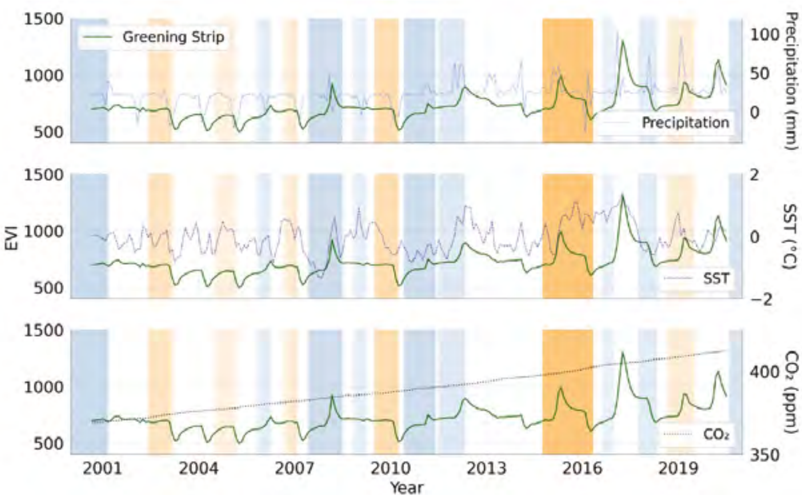


FIG.3

The study shows the need for more regional studies in mountainous regions to obtain ground-truth data and confirm the long-term impacts of climate change in Peru.

As Hugo Lepage stated: “This is a warning sign, like the canary in the mine. There is nothing we can do to stop changes at such a large scale. But knowing about it will help to plan better for the future.”

Reference:
Lepage et al. 2023., 'Greening and Browning Trends on the Pacific Slope of Peru and Northern Chile', *Remote Sensing*. DOI: 10.3390/rs15143628

Uncovering long-period exoplanets in a game of hide-and-seek

AMY TUSON and **DIDIER QUELOZ** describe their remarkable discovery of long-period warm mini-Neptunes, providing further steps in the search for habitable planets and life in the Universe.

Since the discovery of the first exoplanet orbiting a Sun-like star in 1995, more than 5500 exoplanets have been discovered and this number is constantly rising. All sorts of exotic worlds, including hot Jupiters, lava planets and planets orbiting two stars instead of one, just like Tatooine from Star Wars, have been discovered. Most of the known exoplanets are very different from the planets in our Solar System because they have much shorter orbital periods, are much closer to their host stars and are typically very hot. This arises because most of our discovery methods are heavily biased towards short-period exoplanets.

The effect of this detection bias on the exoplanet population is illustrated in Figure 1. If we expand the sample of long-period exoplanets, we will improve our understanding of planet formation and evolution. We will also be able to explore how our Solar System fits into the broader exoplanet population and, thanks to their cooler temperatures, we could discover potentially habitable worlds.

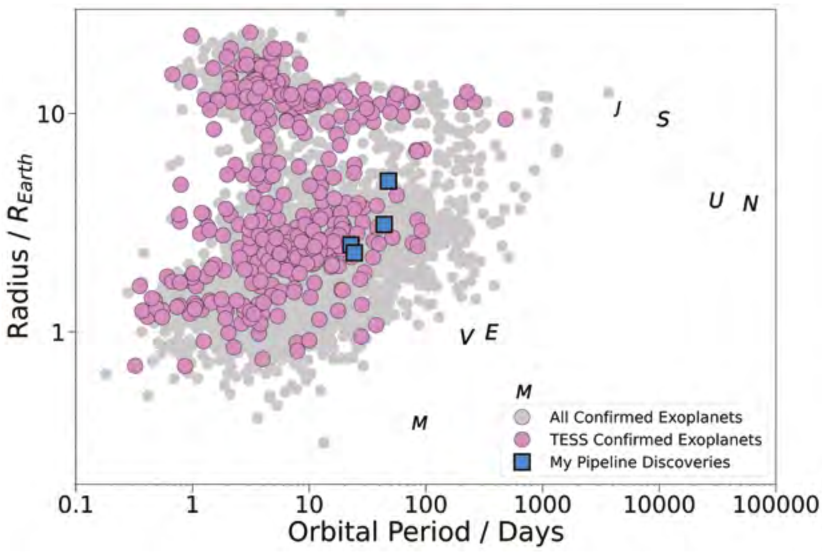


FIG 1: Period-radius diagram of all confirmed transiting exoplanets. The x-axis is the orbital period in days and the y-axis is the radius of the planet compared to Earth. Discoveries made by TESS are highlighted in pink, four of the new discoveries from Amy's pipeline are highlighted in blue and the Solar System planets (MVEMJSUN) are included for reference. The entire exoplanet population is heavily biased towards shorter orbital periods than our Solar System. Amy's pipeline discoveries are amongst the longest period planets discovered by TESS.

Amy and Didier have used two space-based telescopes, NASA's TESS mission and ESA's CHEOPS mission, to discover long-period exoplanets. Both telescopes use the transit method to observe exoplanets. A transit happens when a planet passes in front of its host star, causing a small but detectable drop in the star's brightness. From these transits, we can infer the presence of a planet, measure its radius and, by observing multiple repeating events, determine its orbital period. TESS observes most of the sky for only 27 days at a time, making it particularly susceptible to the short-period detection bias (see Figure 1). Any planet with an orbital period greater than about 13 days would only have a single transit observed, from which we cannot estimate the planet's orbital period and therefore cannot confirm the discovery.

TESS has however observed most of the sky multiple times over the course of several years. In some cases, a single transit becomes a 'duotransit' – a planet with two transits separated by a large time gap, typically two years. From two non-consecutive transits, the period of the planet remains unknown but there now exists a discrete set of allowed period aliases. Duotransits are the observational signatures of long-period planets, but how can we recover their true period?

Unlike TESS, CHEOPS is a targeted follow-up mission that observes known exoplanets. Amy is a member of the CHEOPS Duotransit Program in which TESS duotransits are observed

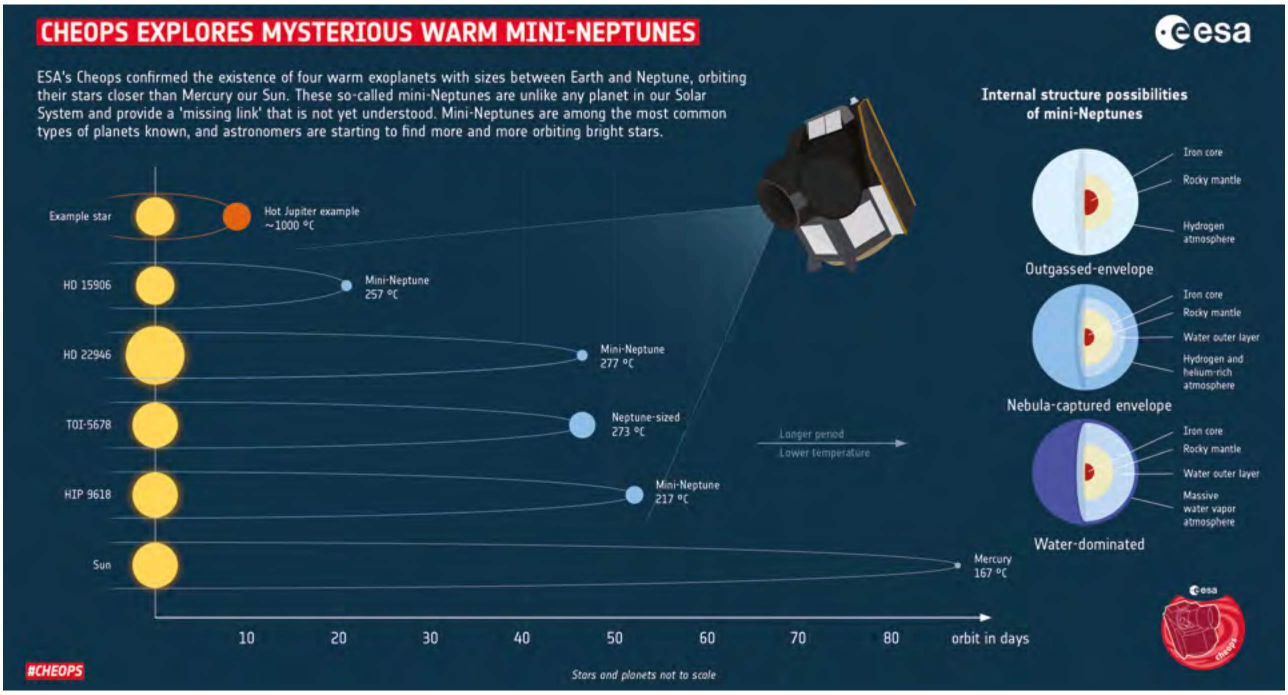


FIG 2: ESA press release about the discovery of mini-Neptune duotransits, including HD 15906 and another of the planets discovered by Amy's duotransit pipeline, TOI 5678.

to reveal their true periods. The process is like a game of hide-and-seek. For each possible period alias, we observe when we would expect another transit to happen. If a transit is not found, we rule out that period alias - if we do observe a transit, we successfully confirm the period. In this way, we discover longer period planets than TESS can find on its own.

