UNIVERSITY OF CAMBRIDGE

APRIL 2022
ISSUE 27

CAVMAG

News from the Cavendish Laboratory

Leverhulme Centre for Life in the Universe

INSIDE

COVER PAGE:
An artist's impression shows Proxima d, a planet candidate recently found orbiting the red dwarf star Proxima Centauri, the closest star to the Solar System. The planet is believed to be rocky and to have a mass about a quarter that of Earth. Two other planets known to orbit Proxima Centauri are also visible in the image: Proxima b, a planet with about the same mass as Earth that orbits the star every 11 days and is within the habitable zone, and candidate Proxima c, which is on a longer five-year orbit about the star.
Credit: ESO/L. Calçada

Guest Editorial

Andy Parker

After two long years of successive lockdowns and stringent restrictions due to the Covid pandemic, we are slowly entering a new, more vibrant stage where we can see a welcome increase in levels of activity within the Department.

In particular, after we were able to welcome back our students in person for the majority of their lectures and supervisions for the 2022 Lent term, we expect our teaching activity to be fully back to 'normal' in the Easter term with students back for lectures in the Pippard Lecture theatre at full capacity.

Throughout this unique time, our staff have been exemplary in both keeping the department open and a safe place to work, and in ensuring we can continue our core services: producing pioneering research and providing outstanding teaching. I would like to express my profound gratitude to all our researchers, technicians, professional services staff and students and salute their exceptional fortitude and resilience over the last two years.

Needless to say, this pandemic is not over and, just as I am writing this, infection rates are creeping up again in Cambridge and in the country. I am, as we all are, very aware that this state of play is fragile and could

deteriorate at any time. But even though we remain on our guard, the new season brings new hope and it is time to look to a brighter future.

For us, it's a very visible future made of bricks and mortar, just around the corner from our current offices and labs. We are now one year away from taking possession of our new home, the Ray Dolby Centre. As you will read in this issue's progress update (pp 12-13), its construction is coming along very nicely with some parts already fitted with shelves and carpets!

With this new building well under way, we are also looking to expand our research opportunities and bring in new research and new projects. We are currently recruiting for our most prestigious Chair, the Cavendish Professorship, as well as the newly created Ray Dolby Professorship, established in memory of Dr Ray Dolby OBE, an alumnus of the Laboratory and a world-famous innovator and entrepreneur. The establishment of this Chair forms part of the exceptional donation from the Dolby family in his memory, which also made possible the construction of the Ray Dolby Centre.

FIG. 1. (TOP) Wing 1 of the Ray Dolby Centre showing the completed facings. (BOTTOM) A 'furnished' office in the Ray Dolby Centre.

For both these Chairs, we have been looking for outstanding individuals who will set up new and visionary major research programmes in any area of fundamental physics. I am pleased to say that we have received exceptionally high levels of interest from outstanding candidates, and we should have an update on these appointments by the next issue of CavMag.

Continued overleaf...

FIG. 2. (LEFT) Sandro Tachella, (RIGHT) Paul Rimmer

Continued from overleaf...

More recruitment is underway with two new astronomers joining the Cavendish in the next few months: Sandro Tacchella will join the Department as Assistant Professor in Extragalactic Astrophysics from April, and Paul Rimmer will start his tenure as Assistant Professor in Experimental Astrophysics (Exoplanets) in July. We are very much looking forward to welcoming them both to the Cavendish.

Sandro is a well-known expert in the field of galaxy formation and evolution. He has made key contributions to the understanding of the mechanisms and physical processes driving the formation, evolution and transformation of galaxies across the cosmic epochs. He is also heavily involved in the new James Webb Space Telescope, playing a key role both in the data processing of the NIRCam instrument and by leading major scientific projects that are aimed at detecting galaxies formed in the early Universe and at characterising their primeval properties. This will be one of his primary projects in the coming years at the Cavendish Laboratory.

Paul is a planetary astrochemist, working on both experiment and theory. His research focuses on using the principles of chemical kinetics to describe the atmospheres and surfaces of other planets, and to test whether origins of life scenarios could occur somewhere on these planets.

Looking ahead, we will be recruiting new lecturers over the next few months, in particular, in the fields of High Energy Physics and Biological and Biomedical Physics.

This is definitely a busy period for the department as our researchers have been hugely successful at securing grants for their projects (see p.26). We are naturally immensely proud of the launch of the new Leverhulme Centre for Life in the Universe, led by 2019 Nobel Laureate Didier Queloz with a £10 million grant awarded by the Leverhulme Trust (pp 6-7).

Our High Energy Physics group is to receive £2.67 million funding from the Science and Technology Facilities Council (STFC), as part of its continued support of the particle physics research community in the UK backed by a £60 million investment.

I am also delighted to see successes on the European stage. Early-career researchers Alice Thorneywork and Robert-Jan Slager have won two prestigious European Research Council (ERC) Starting Grants to help launch their own projects, form their teams and pursue their best ideas at the Cavendish (pp. 20-21, 22-23). Meanwhile, Ulrich Schneider has been awarded an ERC Consolidator Grant, to build the first Quantum Gas Microscope for the Kagome lattice in order to study the rich physics of frustration, flat bands, and novel strongly-correlated states.

Lastly, Dr Diana Fusco Assistant Professor in Biological Physics has recently won a prestigious 2022 Human Frontier Science Program collaborative Research Grant to investigate biofilms and their resilience to complex environments.

I welcome this renewed breadth of activity and the many changes it will bring, including at a personal level, as I start preparing to pass on the baton to the next Head of Department – more on this topic in the next issue of CavMag in the autumn.

Our department has always thrived and shone on a constant flow of new ideas, visions and actions from exceptional staff. May this long continue in 2022 and beyond.

Explore the personal side of physics with People doing Physics, the new Cavendish podcast

VANESSA BISMUTH introduces a wonderful addition to our outreach and communication endeavours.

As fascinating as physics can be, it can also seem very abstract, but behind each experiment and discovery stands a real person trying to understand the universe.

Because we know how powerful personal stories can be, we have launched a new monthly podcast to shine a light on a wide variety of interesting profiles across the Cavendish to help us demystify physics and make it accessible and relatable,

Join us on the **first Thursday of every month**, as we get up close and personal with the researchers, technicians, students, teachers, support staff and the people that are the beating heart of Cambridge University's Physics department. Each episode also covers the most exciting and up-to-date physics news coming out of our labs.

In our first ever episode we welcomed Louise Hirst, Assistant Professor of Physics, and specialist in the development of advanced, high efficiency photovoltaics for space applications. With her we talked about her hesitations between music and physics, finance and research, the wonders of photovoltaics and how to power up space satellites, but also about what it takes to be a woman in science and sticking up for oneself.

The second episode aired in March with High Energy physicist Tina Potter, expert in particle physics *Beyond the Standard Model*. Together we talked about dark matter and answering the big, fundamental questions about our universe, how to forge one's own path in science and to survive the unforgiving research career pyramid and the beauty and challenges of working on cathedral projects.

If you want to know what goes on behind the doors of a Physics department, are curious to know how people get into physics, or simply wonder what physicists think and dream about, please listen in.

FIG. 1. (TOP) The podcast cover image. (ABOVE) Louise Hirst in podcast interview mode.

The show is available for free on all good podcast apps (Apple Podcasts, Spotify, Google Podcasts and many more), or directly on our website: people-doing-physics.captivate.fm

Share and join the conversation

- If you like the podcast, please subscribe to it and leave us a review on your usual podcast platform.
- On Twitter, join the conversation using the hashtag #PeopleDoingPhysics.

Do you have any pressing questions you would like to ask one of our physicists? Any comment on the podcast? Drop us an email at podcast@phy.cam.ac.uk

Leverhulme Centre for Life in the Universe

Many congratulations to DIDIER QUELOZ and his colleagues on winning a £10M grant from the Leverhulme Trust to create a multidisciplinary Leverhulme Centre for Life in the Universe. Here Didier describes his extensive vision for a unique approach to tackling one of the most challenging but inspiring programmes in contemporary science.