Recently Amy and her colleagues reported the TESS and CHEOPS discovery of two planets transiting the bright star called HD 15906. Intriguingly, both planets are warm mini-Neptunes, meaning they have temperatures below about 700K (257C) and radii between that of the Earth and Neptune. There is no such planet in our own Solar System, and we don't know of many other exoplanets like them. Warm mini-Neptunes are therefore mysterious objects.

A major part of Amy's PhD programme has been creating an automated pipeline to search for TESS duotransits. Conventional planet searches are designed for the discovery of planets with multiple transit events, and so many duotransits go undetected. Her pipeline is optimised for the discovery of duotransits and, after running it on about 40,000 stars, five new duotransits were discovered. These five have now been observed by CHEOPS, and periods of four of them already confirmed (Figure 1). This includes a planet transiting the bright star TOI 5678 with a period of 48 days, confirmed thanks to CHEOPS observations.

The papers about HD 15906, TOI 5678, and two other duotransits from the CHEOPS team (see, for example, Tuson et al. MNRAS, 523, 3090–3118, (2023) for further references) were announced in an ESA press release earlier this year (Figure 2). By pushing towards longer period exoplanets, the work of Amy and her colleagues acts as a stepping-stone in the ultimate search for habitable planets and life in the Universe.

The Magnetic Proximity Effect in Graphene

ADRIAN IONESCU describes the measurement of the induced magnetic properties of graphene due to the magnetic proximity effect that describes the influence which a magnetically ordered state such as a ferromagnetic crystal has on a nearby structure. In magnetic systems, however, the coherence length of the exchange interaction is only of the order of a few inter-atomic spacings and hence very short-ranged [1].

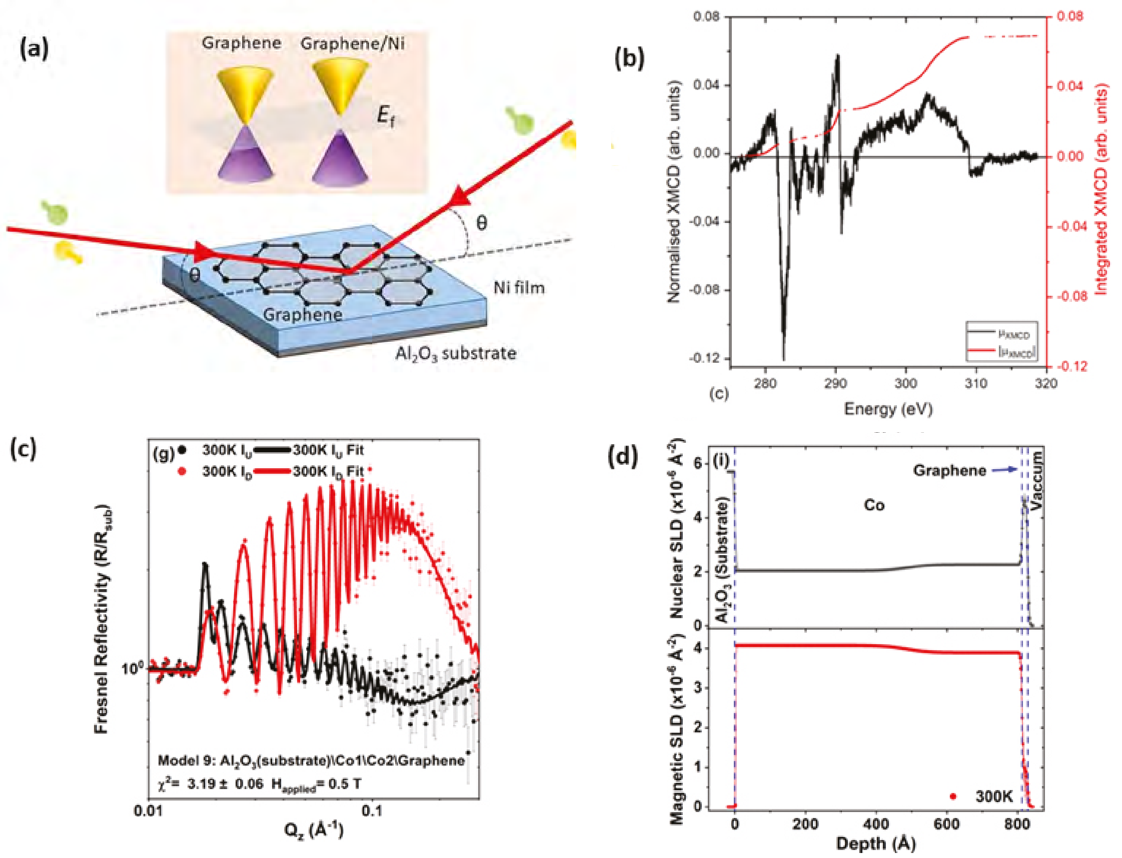
Two-dimensional (2D) materials have been at the forefront of research for the last few decades. Their reduced scale leads to physical properties distinct from their bulk counterparts and the possibility of combining them into various heterostructures, meaning that different layers of various stoichiometries and compositions can restrict the movements of the charge carriers resulting thereby in quantum confinement. This leads to new devices such as the quantum cascade lasers which produce Terahertz radiation by means of semiconductor 'band-gap engineering' [2].

One noteworthy candidate among 2D materials is graphene, an allotrope of carbon consisting ideally of a monolayer of atoms arranged in a hexagonal lattice as schematically shown in Fig. 1a. It has the advantage of remaining chemically stable under atmospheric conditions. Graphene is described as a zero-gap semiconductor, because its valence and conduction bands join at the Dirac points, six locations in momentum space at the edge of the Brillouin zone. Due to this remarkable feature, electrons propagating through its honeycomb lattice *de facto* become massless, that is, the energy and momentum are proportional to one another, producing quasi-particles that are better described by a 2D analogue of the Dirac equation rather than the Schrödinger equation for spin-1/2 particles. By now graphene has seen some practical applications, such as in metrology, where it is currently used as an electrical resistance standard through the quantum Hall effect [3]. But other applications have been proposed, such as in spin-transport electronics, or spintronics, which aims to utilise both the charge and spin degrees of freedom of electrons in devices.

How did we get interested in understanding magnetic interactions in graphene which resulted in two recent publications [4,5]? In the summer of 2012, we had a visit by Eugen Kogan from Bar-Ilan University, Israel, who had recently published work on the Ruderman–Kittel–Kasuya–Yosida interaction between two magnetic impurities in graphene [6]. Knowing that I was interested in anything related to magnetism at the nanometre scale, he encouraged our research group to investigate the use of graphene in spintronics. This was because of its remarkable physical properties such as an intrinsic charge carrier mobility of more than 10,000 cm^2 V^{-1} s^{-1} at room temperature, a large spin relaxation time as a result of its long electron mean free path and its negligible spin−orbit and hyperfine couplings [7].

Earlier we had quantified the magnetic moments of thin films of one nm and thicker by polarised neutron reflectivity (PNR) or X-ray magnetic circular dichroism (XMCD). The former uses the concept that neutrons, having a magnetic moment but no charge, are scattered not only by the nucleus, but also by the magnetisation. Hence, besides the structural information about the film thickness, atomic density and interface roughness, we can also simultaneously quantify the magnetic moment per atom, if the material has a net magnetisation, either intrinsic or induced. The latter technique is based on the absorption of polarised photons, that is, left-handed and right-handed photons, in the X-ray regime by the atoms in the solid which create electronic interband transitions. This absorption is different for materials with an imbalance in the local density of states close to the chemical potential such as for the itinerant transition metal ferromagnets nickel and cobalt. Hence, this technique has been widely applied to extract information about the spin and orbital contributions to the magnetic moment of such materials. However, neither computational work, based on density functional theory, nor previous work based on measurement of graphite in the vicinity of ferromagnets or Fe/C multilayers, indicated a significant induced moment in the carbon due to its proximity to a ferromagnetic material. There were, however, two pioneering publications which used XMCD at the Carbon K-edge [8,9] stopping just short of the quantification of the induced magnetic moment in the graphene.