How did life emerge on Earth? Is the Universe full of life? What is the nature of life? For the first time, addressing these questions is within the grasp of modern science. Organic chemists have discovered new pathways that could have generated the building blocks of life on Earth from simple molecules in ancient environments. Orbiter and lander missions to Mars have recently discovered a geological record that was erased long ago on Earth, providing a unique opportunity to understand whether these chemical pathways may have occurred on Earth or elsewhere. Planetary science has been transformed by the exoplanet revolution, providing our first opportunity to investigate whether the Earth, and the processes that made life possible, are unique in the Universe.

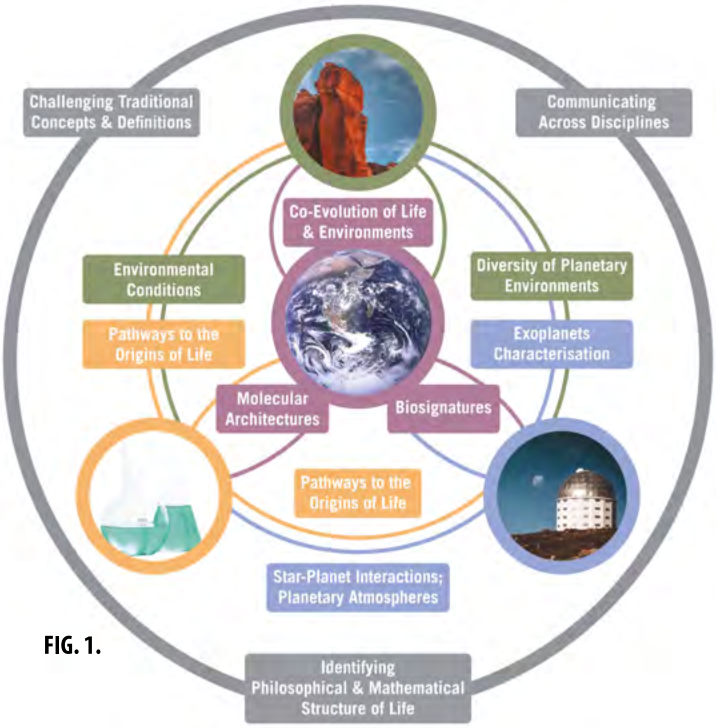


FIG. 1.

With these developments we are at a defining moment for understanding the origins of life in the Universe. Ten years from now, samples collected by the Mars 2020 Perseverance Rover will have been returned to Earth and new generations of extremely powerful telescopes have the potential to detect the first signatures of life in planetary and exoplanetary atmospheres. To understand the significance of these extraordinary opportunities, the academic community needs a deeper and more robust understanding of what life is, how life originated on our planet, and how life might have emerged elsewhere in our Universe. This requires an unprecedented innovative collaboration among the physical, biological and mathematical sciences as well as the arts and humanities (Fig.1).

The objectives of the new Leverhulme Centre are to harness simultaneous breakthroughs in astrophysics, planetology, organic chemistry, biology and cognate disciplines to tackle one of the greatest interdisciplinary challenges of our time. The 10-year programme of the Centre will address four fundamental questions:

- What are the chemical pathways which led to the origins of life that are consistent with benign conditions for life in different planetary environments?
- How do we characterise the environments on Earth and other planets that could act as the cradle of prebiotic chemistry and life?
- What observational facilities and methods will allow investigation of bodies beyond the Solar System, the remote sensing of their atmospheres and the search for signatures of geological and biological evolution?
- How can philosophical and mathematical concepts refine our understanding of what we mean by life and raise new issues and possibilities, leading to new interdisciplinary collaborations and modes of scientific enquiry?

The Centre will include researchers from Cambridge's Cavendish Laboratory, Department of Earth Sciences, Yusuf Hamied Department of Chemistry, Department of Applied Mathematics

and Theoretical Physics, Institute of Astronomy, Department of Zoology, Department of History and Philosophy of Science, Faculty of Divinity, and the MRC Laboratory of Molecular Biology. The Centre will collaborate with researchers at the University of Colorado Boulder (USA), University College London, ETH Zurich (Switzerland), Harvard University (USA) and the Centre of Theological Inquiry in Princeton, New Jersey (USA)
.
Of course, this field of research is booming worldwide, but what is distinctive about the Leverhulme programme is the vision of creating a new breed of young researchers who will feel equally at home in the many different disciplines which will contribute to the advance of knowledge. The questions we ask necessarily require interdisciplinary answers. This is why the 10 year grant will foster the development of young lecturers, post-docs and graduate students with the necessary multidisciplinary skills.

The flow of information and research activities across the Centre, and their contribution towards achieving key objectives are encapsulated in Figure 1. Developing a deep and robust understanding of life in the Universe can only be achieved through continuous communication and iteration among several physical sciences and the Arts and Humanities. These connections provide a flexible framework to respond rapidly to new discoveries.

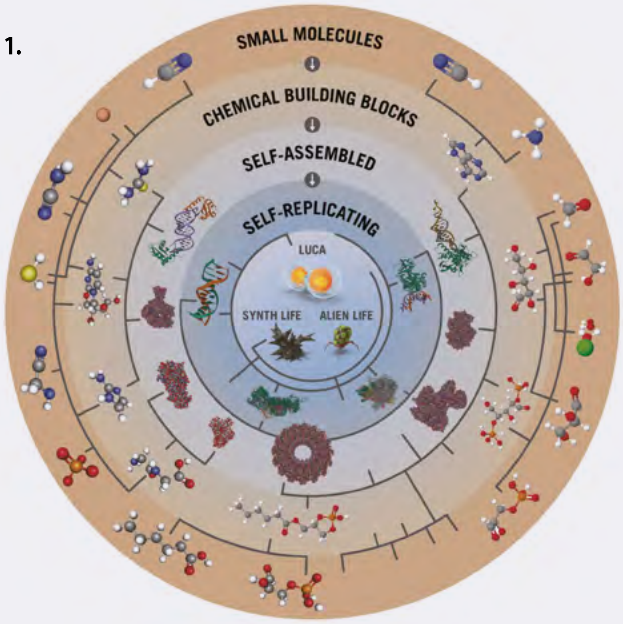
A unique feature of the Centre is the full inclusion of academics from the Arts and Humanities. Their role is beautifully described by one of our collaborators, Carol Cleland, Director of the Center for the Study of Origins and Professor of Philosophy at the University of Colorado Boulder.

'The new Centre is unique in the breadth of its interdisciplinarity, bringing together scientists and philosophers to address central questions about the nature and extent of life in the universe. Characteristics that scientists currently take as fundamental to life reflect our experience with a single example of life, familiar Earth life. These characteristics may represent little more than chemical and physical contingencies unique to the conditions under which life arose on Earth. If this is the case, our concepts for theorising about life will be misleading. Philosophers of science are especially well trained to help scientists 'think outside the box' by identifying and exploring the conceptual foundations of contemporary scientific theorising about life with an emphasis on developing strategies for searching for truly novel forms of life on other worlds.'

Expanding the perspective of those involved in the programme will be informed by those involved in the creative arts, bringing their unique vision of 'human' values through their imaginative projection of what we really mean by 'Life'.

Achieving this new trans-disciplinary approach is a very serious challenge, but we are convinced that the new understandings require this unique broad, diverse, yet integrated approach.

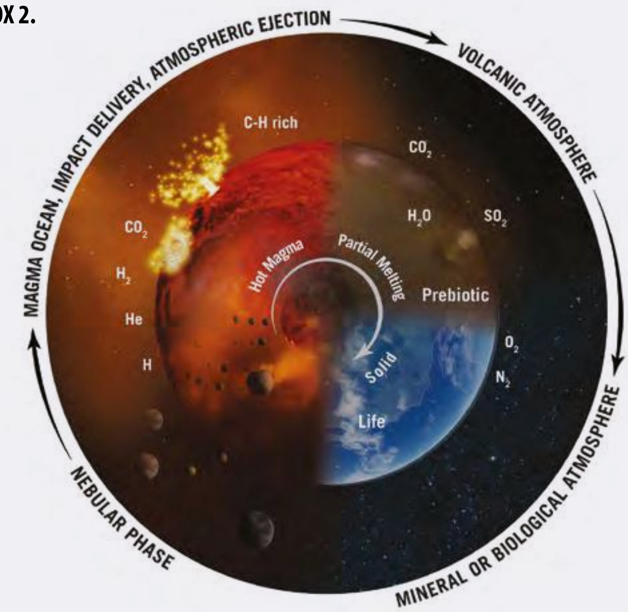
BOX 1.