To measure and analyse this induced magnetic moment in a single layer of carbon, we would need to push the technological boundaries – this involved powerful analytical software to simulate the interface roughness on a supercomputer including rigorous Bayesian analysis, facing up to the difficulty of carbon contamination of the optical elements in the XMCD set-up, and so on. To tackle these problems, we needed expert instrument scientists at the ISIS Neutron Source for PNR and at the Swiss Light Source, Pauls Scherrer Institute, for XMCD experiments. After several failed attempts, we approached



ABOVE: (a) Schematic of the effect of the induced polarisation on the opening of the graphene's Dirac cone and measurement geometry for PNR experiments. (b) Element specific XMCD spectra for the graphene layer at the Carbon K-edge, showing clearly an induced magnetisation in the carbon. (c) PNR Fresnel reflectivity data and fit for the Co/graphene sample at 300 K and (d) the nuclear scattering length density profile (upper panel) and the magnetic scattering length density profile (lower panel) as extracted by the fit to the data.

Stephan Hofmann's group at the Department of Engineering, who were growing high-quality graphene in-situ on Ni(111) already. In addition, they kindly agreed to synthesise graphene on various other substrates for us such as on a reference sample of $Ni_9Mo(111)$ and Co(0001).

Finally, after many years we were then able to quantify successfully the induced magnetic moment in graphene due to the proximity effect in the vicinity of ferromagnetic substrates by XMCD and to estimate a total magnetic moment based on its orbital and spin contribution by applying the sum rules to a Carbon K-edge (Figure 1b). The PNR experiments (Figure 1c, d) were then carried out and analysed as an independent means and sanity test to determine the magnitude of the induced total magnetic moment and its dependence on epitaxy and magnetic moment amplitude by altering the substrates and growth conditions. Although a higher magnetic moment was expected to be induced in the epitaxial graphene sample, the PNR results indicate that the graphene film had a magnetic moment of ~0.41 μ_B/C atom on Ni(111) at 10 K, regardless of whether it was grown epitaxially or rotated. These results were compared with ~0.49 μ_B/C on Co(0001) and zero on $Ni_9Mo(111)$ at room temperature.

These results support a model in which the induced magnetic moment in graphene arises because of the opening of graphene's Dirac cone because of the strong Carbon p_z- transition-metal 3d atomic orbital hybridization. These results provide a first quantitative estimation of the induced magnetization in a 2D material such as graphene in the vicinity of a ferromagnet and paves the way not only for a better understanding of interlayer coupling of graphene to a ferromagnetic substrate, but more importantly to apply these techniques to other 2D materials.

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Breaking the Glass Ceiling, the 'Invisible Glass' Legacy of Katharine Burr Blodgett

POOJA PANDEY celebrates the remarkable story of Katharine Blodgett in her pioneering physics research and advancing the role of women in Physics.

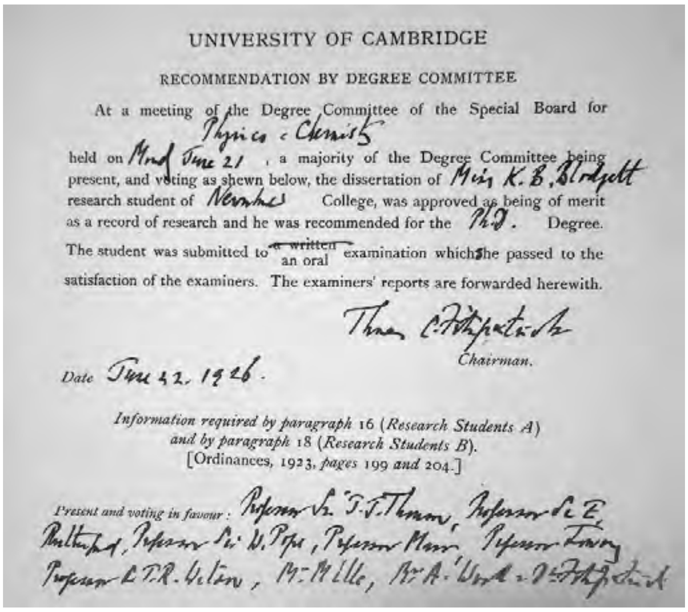
In a historic photograph from 1926, amidst a distinguished group of scientists at the Cavendish Laboratory, sits Katharine Blodgett, a trailblazer in the world of physics. This image encapsulates her unique place in history as the first woman to earn a Ph.D. in Physics from the Cavendish Laboratory in 1926 – the degree had only been established in 1920.

In the world of science, there are pioneers whose work not only reshapes their field but also removes barriers of inequality. Katharine Blodgett, a pioneering physicist of the 20th century, is a name that stands out vividly in this regard. Her groundbreaking research not only revolutionised multiple industries related to optics but also symbolizes the triumph of persistence and innovation over the glass ceiling that once restricted women's advancement in scientific fields.

Born in Schenectady, New York, Katharine Blodgett's journey to scientific greatness was marked by a relentless pursuit of knowledge and unwavering determination. Her academic path led her to Bryn Mawr College, where she found inspiration in the teachings of eminent professors such as Charlotte Angas Scott and James Barnes. Yet, it was Irving Langmuir, a close family connection and a future Nobel laureate, who would become the pivotal figure in her career.

Langmuir offered Katharine a rare opportunity: a research position at General Electric (GE), contingent upon her completing her higher education. Determined to seize this chance, she completed a master's programme at the University of Chicago in 1918, where she contributed, under the guidance of Harvey B. Lemon, to the development of charcoal filtering applications crucial for gas masks in the World Wars. This work earned her scientific acclaim and marked her entrance into the male-dominated field of science as the first woman scientist at GE.

Katharine's ambition did not stop there - she set her sights on earning a Ph.D. With the strong support of Langmuir, she embarked on a transformative period at the Cavendish Laboratory (Figure 1). Under the supervision of Ernest Rutherford, a towering figure in the world of physics, her scientific career reached new heights. Her research at the



UNIVERSITY OF CAMBRIDGE

RECOMMENDATION BY DEGREE COMMITTEE

At a meeting of the Degree Committee of the Special Board for Physics & Chemistry held on Mond June 21, a majority of the Degree Committee being present, and voting as shewn below, the dissertation of Miss K. B. Blodgett research student of Newnham College, was approved as being of merit as a record of research and he was recommended for the Ph.D. Degree.

The student was submitted to ~~a written~~ an oral examination which she passed to the satisfaction of the examiners. The examiners' reports are forwarded herewith.

Chairman.

Date June 22, 1926.

Information required by paragraph 16 (*Research Students A*) *and by paragraph* 18 (*Research Students B*).
[Ordinances, 1923, *pages* 199 *and* 204.]

Present and voting in favour:

FIG. 2. The approval of Blodgett's PhD dissertation by the Faculty Board of Physics and Chemistry. ©University Library Archives

FIG. 3 Katharine Burr Blodgett (1898–1979) demonstrating equipment in the laboratory © Wikimedia Commons

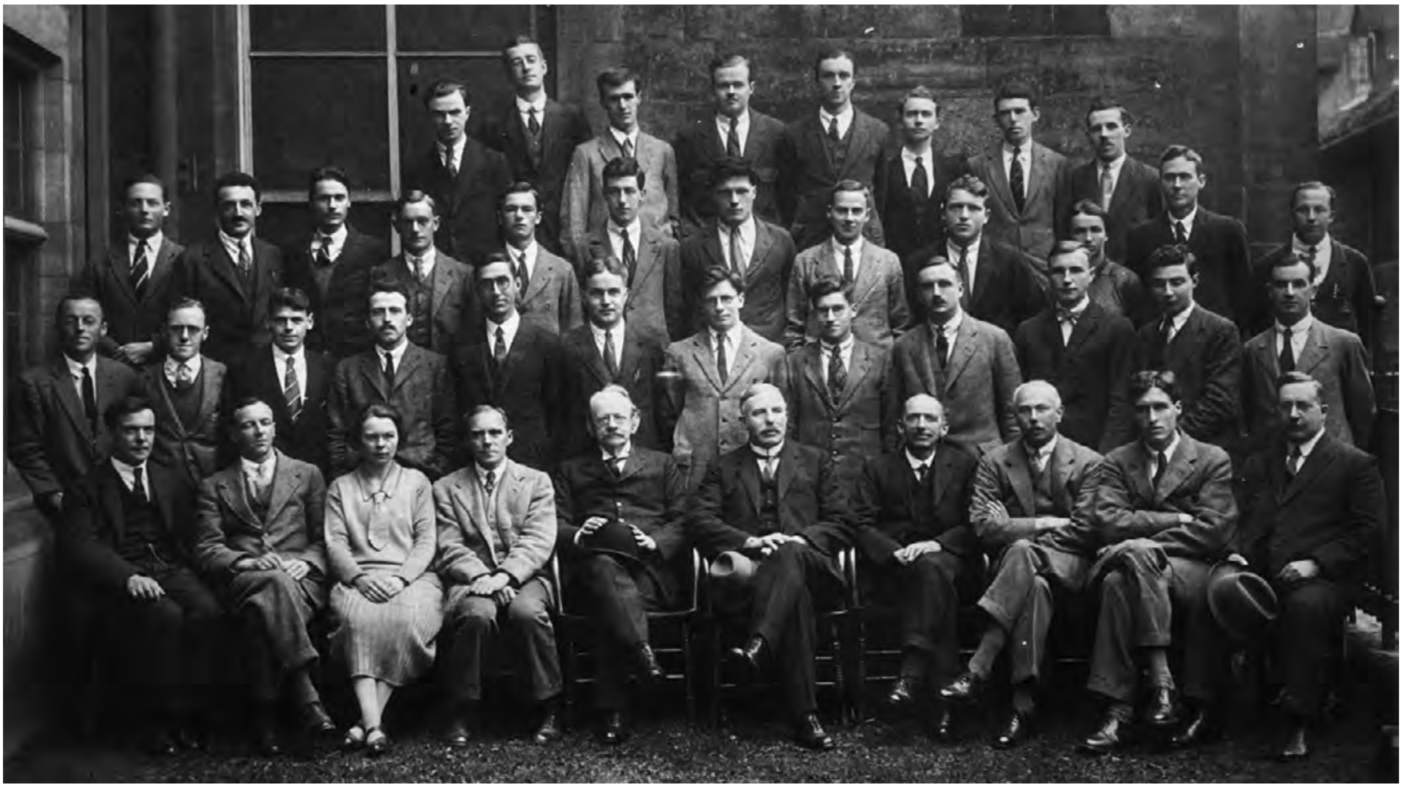


FIG. 1. The Cavendish staff-Graduate student annual photograph from 1926. Katharine Blodgett is third from the left in the front row, sitting among a galaxy of distinguished scientists, from left to right, Kapitsa, Chadwick, KBB, Taylor, Thomson, Rutherford, Wilson, Aston, Blackett and Chamberlain.

Cavendish explored the behaviour of electrons in mercury vapor. Her final research thesis, 'A method of measuring the mean free path of electrons in ionized mercury vapor', was highly lauded by the degree committee.

'She has certainly shown much originality and experimental skill in the examination of her problem. She has made substantial contributions to our knowledge in this most difficult field of investigation ... (the Board members) consider the thesis of undoubted merit and originality and can strongly recommend the candidate for the degree of Ph.D.'

said Rutherford in his recommendation for awarding Katharine the PhD degree (Figure. 2).

During her time at the laboratory, she made significant breakthroughs in smoke screening technologies, making the vaporization of oil more efficient—a critical innovation that would make smoke screening more effective during World War II.

But it was her work with 'invisible glass' that would leave an indelible mark on science and technology. On her return to the GE, Katharine's pioneering research led to the creation of multilayer anti-reflective coatings on glass. While Irving Langmuir had previously developed the process for single atomic layers, Blodgett took this further and advanced the technique for use with polymers on glass, enabling the creation of multiple layers that rendered the glass truly invisible (Figure.3). These innovations, known as Langmuir–Blodgett films, were the world's first 100% transparent or truly invisible glass.

The Langmuir-Blodgett film deposition process allows molecules to be deposited in a single layer across a solid surface, a breakthrough in film deposition processes and still widely used in manufacturing applications today. This groundbreaking innovation eliminated distortions caused by reflected light in a wide range of optical equipment, from eyeglasses to microscopes.

The impact of Blodgett's work transcended the scientific realm and entered the world of cinema. The iconic film 'Gone with the Wind' (1939) was the first major cinematic production to use Blodgett's invisible glass. The film was noted for its crystal-clear cinematography. Blodgett's nonreflective lenses also played essential roles in submarine periscopes and airplane spy cameras during World War II besides being used in projectors and cameras by the post-war movie industry. She obtained eight U.S. patents for industrial applications of her discoveries during her career, cementing her legacy as a pioneering scientist and inventor.

Katharine Blodgett's life and work serve as a testament to the profound impact of persistent dedication and innovation, regardless of gender barriers. Her legacy continues to inspire generations of women scientists. As we remember her scientific contributions, we also celebrate her spirit of trying to break the glass ceiling, exemplified by her 'invisible glass'—a metaphorical and literal breakthrough that transformed the world of science and paved further the way for future women scientists.

Ray Dolby's X-ray imaging proportional counter recreated

To celebrate the generosity of RAY DOLBY (right) and his outstanding research as a graduate student in the Cavendish, there will be exhibits in the atrium of the Ray Dolby Centre. These will include this replica of his ingenious X-ray detector.

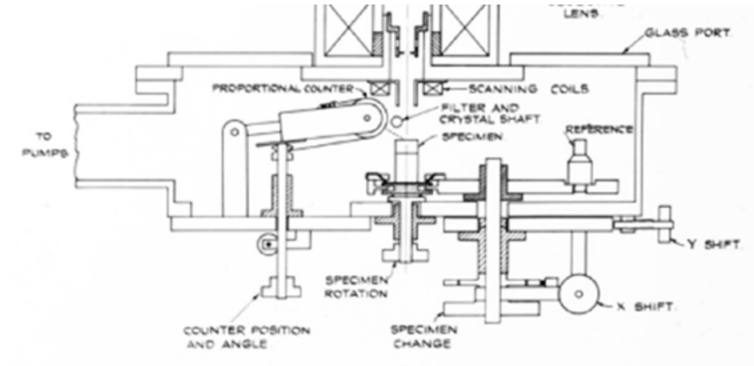
Ray Dolby carried out his PhD research in the Cavendish Laboratory's Electron Microscope Group under the supervision of its leader, Ellis Cosslett, from 1957 to 1961. His project concerned the X-ray imaging spectroscopy of the light elements, particularly carbon, an atom of great importance but very difficult to measure at that time because of the low energies of the characteristic X-rays (see CavMag19, pages 6–7).

In our planning for a display in the atrium of the new Ray Dolby Centre to celebrate Dolby's scientific work in the Laboratory, Sean Geraghty has built a replica of the key element of the experiments which Dolby carried out in the first year of his research programme. This was his X-ray imaging proportional counter, an approach suggested by Cosslett. In his dissertation, which will also be on display in a facsimile edition, Dolby explains why this approach was the best available at the time for imaging the light elements in, for example, alloys. As expressed by Peter Duncumb, this enabled 'the detectable range of X-ray emission downwards to include carbon at about 0.3 keV and below This gave much poorer energy resolution than crystal diffraction but much higher intensities.'

Dolby's photograph of the detector assembly is shown in the inset of Figure 1 and the replica in the right hand panel. The movements of the detector could be manipulated from outside the vacuum chamber and these are all functional in the replica. No attempt was made to make the proportional counter an active device. The gas in the counter was argon and had to be continuously maintained at a standard pressure by a flow of the gas through the plastic tubes seen in the photographs.

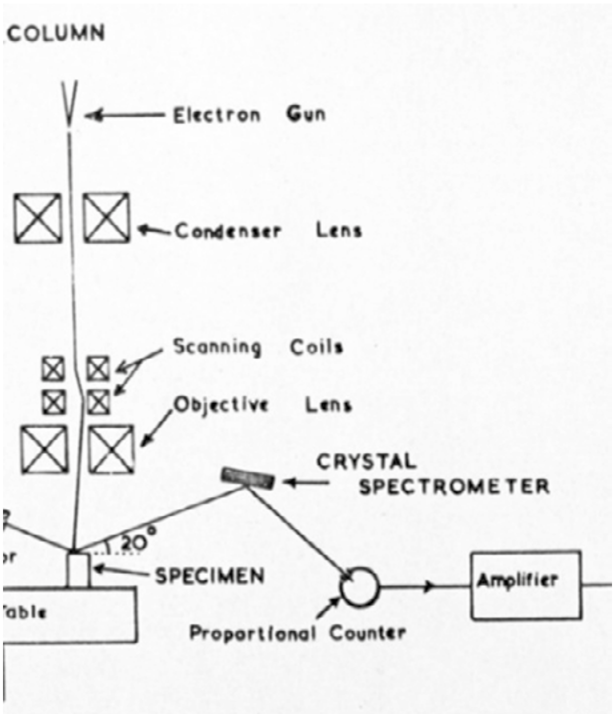
FIG. 1. The proportional counter used to measure the X-ray spectra of light elements such as carbon. (Above) Replica designed and built by Sean Geraghty. (Inset) A photograph from Dolby's dissertation.