THEME: Identifying the chemical pathways to the origins of life, as expressed by Matthew Powner from University College London.

'Understanding the reactions that predisposed the first cells to form on Earth is the greatest unsolved mystery in science. Critical challenges of increasing complexity must be addressed in this field, but these challenges represent one of the most exciting frontiers in science.'

BOX 2.



THEME: Generalised evolution of a rocky planetary body. Boundary conditions such as size, proximity to the host star, composition, orbital/dynamical environment during planetary formation and evolution influence planetary environments, available chemical pathways, and the capacity of any planet, including our own, to support life.

Physics and Aesthetics of our World: First Cavendish Arts Science Fellow Appointed

Moving image artist LOGAN RYLAND DANDRIDGE has been appointed to the first Cavendish Arts Science Fellowship at Girton College, Cambridge.

The Cavendish Arts Science programme, founded by Suchitra Sebastian in 2016, is a pioneering venture supporting collaborative and creative processes that examine the world and our place within it through the creation of new artistic work. The fellowship, supported by Una Ryan, is an opportunity for artists who are new to science to develop ideas in dialogue and community with Cavendish physicists in order to explore new ways of thinking about the world. It is facilitated by a partnership between Cavendish Arts Science and Girton College.

Logan is Assistant Professor of Film at Syracuse University, New York. His recent practice has centred around the creation of multi-channel installation video art projects. His film-making interrogates many concepts, including ideas of spirituality, Gothicism and science fiction, Blackness and the American South and his own familial bonds through the poetics and aesthetics of experimental cinema. He draws on a range of processes including assemblage, superimposition, multi-channel orientation as well as jazz, hip hop, spoken word poetry and other experimentations with sound. He has been influenced by John Akomfrah and Arthur Jafa, as well as Audre Lorde and Octavia Butler. The contrapuntal and probing nature of Logan's research and interests provide a unique catalyst for raising questions about our world.

Logan's year-long fellowship is hosted by Girton College and the Laboratory. He is engaging with physicists at the Cavendish to create work that grapples with questions of memory, and potential re-imagined futures, in the context of ideas such as non-linear time, in which the past and the future are no longer distinct. Logan said:

> *'I'm thinking about how physics can be used to reckon with the continuum of Black experience in the interest of more disruptive scientific and artistic interventions. The research project will channel an experimental storytelling practice through an afro-futurist lens.'*

Suchitra Sebastian, Director of Cavendish Arts Science said:

> *Our programme looks to challenge the imagination, and to ask big questions of life, the universe, and our place in it from a plurality of viewpoints. We are thrilled to welcome Logan as our first fellow, and look forward to engaging with him on a journey that explores race, memory, and time through sound and the moving image."*

Logan will be fully supported to produce and exhibit new work in diverse contexts, including the opening of the Ray Dolby Centre at the Cavendish Laboratory in 2023 and those created through national and international partnerships. Susan Smith, Mistress of Girton College, said:

> *"Creativity is at the heart of residential academic life at Cambridge. We are delighted to support this visionary scheme to produce great art through encounter with great science."*

For more information please visit: cavendish-artscience.org.uk

You can also hear Logan and Suchitra talking about Cavendish Arts Science and their relationship with physics in the latest episode of the Cavendish podcast **People doing Physics.** Listen on people-doing-physics.captivate.fm or anywhere you access your podcasts.

In Conversation with Logan Dandridge

I met up with Logan to learn more about him, his art and his plans. The Directors of the Arts Science Fellowship have been very keen that he has interactions with many different scientists in the early stages of the fellowship. He says:

> 'Everyone has been more than accommodating since I have been here. I am having several conversations each day with astronomers, chemists, physicists and biologists – a really frenzied introduction to science and scientists in Cambridge.
>
> 'I am an experimental film-maker, using all sorts of techniques – documentary film, animation, montage, found footage and original footage - to create composite video installations.
>
> 'I have always been fascinated by science and love science fiction. I am intrigued by many concepts and ideas coming out of physics – the concept of worlds beyond, the nature of time, the idea of emergence, the nature of the Universe, the deeper meaning of what science is really telling us and so on. But I have never interacted with physicists before at a really serious level – this is a new departure for me. I am being encouraged to interact with the physicists in a really theoretical and tangible way.

As an example, we talked about the artist's and the physicist's view of time.

> 'I am fascinated by the linear nature of time as perceived by the physicists. As a film-maker, I am constantly grappling with the concept of time, editing, chopping and changing in response to my interpretation of the narrative. While the physicist needs to codify the concept of time as a progression A leads to B leads to C, I have a much more disruptive view of the flow of time. Physics can help inform and refine my thinking about time-ordering.'

We discussed the major influences on his work to date.

> 'I broadly define my approach to film-making as Afro-surrealism/Afro-futurist, but of course informed by so many other influences such as German expressionism. But underlying it all is an almost mythological texture. There's a general sense of trauma that outlines the Black diaspora. It tends to be very unsettling. I cannot divorce myself from the context that has outlined my heritage and my cultural background. What my parents and grandparents experienced because of the undercurrents of slavery are part of my upbringing - they've informed my character. This is the source of my ongoing relationship to trauma. It's also a form of 'haunting' in that these feelings and horrors are always there in the background of my thoughts and in my work. The poet Kamau Brathwaite expresses it beautifully with the expression 'psychic night."

The impact of other arts upon his thinking and inspiration is central to his artistic vision – music, poetry, dance, and so on. There is a strong resonance between the works of poets he admires and some of the non-intuitive content of relativity and quantum mechanics. An example is the basic insight of quantum mechanics that things which might have happened but did not, affect the outcome of a quantum physics experiment. Other examples include the concept of the 'many-worlds' interpretation of quantum mechanics and the 'multiverses' of theoretical cosmology.

> 'I have been strongly influenced by the poet Nathaniel MacKay whose long poem is composed of 50 or more "sub-poems" which can be appreciated separately or as a whole and take different meanings depending upon how these elements are selected and ordered.'

We kept returning to the theme of time in the music of great jazz musicians such as Ornette Coleman and John Coltrane and in the minimalist works of Philip Glass, such as his 'Music in Twelve Parts' and his remarkable 4-hour opera 'Einstein on the Beach'.

> 'The different ways of understanding the passage of time and the intellectual and artistic flexibility of time is both interesting and terrifying at the same time. But so are many other aspects of my interests. The idea of emergence in physics, for example, in advanced quantum mechanics and low temperature physics, find their resonances in many works of poets, artists and musicians I admire.'

How are his plans for forthcoming artworks developing? Logan is still getting on top of the flood of science he is encountering.

> 'Ideas are still at the formative stage, but there will certainly be exhibitions and other events once the way forward comes into focus. A major challenge is an Arts Science event to be associated with the opening of the Ray Dolby Centre in 2023. The precedent for innovation was set by the remarkable dance event, the inspiration of Suchitra Sebastian, and choreographed brilliantly by Wayne MacGregor for the opening of the Maxwell Centre (see CavMag16, pp. 8-11).[1] That event set the bar very high, but I will be aiming to make a similar major Arts Science impact through this fellowship. I am delighted by the enthusiasm of everyone involved with the Fellowship that I create something innovative and original without constraint."

I am certain that Logan will deliver the goods in a profoundly original way. Watch this space!

MALCOLM LONGAIR

1. www.phy.cam.ac.uk/files/documents/cavmag-16.pdf

Winton Symposium 2022 - Sustainable Futures

The Ninth Winton Symposium was held in the Cavendish Laboratory on Thursday 10th March 2022. The theme of the meeting was sustainable futures with the emphasis upon how to accelerate the global transition away from the use of fossil fuels. A distinguished group of speakers addressed many of the issues involved, focussing on the physics and chemistry of sustainability.