In the photograph of the replica, the specimen to be bombarded by electrons is mounted on top of a pillar. In the apparatus built by Dolby, the pillar and specimen were mounted on a turntable which is shown in his photograph (Figure. 2). The spectra obtained for the materials on the other pillars are reference samples of different elements which can be moved quickly into the electron beam to calibrate the spectra. As explained by Mick Brown, 'any detector must be placed within the vacuum system and as close as possible to the specimen'. In Figure 2 there is a 'filter and crystal shaft' used to orient a crystal spectrometer (see also Figure 3), rotating it to pick up the X-rays scattered from the specimen.



The energies of the scattered X-rays were estimated from the pulse height signals from the proportional counter. This does not require the use of a crystal to scatter the radiation, but is of much lower spectral resolution. Figure 4 shows the specimen and a thin dashed line indicating the direct route from the specimen to the thin window of the proportional counter for pulse height analysis.

As Dolby explained in his dissertation, ‘In the crystal configuration the counter is lowered and rotated for optimum detection of the Bragg angle reflection. The filter and crystal facilities have not yet been used.’ Thus, his programme involved gaining the maximum amount



of information from the lower spectral resolution pulse height distribution.

This was the reason that Dolby devoted almost half his dissertation to the procedures used for deconvoluting the pulse height signals to obtain images in the characteristic lines of carbon and other elements. The problem is not so different from the procedures adopted in his famous noise-reduction algorithms which he patented not long after this research was carried out. At the beginning of Chapter 8 on ‘The Waveform Analysis Method’, he states that: ‘In this chapter a modified Fourier analysis scheme, which will be called the waveform analysis method, is derived. Some possible practical approaches are suggested and discussed.’ But he was keeping their potential applications to sound reproduction to himself.

In his memoirs, Ellis Cosslett wrote: ‘Dolby was one of the most inventive research students I ever had, being fertile in ideas and adept at experimental realisation...’

Once the Ray Dolby Centre is opened, please come and view this beautiful replica of an instrument from Ray Dolby’s early research - it will be located in the public area.

MALCOLM LONGAIR

FIG 2. (Above left) The proportional counter with the specimen and reference elements on a turntable. The specimen target is shown close to the window of the proportional counter.

FIG 3. (Left) A schematic diagram from Dolby’s dissertation showing the arrangements for obtaining spectral information with the crystal spectrometer in place. The electron beam can be scanned across the sample by means of the scanning coils.

FIG 4. (Above right) The layout of the proportional counter, the specimen pillar and the ‘filter and crystal shaft’ as displayed in the technical drawing from Dolby’s dissertation.

Malcolm Longair - A personal tribute

JOHN PEACOCK

In October 1963, a strange new creature was sighted in the Fens. Only after some months did the locals realise that its cries were a form of English. Thus did Malcolm Longair appear in Martin Ryle's radio astronomy group, fresh from a degree in Electronic Physics at Dundee. This was a revolutionary time, with radio astronomy discovering radio galaxies and quasars, fuelled by supermassive black holes. These objects were far enough away that their radiation was emitted billions of years in the past, placing them in the front line of controversy in cosmological modelling. North of the no-man's land of Madingley Road lay Fred Hoyle's Steady-State theory in which the expanding universe was unchanging in its overall properties, set against Ryle's preference for a Big Bang in which the universe had a finite age of around 10 billion years. The radio sources could settle this, since their abundance would alter with time in a Big Bang universe; Malcolm's PhD work showed how such evolution was needed to understand the counts of radio sources, establishing him as an authority in the still infant science of cosmology.

ABOVE: Malcolm as a member of Martin Ryle's Radio Astronomy Group in 1973.

The natural route followed by so many UK astronomers in those days was to seek out a postdoc in the USA, but Malcolm took the radical step of going East: spending 1968 to 1969 as a Royal Society Exchange Visitor at the Lebedev Institute in Moscow. This was a shrewd move, as Moscow housed the great Soviet cosmologist Yakov Zeldovich. He had developed a distinctive school of theory whose ideas leaked only slowly to the West, but which were well in the lead in some aspects – notably the scattering of radiation in the Cosmic Microwave Background relic radiation by ionized plasma. Malcolm was able to learn about these developments first hand, and to alert Zeldovich to the achievements of Ryle's group. This only required the minor effort of learning Russian... As a result, Malcolm returned to Cambridge as the first Western scientist to write a paper with Zeldovich and filled with new ideas. Malcolm developed a close bond with Zeldovich's student, Rashid Sunyaev, and they envisaged a textbook on the new cosmology, 'Matter & Radiation in the Universe'. This opus was much anticipated by generations of students, although in the event it was eventually left to Malcolm's prodigious energy as a writer of textbooks to realise some of this plan alone in 'High-energy astrophysics' (1981) and 'Galaxy formation' (1995).

Subsequently Malcolm joined the teaching staff of the Cavendish, and it was in this role that I first encountered him as an undergraduate in 1975. His excited presentation of atomic physics involved dashing between two overhead projectors at either end of a bench – which in due course acquired a poster carrying the inscription "warning: relativistic motion in this area". Our next meeting was in 1977, when I too began a PhD in Ryle's group. I was keen to do cosmology, and wanted to speak to Malcolm about possible projects – but how? He never seemed to be in his office and was typically to be seen moving down a corridor at high speed. I hailed him, "excuse me, Dr Longair?", whereupon he turned and said fiercely, "You will call me Malcolm!". In the end, I began a project with Jasper Wall, but when Jasper left after a year, Malcolm took charge of me – and then immediately went on a term's sabbatical. So supervision was remote, without Zoom or even email. But this turned out to be a fruitful mix of important strategic guidance coupled with the space to work independently, which certainly benefited me in the long term. But undoubtedly Malcolm's most important input came at the very end of the PhD: just when I needed a postdoc, at the end of 1980, he was appointed Director of the Royal Observatory Edinburgh.

Malcolm's new job was actually three in one: also Astronomer Royal for Scotland and Regius Professor in the University of Edinburgh. But the dominant role was ROE Director, and in that capacity he controlled resources hard to imagine in the current funding climate. The ROE had around 100 staff, some of whom were on secondment to overseas observatories that the ROE had created and operated: the UK Schmidt Telescope in Australia and the UK Infrared Telescope on Hawaii. Included in this staff complement were a number of research fellowships that were in the gift of the Director; one of these was given to me, and I arrived in early 1981. Malcolm took this well-funded but possibly somewhat sleepy establishment and electrified it with his energy and ambition. Within months of arrival, he won the argument that the new James Clerk Maxwell submillimetre telescope should be sited on Hawaii, and hence come under the control of the ROE. The remote Hawaii operation expanded massively, and so did the instrument-building capability at Edinburgh, which focused on novel long-wavelength instruments: the world's first 1-2 micron imaging camera on UKIRT in 1986, and setting in motion the technology development that led to the SCUBA submm imager on the JCMT in 1997. SCUBA's ability to reveal activity hidden by interstellar dust was revolutionary, and its results were the pinnacle of Malcolm's research on cosmic star formation. These years arguably represented the high-water mark of UK astronomy: a time when we were able to lead the world in a number of technical areas.

Although these high-level developments dominated Malcolm's time, he also left a strong intellectual mark on the university; most notably in instituting the Kamikaze Seminars. These were a brutally effective device for postgraduate education: a syllabus was issued, students were collected in a lecture theatre, and a name was drawn from a hat. This person then had to lecture on the topic of the day. What made these sessions such a memorable success was that some university staff and ROE fellows also participated and shared the risks of public embarrassment. This procedure might be considered excessive in the current climate – but everyone absorbed a huge range of astrophysics.

The power of a Royal Observatory Director came at a huge price, however, with unceasing pressure from funding agencies. At the end of 1990, Malcolm announced that he would return to Cambridge as the Jacksonian Professor. It is now hard to believe that he was in charge at Edinburgh for a mere decade – but so much of the subsequent success of the ROE flowed from the initiatives that he put in place. At the time, however, ROE's future seemed far from assured. Its English counterpart was the Royal Greenwich Observatory, and tidy minds in the Research Councils had long wondered if a single National Observatory might be more efficient – and cheaper. Indeed, a review in 1983 recommended that the RGO activities should be transferred to a greatly expanded ROE; it seemed that Malcolm had won a tremendous victory. But somehow this decision was subverted, and instead the RGO transferred to a brand new building in Cambridge. Nevertheless, the pressure for a merger proved irresistible: a further review in 1997 closed the Cambridge RGO and created a new 'UK Astronomy Technology Centre' at

Malcolm surveying his new empire: at the Royal Observatory Edinburgh in 1981, together with John Kingman, SERC Chairman.

Edinburgh. I was a small bargaining chip in this power game, with the University of Edinburgh creating a Chair to buy me out of my position as an ROE staff scientist. Ironically, the final decision was reached by a panel chaired by none other than Malcolm – one of the few senior astronomers whose sympathies towards Edinburgh and Cambridge could be seen to be balanced.

After these days of upheaval, I saw much less of Malcolm – others will write more broadly here about his contributions during his second phase in Cambridge, especially as Head of the Cavendish. He touched my career once again in 2008, by retiring from the Jacksonian Chair, and efforts were made to interest me in becoming his successor; but I had become too deeply rooted in Edinburgh to feel that scientific gains from a move could outweigh losses on the personal front. I was also rather intimidated by learning that the Jacksonian Professor would need to be active in raising funds for new accommodation for the radio astronomy group – I didn't think this was something I would be good at. In the event, I shouldn't have worried: the 'retired' Malcolm now had extra energies for fund raising, and rehousing radio astronomy was really a very minor matter in comparison with the Dolby-funded new Cavendish. I really was staggered by the scale and ambition of this development on a recent visit: it leaves the West Cambridge site unrecognisable from what I knew as a student.

So Malcolm is retiring for a second time, and one can only wonder where his unflagging energies will be directed now. He's running out of mountains: he and his wife Deborah completed the 282 Munros long ago, and I recently learned that they are more than halfway through adding their lower siblings, the 222 Corbetts. More books, perhaps. I can think of six textbooks, covering a wide range of physics and all presented with admirable clarity and characteristic enthusiasm. How he managed to achieve this on top of his many great contributions to the scientific community is a mystery to me. One of the many debts I owe to Malcolm is his encouragement to write a textbook of my own; but the effort involved in just this single project nearly finished me. In any case, Malcolm's career leaves an unmatched legacy that hardly needs extending: generations of scientists have benefitted from the ideas he propagated, and from the scientific facilities that he had the foresight to create. He also transformed my own scientific career along the way, and I'm delighted to have this opportunity to try to express my gratitude.

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Repaying the debt: I was delighted to be able to officiate when the University of Edinburgh awarded Malcolm an Honorary Degree in 2012.

A tireless Director of Development for the Cavendish

After his time as Head of Department, Malcolm accepted the role of Director of Development under Peter Littlewood. In 2002, he persuaded the University that the Cavendish should be rebuilt and was then asked to raise the funds. He brought his usual irrepressible energy and enthusiasm to the task and led the first wave of building projects which have transformed the Laboratory. He raised money for the Physics of Medicine building and the related strategic investments, including the Herchel Smith Chair and the associated funding to develop research in this area. He was then instrumental in the creation of the Battcock Centre for Experimental Astrophysics and supported the creation of the Kavli Centre, uniting the astronomers on a single campus for the first time. The Maxwell Centre followed, creating an interdisciplinary hub with industry which serves the entire physical science community. Each of these projects was a bold strategic move and each has proven to be transformational for the research done at the Cavendish.

Malcolm was then closely involved with the planning for the Ray Dolby Centre. He was largely responsible for drafting the case for Government support, struggling with the constraints of the Treasury economic model, which requires a return on investment under very strict and arcane conditions. This ultimately led to the creation of CORDE, our open R&D offering to the UK STEM community.

Malcolm was not only concerned with building projects. He worked tirelessly to engage donors across all areas of Laboratory's work. One notable success among many was the endowment of three PhD studentships by the Huo Family Foundation in honour of Professor PC Ho, who worked at the Cavendish in the 1930s. This donation has already supported four students selected for their outstanding qualifications.

One of Malcolm's most visible contributions has been in Outreach, where he curated our Collection with loving care and preserving it for the future, as well as cataloguing and curating the remarkable Photo Archive of images from the earliest days of the Laboratory. Most of us will have seen him accompanying visitors and explaining the science behind the exhibits with his characteristic verve and enthusiasm. He will be greatly missed by all.

ANDY PARKER
Former Head of the Cavendish Laboratory

CavMag reaches Issue 30

It is scarcely believable that this is the 30th issue of CavMag. It all began somewhat tentatively with Issue 1, soon after I took over as Director of Development in 2008 with the role of reconnecting with alumni and encouraging philanthropic giving. It also was to provide a means of welcoming newcomers to the Laboratory and keeping the staff aware of highlights of what was going on scientifically and managerially within the Cavendish. It remarkably quickly evolved towards its present format which is typically 24 to 28 pages illustrated by excellent photographs and diagrams.

Obviously, I am far too close to the magazine to give an objective assessment of how successful the endeavour has been, but one aspect of the story, which I find compelling, is that cumulatively, CavMags 1 to 30 provide very useful material for future historians to gain quickly an impression of how the laboratory evolved over this 15 year period, in particular the changing emphases of the programme in response to new opportunities and challenges.

Some contributions have been particularly memorable. To name but a few, Marie Constable's first hand memories of working with Chadwick during the tumultuous year of 1932 bring a human touch to the work of the Laboratory – she was 101 years old when her essay was written (CavMag3). Showing her the apparatus which, for Chadwick and she, were the everyday tools of particle physics was a memorable and touching moment. Celebrating the magnificent gift of David Harding in sparking off the Physics of Sustainability was one of the key early successes of the Development programme (CavMag5 and 6). The continuing successive buildings which we were able to fund as part of the vision of the new Cavendish Laboratory (see CavMag 20) was crucial in persuading Vice-Chancellor Leszek Borysiewicz that we were really serious and to throw the University's weight behind our ambitions (CavMag16). And course, the Dolby gifts were quite unparalleled in generosity in fully enabling the rebuilding of the Laboratory to be completed (CavMag19) and supporting future research programmes (CavMag29). Then, there were the Nobel celebrations of Didier Queloz's Nobel Prize in CavMag23 and the joyous opening of the Maxwell Centre with an amazing dance performance choreographed by Wayne McGregor in CavMag16.

None of this could have been achieved without the generous support of my colleagues in writing excellent articles and our colleagues in CUDAR who have been wonderfully supportive of our ambitions in outreach and philanthropy. Special thanks must go to Matt Bilton for his outstanding graphic designs for all except one of the 30 CavMags, the omission being one of the casualties of the Covid pandemic. The full support of the successive heads of the Cavendish, Peter Littlewood, James Stirling and Andy Parker, has been crucial.

But that is the past – the future is just as exciting. As the title of the Editorial has it, this edition marks the changing of the guard. In one sense, CavMag has fulfilled one of its purposes – supporting the rebuilding of the whole Laboratory. But, the need for continuing to engage with our alumni is as important as ever. The story of the last thirty years has been one of embracing changes of direction and making a success of them. This will continue beyond the foreseeable future and the support of our alumni is crucial. Vanessa Bismuth has already made a major contribution to the Department in her role as communications manager and she wants to know what alumni really want us to provide. Here is her manifesto.

MALCOLM LONGAIR

Help us celebrate 150 years of history!

When the Cavendish Laboratory opened in 1874, it housed one of the most modern laboratories, with a focus on experimental physics. Under the inspired leadership of Maxwell, Rayleigh and J.J. Thomson, the Laboratory rapidly became recognised as a world-leading centre for physics. Since then, it has consistently led the way in scientific discovery and excellence.

As we approach our institution's monumental 150th anniversary next year, we are inviting all alumni to take part in a special initiative that will make this milestone truly memorable.

We would like to hear your stories, your experiences and your treasured memories from your time at the Cavendish and that have shaped our world-leading institution into what it is today.

Your memories might take the form of a picture, a diary entry, a captivating story, or a meaningful object... Whatever the form, we are excited to hear from you.

Your narratives will be woven into the fabric of our 150-year history, creating a tapestry of shared experiences that will be showcased during the year of festivities.

Please submit your memories in image or video formats, complete with a title and a brief description (150 words maximum), to **communications@phy.cam.ac.uk**. If you have any questions or need additional information, do not hesitate to reach out to us at the same email address.

Let's come together to honour 150 years of groundbreaking discoveries and scientific excellence in Physics and celebrate the bright future that lies ahead!

VANESSA BISMUTH

Ray Dolby Centre - Construction update

MARIE CHUET and the Bouygues team

Work on the Ray Dolby Centre has entered an exciting new phase, with fitout and decoration works starting in the Public Wing. Also known as wing 5, this area, visible from JJ Thomson Avenue, will be the main entrance to the building. The ramp and Plaza leading to level 1 from street level is now visible and showcases the sawtooth-shaped white precast façade. As you get inside the building, you cannot escape the two striking lecture theatres, cladded with copper shingles, which are now complete and illuminated.

The dismantlement of the so-called 'birdcage' scaffold, which allowed safe works at height for a long time, has opened up the 3 storey high atrium space.

The common room will house the cafeteria and it is now almost complete, with its feature timber ceiling, kitchen, servery, sitting area and the terrace, allowing great views over the Main entrance.