The scene was set by **Dame Julia King (Baroness Brown of Cambridge)**, Chair of the Carbon Trust and previously of the Climate Change Committee's Adaptation Sub-Committee, on the central theme of the meeting, **Delivering Net Zero: the CCC view.** Over the last 100 years, the average global temperature rise has been about 1°C. The UK's 2008 Climate Change Act committed the UK to reducing dependence upon fossil fuels by 80% by 2050 and more recently the UK Government and the devolved administrations announced their commitment to the Net Zero target, as recommended by CCC.

Julia emphaised that the evidence is already overwhelming of the catastrophes resulting from the continuing global temperature increase - flooding in many countries, 50°C temperatures in North America, wildfires and drought in 'hot climates' and hurricane storms in the UK associated with major weather systems. If we do nothing, the predictions are that the global temperature rise will be 4°C by 2050 which would be globally catastrophic. The current objective is to limit the temperature rise to 2°C by 2050. Achieving 80% of the reduction is doable but the last 20% to net zero is hard. Julia gave an overview of the changes which would have to take place over the next 30 years in the UK to limit the temperature rise to 2°C.

- Electricity system more than doubles in size
- Offshore wind grows from 10 GW to around 100 GW
- Transformation of the grid: scale, flexibility, storage, resilience, intelligence
- Hydrogen production from 27 TWh to over 220 TWh
- Carbon Capture and Storage (CCS) from 0 to 180 Mt CO_2
- 29 million existing buildings installed with low carbon heat
- Zero carbon cars increase from 100,000 to 35 million
- 25,000 to over 500,000 public charging points
- Afforestation from 10,000 to up to 50,000 hectares per annum
- Woodland and forest 14 to 18% of UK area
- Major changes in agriculture
- Major changes to diet: beef, lamb and dairy consumption down by 20-50%

The subsequent speakers described different ways of contributing to these demanding challenges through forward-looking technologies which depend upon advances in physics, chemistry and materials science. As Julia emphasised the necessary researches must take place over the next 10 years if we are to have a hope of meeting the UK's target.

The following notes indicate some of the types of promising innovative research being undertaken.

Dennice Gayme of Johns Hopkins University described her research on exploiting flow physics to advance wind farm control. Wind energy is central to the UK's energy strategy and it is essential to maximise the power output of wind farms. It is an undergraduate problem in fluid dynamics to show that the maximum amount of the kinetic energy of the air-flow past a windmill in uniform steady flow which can be converted into the rotational power of the rotors is 59%. In Dennice's impressive numerical computations, simulations were extended to the optimum layout of the wind turbines and included the turbulent behaviour of the flow downstream. In a realistic model of the airflow, the kinetic energy of the layers above the wind farm can be tapped by entrapment through the turbulent boundary layers. This has the potential to increase the energy efficiency of wind farms. (https://engineering.jhu.edu/gayme/)

LEFT TO RIGHT: Julia King, Dennice Gayme, Ian Metcalfe, Sossina Haile, Alexey Kimel, Erwin Reisner, David Harding with Sian Dutton, Director of the Winton Programme, in discussion with Erwin Reisner.

Ian Metcalfe of Newcastle University described his thoughts on the use of fossil fuels, biofuels and hydrogen as well as carbon capture. A major theme of the symposium was the use of hydrogen as a 'clean' energy technology through the use of hydrogen fuel cells. Ian described the major advances he and his colleagues had made in developing a new means of separating hydrogen from water using innovative membrane technology which approaches the thermodynamic limit for such processes. The major advantage of this reactor is that, unlike the normal processes of hydrogen production, the separation of the hydrogen from the reactants takes place directly. A prototype reactor is currently being commissioned. The process is 'reversible' as part of a continuous cyclical process. (https://www.ncl.ac.uk/engineering/staff/profile/ianmetcalfe.html)

Sossina Haile of Northwestern University gave a splendid description of the current state of the art in hydrogen fuel cell physics and chemistry in her presentation 'Superprotonic Solid Acid Compounds for Sustainable Energy Technologies'. In addition to fuel cell use in transport, they can be used for hydrogen storage because of the reversibility of the processes. She has established a new class of fuel cells based on solid acid electrolytes and demonstrated record power densities for solid oxide fuel cells. Her more recent work on water and carbon dioxide dissociation for solar-fuel generation by thermochemical processes has created new avenues for harnessing sunlight to meet energy demands. (http://addis.ms.northwestern.edu/people.html)

Alexey Kimel of Radboud University tackled the problems of making magnetic and spintronic devices as powerful as standard semiconductor devices. The attraction of developing spintronic devices is that the energy required to flip the spin of the electron is vastly less than that using the electronic charge of the electron. In his presentation, 'Ultrafast Magnetism and Cold Opto-Magnetic Recording at the Edge of Time', he described his active involvement in the development of novel approaches for ultrafast and energy efficient magnetic recording with light, manipulation, control and detection of spin waves and spin currents in the THz spectral range. (https://www.ru.nl/english/people/kimel-a/)

The presentations were completed by **Erwin Reisner** of the Yusuf Hamid Department of Chemistry, University of Cambridge. The focus of his research is the development of new concepts and technologies for the conversion of solar energy and renewable electricity into sustainable fuels and chemicals for a circular economy. He described in particular photo- and electrocatalysis and the interface of synthetic chemistry, materials and nano-science, chemical biology and engineering. The research of his group includes the upcycling of plastic and biomass waste as well as the use of carbon dioxide and water to produce green fuels and chemicals for a sustainable future. As an example, they have demonstrated the conversion of 100 kg of plastics into 100 litres of oil per hour. (https://www.ch.cam.ac.uk/person/er376)

This was an absorbing day full new ideas which will undoubtedly feed into the sustainability agenda which has been the core of the Winton programme since its initiation ten years ago. We are profoundly grateful to **David Harding**, not only for his wonderful gift which pump-primed so many innovative areas of science, but also for his continued interest and involvement in the Winton programme.

MALCOLM LONGAIR

Building Progress on the Ray Dolby Centre: Year minus 1

The overall Bouygues Project recently reached a major milestone with the hand-over to the University team of the **Shared Facilities Hub (SFH)**. The hard work put into the building has paid off and the team are proud of the very unique building. The SFH Operations team is now busy making the finishing touches, installing furniture and packing the fridges in the kitchen. The target is to open the building to the public in the next few months, and we are all waiting with anticipation to having a drink in the café or a meal in the canteen.

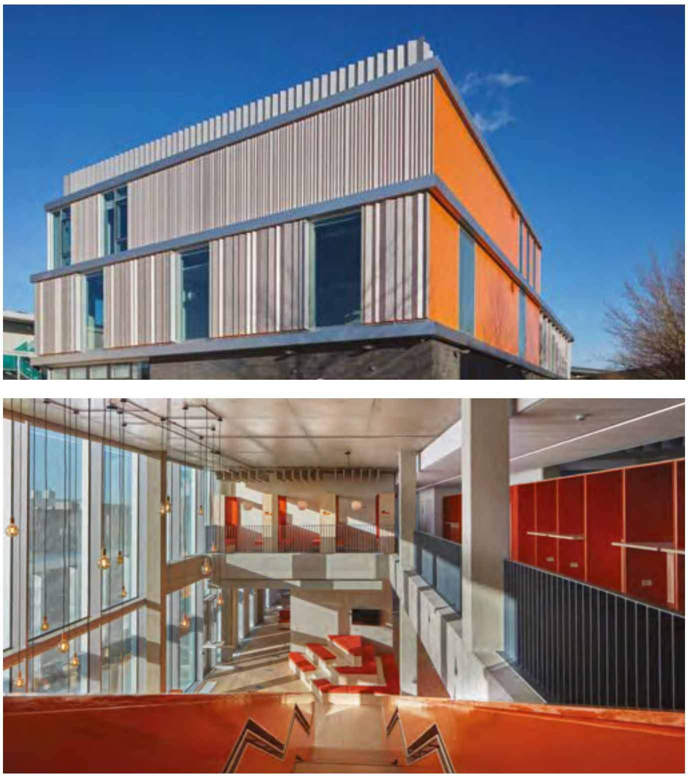


FIG.1. The Shared Facilities Building at Hand-over. Top: exterior view; bottom: internal view.

In the meantime, work on the **Ray Dolby Centre (RDC)** is still going strong, despite the increased pressure of skilled labour shortage and materials availability problems. The site offices have been merged and our remote site office near the Sports Centre has now been closed.

The progress on the facades has been slowed down by the three successive storms that resulted in very high winds on the region in February. Cambridge saw its record wind speed of 73mph, while our remaining tower crane recorded a staggering 86 mph gust at 48m high! We have however managed to make good progress on the south and east elevations of the building, which are starting to look very close to the architects' artist's impressions.

Each one of the more than 1,150 precast concrete panels is thoroughly quality-checked before being lifted into position if it passes all criteria. Each panel weighs between 1T and 20T and their alignment is finely adjusted in the air by our specialist installation team before they are secured and released, offering the very pure white lines that we can now see (Fig. 2 and page 3, top).

FIG. 2. View of Wing 5 and work on the glass façade. The lecture theatres, outreach offices and the main reception are housed in this wing which runs along J.J. Thomson Avenue.

Inside the building, there is also a lot activity. The first offices have been completed and offered for Client inspection (see page 3). This is the start of a long process between the Bouygues team and the Client team to ensure that all rooms are ready by the end of the year.

The workshops and teaching labs fit-out works are nearing completion and should follow shortly.

FIG.3. The Practical Teaching laboratorys nearing completion.

The clean rooms have changed dramatically as the raised access floors have been installed and the walk-on ceilings are being closed. Access control is now in place in both the main clean rooms spaces and the services above the ceiling voids, in order to reach the next cleaning stage.

The Ground Source Heat Pump (GSHP) system, which has been partially operational in the Shared Facilities Hub for the past year, is being commissioned sequentially on the Ray Dolby Centre and is starting to provide heat for the building. The first air-handling units have been started in order to warm up the air going into the basement, where activities have re-started and we are putting up all partitions to the laboratories while finalising the services GSHP distributions.

FIG. 4. Part of the GSHP plant room.

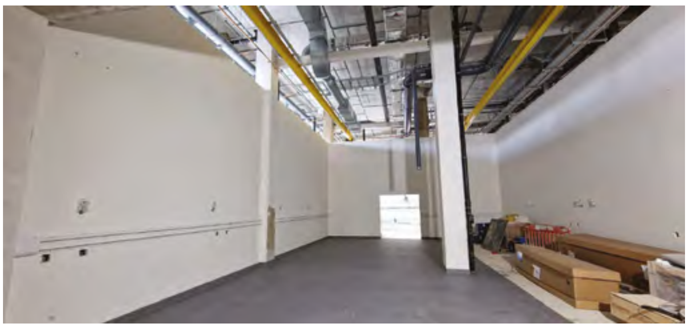


FIG. 5. The cryostat hall and grey space.

The cryostat halls partitions are now completed and the flooring works have started.

Outside our site boundaries, we have started work to upgrade JJ Thomson avenue. We have now handed-over 3 of the 7 phases and are working on the 4th. The new improved cycle and pedestrian pathways will hopefully be worth the minor inconvenience that the sequenced works will present for the public over the next few months.

FIG. 6. Work on the upgrade to the pedestrian and the red asphalt cycle paths.

In line with the Government guidelines, we have lifted most of the Covid rules on site but still carry on targeted testing and strongly recommend self-isolation to all who test positive. We have also restarted our work with the Community, with the organisation of a Lego competition for local schools and continued collaboration with the Wood Recycling Community, for example.

Bouygues has initiated support actions for Ukrainian refugees, including the families of employees and subcontractors, mainly through our subsidiaries Karmar in Poland and VCES in the Czech Republic and Slovakia. On site, we are taking part in a fund-raising effort and have donated first aid kits which are on their way to Poland.

NEIL PIXSLEY

All photographs © Bouygues, except Fig. 6

The Cavendish Laboratory as a National Facility for Physics

The Cavendish Laboratory has undertaken to serve as a world-class facility supporting the physics community across the UK. It will make the Laboratory's state-of-the-art equipment and resources readily accessible to all UK university researchers and will facilitate industry access.

FIG 1

Opening its doors to the nation in 2024, the Cavendish Laboratory National Facility will mostly operate from the Ray Dolby Centre, the centrepiece of the new Cavendish Laboratory designed to match the most exacting standards of current research and currently under construction on the West Cambridge campus (see pp. 12-13). It is backed by a £75M government investment, administered by the Engineering and Physical Sciences Research Council (EPSRC).

We are delighted to welcome **Siddharth (Montu) Saxena** (photograph above) as the new Cavendish Laboratory National Facilities Development Manager. Montu is well known to many readers through his research within the Laboratory and his research contributions to CavMag. With his in-depth experimental knowledge and experience, he is ideally placed to take forward the important task of setting up the Cavendish Laboratory National Facility for Physics (Cavendish Laboratory NF), and ensuring that we match the research needs and expectations of the physics community.

The extensive cleanroom facilities in the Ray Dolby Centre will provide state-of-the-art capabilities for growth, lithographic patterning and processing of electronic and optical devices that explore new physics and underpin a range of technological applications where the quantum properties of electrons and photons are exploited. Our existing expertise in semiconductor physics and quantum multi-functional materials will underpin this part of the National Facility. Our facilities have the capacity to grow semiconductor wafers incorporating materials such as GaAs, AlGaAs and InGaAs in layered structures by molecular beam epitaxy (MBE), a technique that allows the growth of near perfect, ultra-pure single crystals with atomic monolayer control over their composition.

Using sophisticated fabrication techniques, these wafers are patterned into devices. Mesoscopic structures can be etched, electrical contacts formed by metal evaporation, and devices can be packaged for testing and measurement. An important technique available within the Cavendish Laboratory NF for high-resolution device patterning is electron beam lithography, which allows patterning of lines with a width as small as 10nm.

These fabrication capabilities have enabled the development of a wide range of devices which, for example, can measure tunnelling between one-dimensional wires or pump single electrons one by one at GHz frequencies, work carried out in collaboration with the National Physical Laboratory. Other devices under development include terahertz quantum cascade lasers, detectors and modulators for microscopy and communications systems, and work with industrial partners on the fabrication of quantum light emitters and detectors, with applications to quantum communications as well as light detection and ranging systems (LIDAR).

A resource for the nation

Up to 25% of the use of these specialised research facilities will be made available to the UK research community for their own projects, irrespective of prior or new academic collaborations. We aim to provide more than just access to equipment – a key attraction will be access to the world-class knowledge base, expert staff scientists and technical staff. There are also the opportunities to develop new academic collaborations where this adds mutual benefit and value to the project.

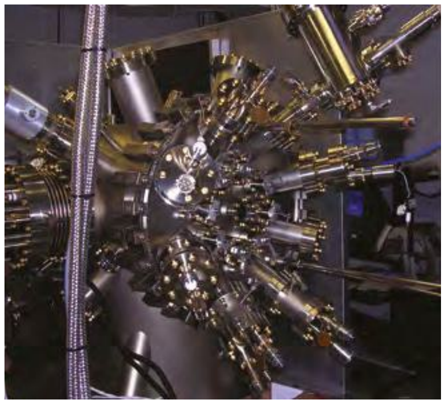
With important investment in additional equipment and technical staff, our ambition is to enhance research capabilities locally and nationally, supporting research excellence and collaboration across UK physics departments and industry, inspiring new research and discoveries.

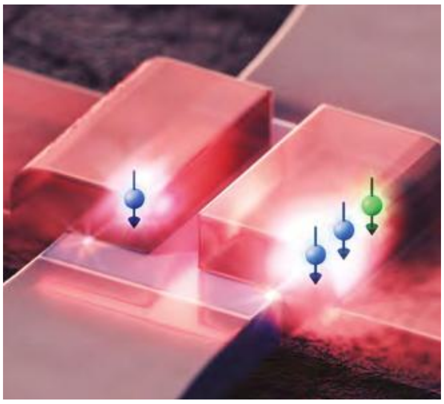
To this end, we are currently seeking suggestions from the local and national physics community for new equipment to enhance our National Facility. Our current priority is for advanced characterization equipment that is not widely available to UK physics departments and which could occupy high specification laboratory space in the Ray Dolby Centre. Please email your suggestions, with an indication of how the equipment would fit into the national research infrastructure landscape, to **Montu Saxena (sss21@cam.ac.uk).**

Making a journey to Cambridge worthwhile

The location of the Cavendish Laboratory NF at the heart of the West Cambridge campus site is a key asset. The Cavendish Laboratory is joining forces with other West Cambridge Departments, including Engineering, Materials Science & Metallurgy and Chemical Engineering & Biotechnology to ease access to a wider range of cutting-edge capabilities and techniques across the site, including facilities that are part of the Sir Henry Royce Institute.