On other fronts, around 50% of the rooms of the building are now complete and desnagged. Works are still progressing in laboratories, with the installation of specialist services, such as fan filter units which will ensure the quality of the air in the clean rooms, specialist gases, process cooling, laser gantries fitting out and laser interlocks system.

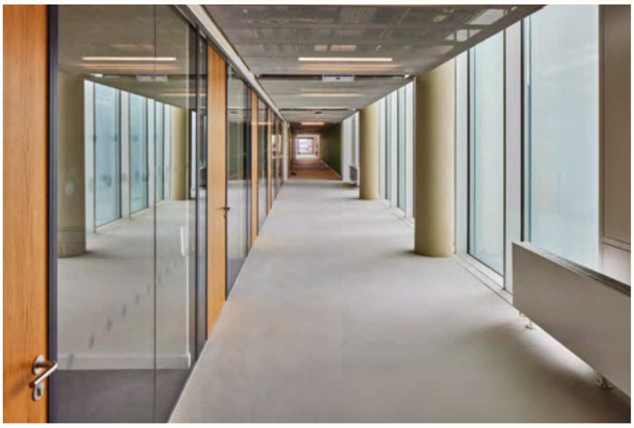
Testing & commissioning of services have started. These activities typically wrap up the construction phase of any building for a few weeks. However, given the quantity and complexity of services in the Ray Dolby Center, this is expected to last several months.

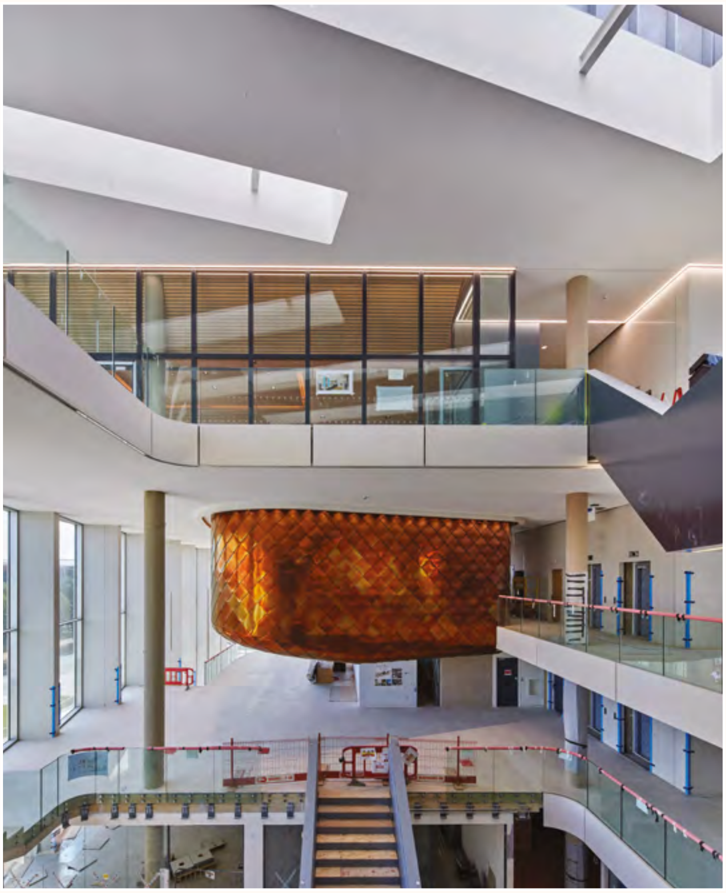
THIS PAGE:
Top; Planting around the building
Bottom: Clean rooms

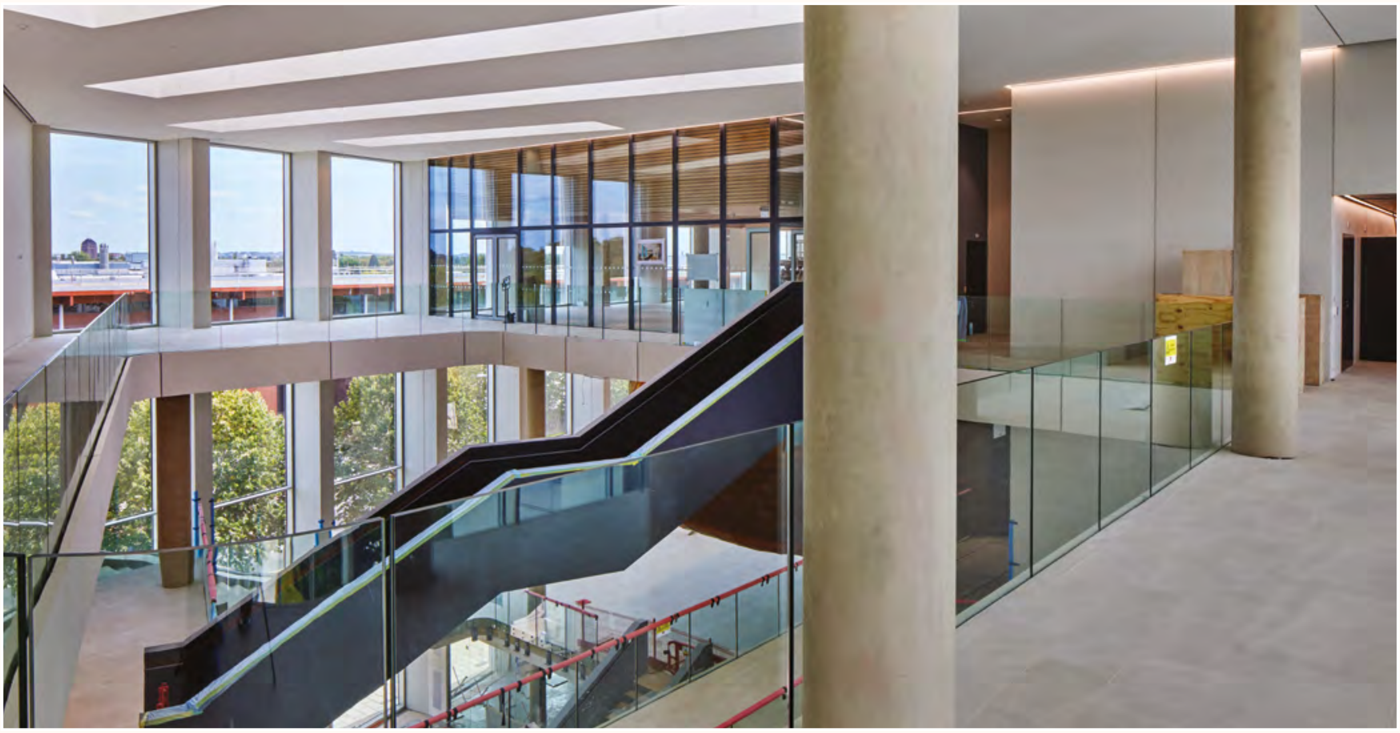
OPPOSITE, CLOCKWISE FROM TOP LEFT:
End of wing 1
The copper-clad small lecture hall
A view of the atrium showing all top three floors
A long corridor spanning all four science and teaching/ workshop wings

Photography by Paul Raftery


RAY DOLBY CENTRE







Nurturing the Next Generation of Physicists

The summer months saw a major increase in the number of large scale student events run at the Cavendish. NICKI HUMPHRY-BAKER describes these wonderful events for young people which proved very rewarding for everyone involve.

STEM SMART students working hard on maths problems at the residential.

In early July the Isaac Physics team ran their **Senior Physics Challenge** for students with one more year of school to go before taking Physics at A Level. The top 50 students out of 700 who have answered the most challenging questions on Isaac Physics were invited to attend. They all attended lectures on quantum mechanics, performed two experiments, one of which was a study of diffraction gratings, and experienced life as an undergraduate. Churchill College hosted the students and Corpus Christi College invited them to a formal hall.

The students bonded very quickly as a group and were immensely grateful for the experience. Some students have already started applying to Cambridge to study Natural Sciences.

At the end of August, the **STEM SMART residential** returned to the Cavendish for its second year. STEM SMART is a 17-month programme, which offers enhanced learning and encouragement to UK state school students studying maths and science at A-level or equivalent – these students have experienced educational disadvantage, or are less likely to apply to university. In August 2023, about 400 of the most engaged students so far were invited to the 4-day residential. The students were split into smaller cohorts distributed across 16 different colleges. Most of the students' time was spent consolidating and extending their school knowledge of A Level maths and the sciences depending on subject choices. On Tuesday morning of the programme, students visited their chosen department - chemistry, engineering, physics or biology - where the template for activities was a sample lecture, a subject-specific admissions talk and a practical activity. In physics, the students investigated the diffraction patterns of slits of varying widths and determined the laser wavelength by studying the diffraction patterns. They were then given a talk on rotational mechanics by Lisa Jardine-Wright, who lectured it in first year physics, for some years.