We will be developing an online platform that will provide a single booking system and customer service, to simplify access to this outstanding selection of state-of-the-art facilities for the physical sciences research communities.





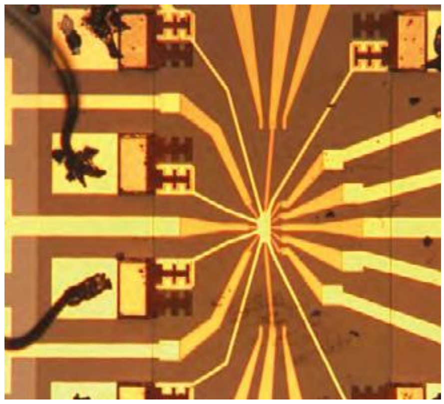


FIG 4 a

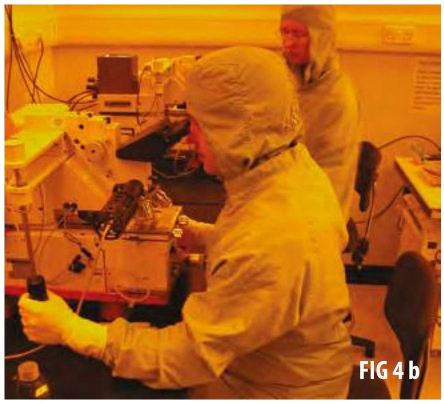


FIG 4 b

If you are interested in learning more about the development of the Cavendish Laboratory NF in the next few months, visit our website **phy.cam.ac.uk/rdc/national-facility** to subscribe to our new mailing list.

ANTHEA MESSENT, NEIL GREENHAM AND VANESSA BISMUTH

Anthea joined the Laboratory over a year ago to manage the Cavendish Laboratory NF, but in November 2021 took over the broader role as West Cambridge Sharing Project Manager.

FIG. 1. The huge clean room suite nearing completion in the Ray Dolby Centre.

FIG. 2. Examples of the facilities to be made available to the physical science community. (a) The electron beam Nanowriter. (b) The GENII-A deposition facility.

FIG.3. (a) A schematic diagram of a split-gate transistor forming quantum dots used for quantum computing applications (Credit- Equinox graphics). (b) Image of the fabricated quantum dot nanoelectronic device.

FIG.4. (a) Working in the device fabrication cleanroom. (b) Optical lithography

Unsung Heroes (3): June Broomhead (Lindsey) and the Structure of DNA

The immediate post-WWII annual photographs of Cavendish Staff and Research Students are remarkable for the small numbers of women present, despite their huge contributions to the war effort (Fig. 1). One of the few women present is June Broomhead, the centenary of whose birth falls this year. She died last year in Ottawa, Canada at the age of 99.

As recounted in the obituary published in *IUCr Newsletter*, (Lindsey et al 2022), June was born in a small Yorkshire village. During her school years, she was inspired by the story of Rutherford's contributions to basic physics and in due course went up to Newnham College, Cambridge on a full scholarship, the first from her school to attend the University.

Once at Cambridge, she soon became aware of Lawrence Bragg and the crystallographic work at the Cavendish. As she wrote later,

> *'When I first went up to Cambridge, I hadn't even heard of [X-ray crystallography], but by a fortunate fluke, chose to study just those sciences which are most essential … physics, chemistry, mineralogy, and mathematics.'*

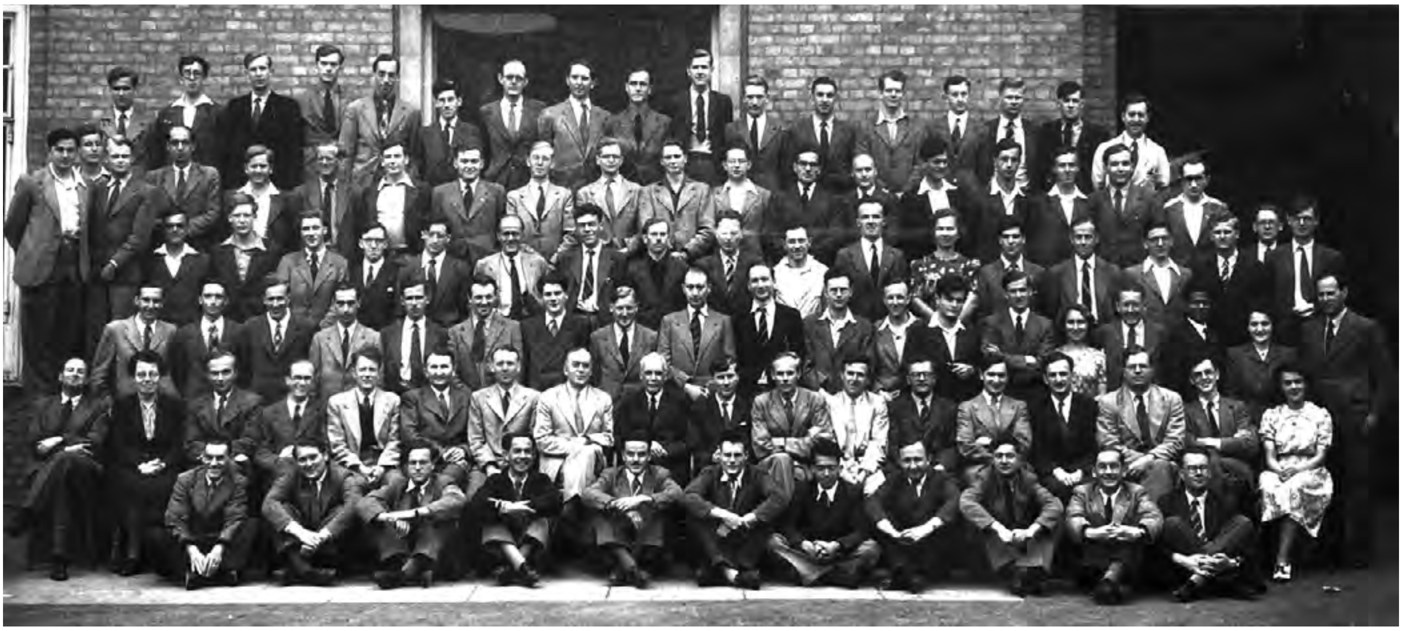
She was awarded a research studentship on graduation and in 1946 returned to the Cavendish to pursue a PhD under W. H. (Will) Taylor. Once there, June developed a friendship with the distinguished crystallographer Bill Cochran, to whom she attributed much of her future success.

In August 1948, she submitted her paper 'The structure of pyrimidines and purines. II. A determination of the structure of adenine hydrochloride by X-ray methods' to the new journal *Acta Crystallographica* (Broomhead, 1948). In addition to measuring the physical dimensions of adenine, she stated, 'Hydrogen bonds linking a purine molecule to chlorine atoms and to water molecules, and short van der Waals contacts with other purine molecules lie approximately in the plane of the molecule'. This observation was the key to James Watson's discovery six years later of the base pairing shown in Fig. 2. Next, June determined the structure of thyamine (Broomhead, 1951). With these precise measurements of the dimensions of molecules, the two nucleic acid strands could thus be evenly joined, adenines linked with thymines and cytosines with guanines, while satisfying Erwin Chargaff's earlier observation that DNA comprised equal quantities of adenines and thymines as well as of cytosines and guanines (Chargaff 1950).

Following her successful defense of her doctorate 'An X-ray investigation of certain sulphonates and purines' in 1950, June moved to Oxford to work with Dorothy Hodgkin on vitamin B12 (Brink et al., 1954). In 1951, she moved to Ottawa with her Canadian husband, George Lindsey, who had also studied for a PhD in physics at Cambridge. She took up a postdoctoral position at the National Research Council of Canada and identified the crystal structure of codeine (Lindsey & Barnes, 1955). When she moved with her husband to Montréal and following the birth of their two children, she retired after almost a decade of very impressive research achievements.

There is no mention of her contribution in the famous Watson and Crick *Nature* letter of 1953, but her name is present in the longer paper in published in Proc. Roy. Soc. in the following year. There it is stated:

> *'The crystal structures of both adenine and guanine have been studied by Broomhead (1948, 1951) … More recently Broomhead's data on adenine have been refined by Cochran*



(1951) and the atomic parameters of this compound are now accurate to within 0.02 Å.' (Watson and Crick 1954)

In 1952, Max Perutz and his colleagues were struggling with the problem of determining the very complex structure of the huge haemoglobin molecule. In a touching letter to June, Bragg wrote:

'We badly need your hands to tackle knotty crystallographic problems, both experimental and theoretical. I wish all these things had come up while you were still with us; they would have been just in your line.'

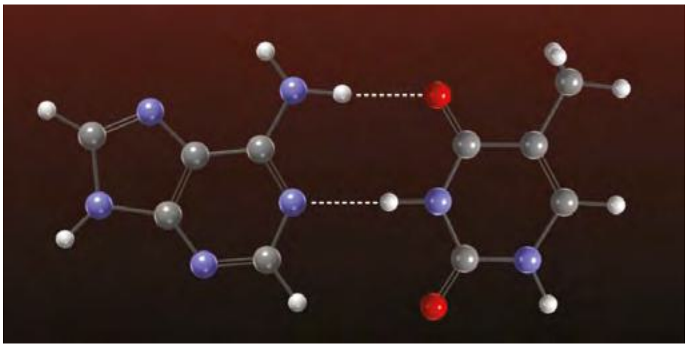
Watson and Crick could not have made their dramatic discovery of matching up the base pairs without June's expert crystallographic studies. It is clear that June was a brilliant scientist who played a key role in one of the great discoveries of the 20th century.

MALCOLM LONGAIR

OPPOSITE: June Broomhead in her PhD graduation robes (Courtesy of the Lindsey family).

FIG.1 (TOP). The Annual Cavendish Staff-Research Student photograph for 1947. June Broomhead is seated on the far right next to Brian Pippard. Lawrence Bragg is in the centre of the front row and on his left Will Taylor. Bill Cochran is seated cross-legged fourth from the left in the front row and George Lindsey, June's future husband, third from the right in the back row. Max Perutz is sixth from the left in the third row from the top.

FIG. 2 (RIGHT). Illustrating the structures of adenine (left) and thymine (right) as well as the hydrogen bonding between them. Carbon atoms are gray, nitrogen atoms blue, oxygen atoms red and hydrogen atoms white (Lindsey et al. 2022).



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Towards quantum simulation of false vacuum decay




By shaking an optical lattice potential, BO SONG and SHOVAN DUTTA with group leaders ULRICH SCHNEIDER and NIGEL COOPER have realised a discontinuous quantum phase transition between a Mott insulator and a superfluid in a strongly correlated quantum gas, opening the door to quantum simulations of false vacuum decay in the early universe.

Phase transitions are everywhere, from water boiling in everyday life to cosmological phase transitions in the early universe. Particularly intriguing among these are quantum phase transitions that occur at temperatures close to absolute zero, driven by quantum rather than thermal fluctuations.

When a system is swept across the critical point of a phase transition, all its constituent particles need to reorganise themselves, leading to far-from-equilibrium scenarios and the spontaneous formation of spatial structures, or defects. While continuous phase transitions have been more commonly studied, many important transitions are discontinuous, including the one thought to have triggered the inflationary phase of the early universe. In these transitions, the competing ground states are separated by an energy barrier which can lead to metastability, in which a system remains stuck in the original phase even though the ground state has changed (see inset of Figure 1). This 'false vacuum' state can later decay, for example, by bubble nucleation where the new phase grows around defects [1]. However, such mechanisms are understood only semi-classically, and how the quantum dynamics unfold in the presence of strong interactions is an open problem.

Ultracold quantum gases in optical lattices formed by standing-wave lasers (Figure 2) provide an ideal platform for exploring the properties of quantum phases and their transitions, particularly in many-body interacting systems. For example, a Mott insulator (MI) can be tuned to a superfluid (SF) by changing the ratio between the onsite interactions and the hopping of atoms between neighbouring lattice sites [2]. This transition typically is continuous, where the system undergoes a smooth change when crossing the phase transition point.

However, in their latest work, the team showed that, in a driven system, the MI-to-SF transition can be turned into a discontinuous, or first-order, transition. By resonantly shaking the position of the lattice potential, they could hybridize the first two bands of the lattice, which can drive a discontinuous change from a MI to a SF [3]. For the right parameters, the shaking can excite the atoms from the lowest band into the first excited band, where they would form a novel superfluid at the edge of the band, visible as the two oscillating peaks appearing towards the front of Figure 1.

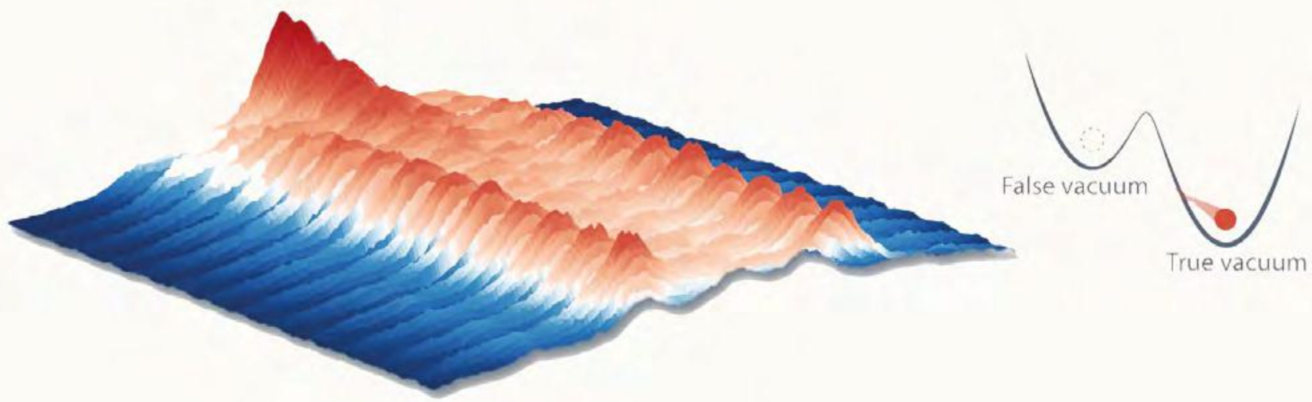

FIG 1. Measured momentum ditribution of the shaken quantum gas during the phase transition. The central peak on the left corresponds to the initial Mott insulator while the two peaks on the right indicate the appearance of the distinct staggered order after crossing the continuous transition. In the discontinuous case, in contrast, the system would remain in its original, now metastable, phase and would later decay from this metastable (false vacuum) state to the ground state (true vacuum) - see inset. This driven system makes it possible to explore the effect of quantum fluctuations.

FIG 3. The vacuum system for ultracold quantum gases used in the experiment.

FIG 2. Illustration of the equipotential surface of a 3D optical lattice formed by reflected standing wave laser beams.

Crucially, the transition from the original Mott insulator in the lowest band to the resulting staggered superfluid in the excited band can be first-order (discontinuous), because the non-staggered order in the Mott insulator is incompatible with the staggered order of this superfluid – so the system has to choose one. The authors could directly probe the metastability and hysteresis associated with this first-order transition by monitoring whether and how fast one phase changes into another—or not. They could directly observe that, after crossing the first-order phase transition, the system remains in its, now metastable, initial state rather than following the evolution of the ground state. The findings are published in *Nature Physics* [3].

The underlying physics involves ideas that have a long history at the Cavendish, from Nevill Mott on correlations to Pyotr Kapitsa on superfluidity and dynamical control by shaking, but are now put to use in a manner that they would never have envisaged.

The discontinuous transition demonstrated in this work opens up new opportunities for simulating the role of quantum fluctuations in false vacuum decay [1], along with further understanding of the mechanism of structure formation when a strongly-interacting quantum system undergoes a discontinuous transition.