In the evenings, the college organised fun team building exercises for the students, as well as college tours and formal halls. Again, the overwhelming feedback from the students was extremely positive. Most students have found the whole experience of STEM SMART hugely rewarding so far and have had a tremendous confidence boost in their ability and understanding in their chosen subjects, not to mention their predicted grades. These students continue to receive online tuition this term and on into 2024. Students from the first STEM SMART cohort, which ended in May 2023, have now started their first year at the University of Cambridge. We wish them all the best with their further studies.

Students building a paper crane as part of the evening activities in the their college.

In September, the Outreach Team ran the 39th **Physics at Work** event for GCSE students. The event aims to showcase to students what you can do with a physics degree and how fascinating physics can be. Across 3 days 1569 students from 30 schools from across the country, as far north as Leeds and Blackpool all the way down south as Poole. Schools came for a morning and/or an afternoon session and saw 6 exhibitors for each half-day session. The exhibitors covered a wide range of areas of physics in both industry and research groups, from printing to levitation, from nanophotonics to the study of fractures.

There were three new exhibitors this year who were our neighbours. The Computer Science Department demonstrated human – robot interactions; the laboratory technician apprentices informed the students about a different route into science; the medical therapeutics group led by Gemma Bale demonstrated brain function using infrared light.

This event is our largest outreach event and continues to have a hugely positive impact on the students, the teachers and the researchers and industry people who take part in the event. For the exhibitors

The Quantum Materials group demonstrated superconductivity.

AWE, winners of the best talk as voted by teachers and by students at Physics at Work 2023.

it is such a great opportunity to practice communicating science to a different audience from developing demos to writing a 20-minute talk to go with them. All of the feedback we had this year from teachers was extremely positive. The students were really excited by all the presentations they saw and about the different careers in physics. One teacher from Pudsey Grammar School who came to Physics at Work last year for the first time told us how up until then they had had low numbers of students taking A Level Physics, but that this year they had over 20 students. You can hear all about it on the Cavendish's Instagram account (https://tinyurl.com/pawhodge).

A student volunteering with the Medical Therapeutics group to monitor brain function.

Throughout the year we run a variety of outreach activities aimed at inspiring and nurturing the next generation of physicists. Our next Cambridge Physics Centre Lecture will be on Tuesday 7^{th} November at the Cavendish Laboratory and given by Prof Sarah Bohndiek on early cancer detection using light. We will also be running our Cambridge Physics Experience days for years 10 and 11 students from 6^{th} to 10^{th} November, which involve an afternoon learning about optics through experiments and problem solving. Booking for those will open shortly. Keep checking outreach.phy.cam.ac.uk for all of our upcoming events.

Lastly, I would like to thank everyone who support and donate to our outreach activities. They enable us to continue to run our programmes such as Physics at Work, Cambridge Physics Experience days and most recently our primary school outreach programme - for all of this, we are immensely grateful.

Sarah Bohndiek and Gemma Bale appointed Founding Programme Directors at ARIA


SARAH BOHNDIEK (left) and **GEMMA BALE** (right) have been selected as two of eight founding Programme Directors of the **Advanced Research and Invention Agency** (ARIA), a new governmental research and development funding agency built to unlock scientific and technological breakthroughs for everyone's benefit. They will be responsible for designing and overseeing ARIA's initial programme focusing on using optics for planetary and human health. ARIA will be seeking input and inspiration from the community as they drive towards launching formal programmes in the coming months. As both contribute to shaping the strategic vision of ARIA, their respective research groups will continue their crucial work at the Cavendish Laboratory, Cancer Research UK Cambridge Institute and the Department of Engineering.

Spaced-based solar power

Congratulations to **LOUISE HIRST** on receiving a major grant from the **Space Based Solar Power Innovation Competition**. Spaced-based solar power collects energy from the Sun using panels on satellites and beaming it safely back to earth with wireless technology. Louise, who is leading a partnership with the University of Southampton and IQE plc., is receiving over £770,000 to develop ultra-lightweight solar panels that can survive long periods in high-radiation environments such as the conditions in space.

Athene Donald's new book: 'Not Just for the Boys'

Congratulations to **ATHENE DONALD** on the publication of her new book in May 2023. The book examines the historic societal exclusion of women from science and the systemic disadvantages women in science operate under. Athene discusses the common myths that science isn't creative and that it is carried out by a lone genius in an ivory tower, offering her perspective on what progress has been made, and how more is needed. Athene discusses the issues raised by her book in the Cavendish podcast 'People Doing Physics'. https://people-doing-physics.captivate.fm/episode/athene-donald

Academic Staff Promotions 2023



Warmest congratulations to our new Professors, **CHIARA CICCARELLI** and **DAVID BUSCHER**, and our new Associate Professor, **DIANA FUSCO**.






We also congratulate our new Teaching Professor **KARISHMA JAIN,** Associate Teaching Professor **CHRIS BRAITHWAITE,** Associate Professor in Experimental Astrophysics **ELOY DE LERA ACEDO, PHILIP BLAKELY** and **STEPHEN MILLMORE**, Assistant Teaching Professors in the Centre for Scientific Computing and **CHRISTOPH SCHRAN** as Assistant Professor in Computational Atomic-Scale Materials Science.
SIMON BRAUBURGER has started a Marie Curie Fellowship in Ulrich Keyser's group.

New Ray Dolby Centre Project Manager

VICTORIA STEENKAMP (VICKY) has been appointed as the new Ray Dolby Centre (RDC) Project Manager. The fundamental focus of Vicky's role will be to provide essential support to the RDC Project Lead to enable the successful design and implementation of an effective operations strategy as the Cavendish Laboratory prepares for relocation to its new home, the Ray Dolby Centre. In her new role, Vicky will be working closely with all PSS teams, reviewing ineffective and inefficient processes and proposing new ways of working that better serve the wider Cavendish Community

MPhil in Life in the Universe

This term sees the launch of Cambridge's new MPhil course in **Planetary Sciences and Life in the Universe**. The new programme will be jointly taught and led by Physics, alongside the Institute of Astronomy, and the Departments of Chemistry, Zoology, Plant Sciences and Earth Sciences. Applications are now open.

Talented theoretical physicist recognised by the Mark Warner Prize

The second Mark Warner Prize for talented theoretical physicists has been awarded to **YUCHEN YANG**, Physics student at Trinity College, for his outstanding work in Experimental and Theoretical Physics in Part II of the Natural Sciences Tripos.The £250 prize, sponsored by the Ogden Trust, is awarded in memory of Professor Mark Warner, FRS, theoretical physicist, pioneer in the field of liquid crystal elastomers who inspired and mentored generations of physicists.

Raising the Veil on Star formation Near and Far

This conference in honour of the late Richard Hills, organised by the Cavendish Astrophysics Group, will be held at the Kavli Institute for Cosmology, 22–26 April 2024. The conference will bring together scientists from multiple areas to discuss the recent developments in understanding star formation both in our Galaxy and across the cosmic epochs, focussing on its elusive and obscured components.

New Appointments to the Professional Staff

ROBBIE YUAN appointed the new Finance Manager
YANYING CHEN Kapitza Hub Manager
TONY HILL Kapitza Finance Assistant
JULIA PORTURAS Mott Research Project Administrator
KHANTI TSUI Mott Finance Assistant
MARC AUGER Rutherford Finance Administrator
EMMA RIEGEL Rutherford HR Administrator
JOHN ARNOLD Bragg Accounts Assistant
LINGTAO KONG Research Grants Administrator
BETH WARMINGTON Maxwell Centre Programme Coordinator
JAY GUYETT Bragg Workshop Principal Technician
THOMAS IVESON HEP Research Laboratory Technician
MUHAMMAD NASEEM IT Linux Systems Developer/ Administrator
EMILY ROE Bragg Senior Research Laboratory Technician – Cryogenics
GAURAV KUMAR Rutherford Research Laboratory Technician
GEORGE HAWKINS Bragg Research Laboratory Apprentice
JAMIE WARDLE Bragg IT Customer Service Assistant
SELEN ETINGU IPLU Project Manager

A new home for Physics...

A new home for CavMag

We are developing a new home for CavMag online, coming up in 2024.

You will soon be able to opt out of receiving the print edition and/or be sent an email when the latest edition is available online.

More details will be shared in the next issue!

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 the Head of Department. The Development portfolio is described in CavMag 18 and can be viewed online at:
www.phy.cam.ac.uk/alumnifilesCavmag18Aug2017online.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 Samantha Stokes (**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 Mete Atatüre (**hod@phy.cam.ac.uk**), who will be very pleased to talk to you confidentially.

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