The research is funded in part by the European Research Council (ERC), and the UK Engineering and Physical Sciences Research Council (EPSRC) as well as the Simons Foundation.

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Dimensionality is key:
hexagonal boron nitride provides new room-temperature spin-photon interfaces

A new class of single 'isolated atoms' identified by METE ATATURE and his colleagues, HANNAH STERN and QIUSHI GU, with collaborators from UT Sydney, Australia, creates promising new directions for spin-photon interfaces based on the novel two-dimensional material, hexagonal boron nitride.

FIG. 1. The Cavendish hBN team: (left to right) Hannah Stern, John Jarman, Qiushi Gu, and Simone Eizagirre Barker.

A global effort is underway to develop the next generation of information technologies based on the laws of quantum mechanics. The realisation of a global quantum network, a distribution of quantum states and quantum entanglement between any two points on the Earth's surface, would enable quantum-safe cryptography and quantum computation.

A major building block of future quantum networks is quantum memory, nodes in a network where quantum information is securely sent via photons, and stored in spin-based quantum bits, comprising a 'spin-photon interface'. One of the leading candidates for a network-based quantum memory are optically active impurity (or defect) spins in a small range of wideband bulk crystals. Diamond and silicon carbide, for example, host defects that interact with visible light to form ground state electronic spin populations with millisecond-long spin coherence times and high-fidelity optical control and readout. Last year, the nitrogen vacancy centre in diamond formed the first three-node quantum network [1]. Despite this progress, there are major challenges in scaling bulk crystals from lab-based demonstrations to a global technology. These include challenging material processing and low-temperature operation.

Two-dimensional materials offer a new platform, where the point defects are among the brightest to date, show room-temperature operation and their reduced dimensionality opens new routes to scalable quantum devices. A major question however has been whether two dimensional materials have optically addressable ground state spins. Our team, in collaboration with our Cavendish colleague Henning Sirringhaus and colleagues from UT Sydney in Australia, focused on investigating the presence of optically addressable spins in two-dimensional Boron Nitride, hexagonal Boron Nitride or hBN.

We used a well-known optical technique that detects the presence of ground state electronic spins from the integrated fluorescence in response to an applied magnetic field, optically detected magnetic resonance (ODMR). The experiment involved setting up a hexagonal boron nitride sample near a tiny gold

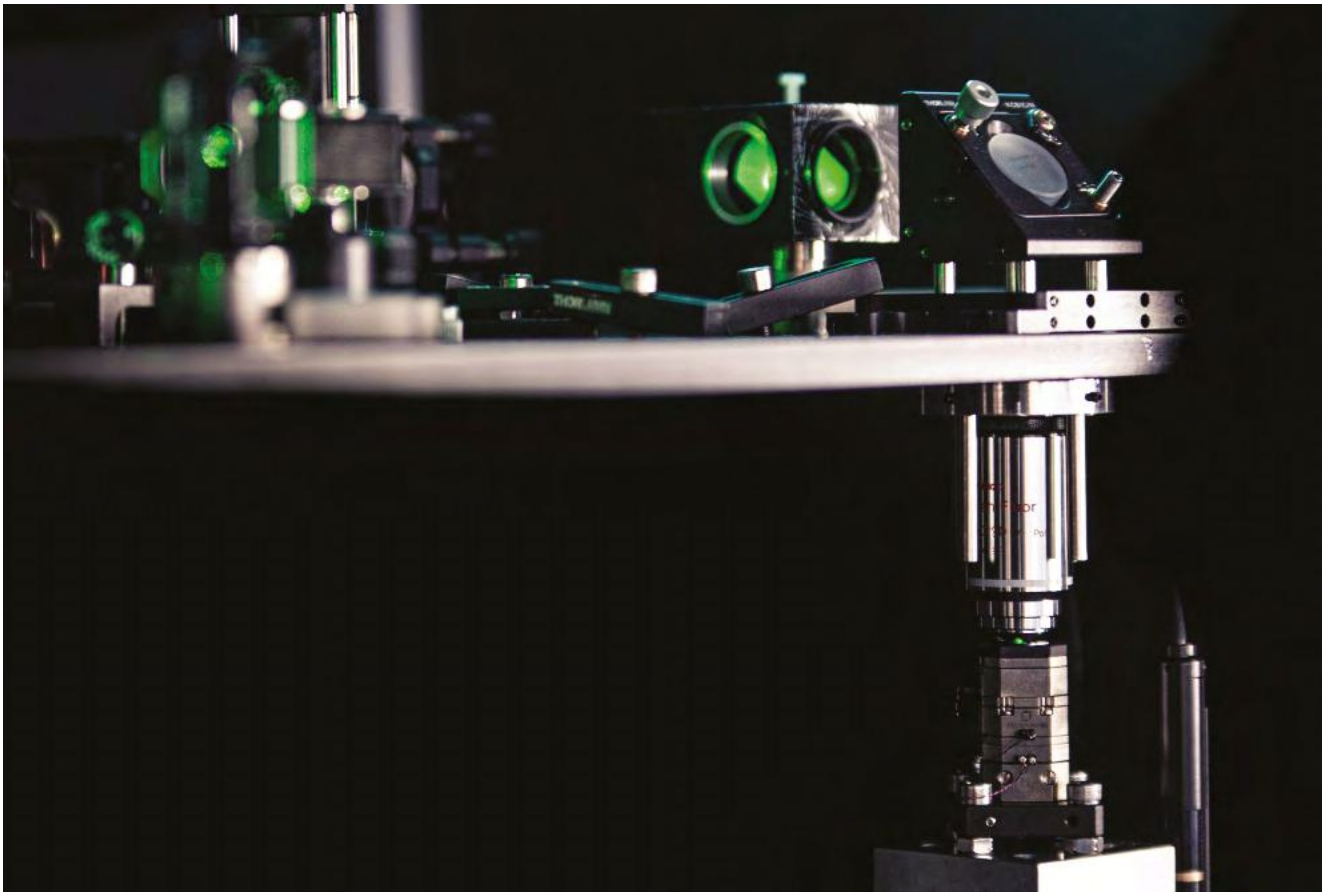


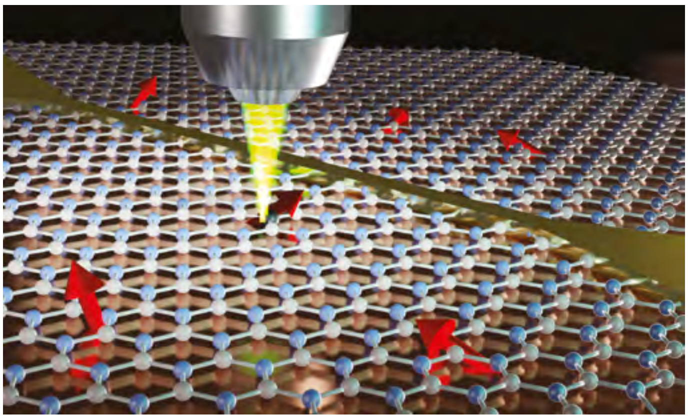
FIG 2. (a, ABOVE) A photograph of a room-temperature confocal microscope in the Atature group. (b, BELOW) A schematic diagram of the optically detected magnetic resonance experiment showing a focused laser exciting spin defects in hexagonal Boron Nitride adjacent to a gold antenna, which is used to deliver microwaves to the sample.

antenna to observe different magnetic field-dependent responses from the light emitted from a single defect (Fig. 2).

Our results identified an ODMR signal at room temperature for the single defects, the first report of optically-addressable single spins in a two-dimensional material [2].

In addition, our experiments presented some unexpected and surprising findings: we observed that not all defects show an ODMR signal, and that the signal can be positive or negative per defect, something that has not been observed for bulk crystals like diamond. What is the origin of this variability? From studying hundreds of defects, we developed a kinetic model that indicates the energy levels of each defect are highly sensitive to its local environment, a result that could see deterministic strain tuning of spin properties.

We are still in the early stage of investigating these defects, and are pursuing exciting avenues for sensing, coherent optical manipulation, coherent spin manipulation, and cavity coupling. Our findings present two-dimensional materials as an important candidate for future quantum technologies. Their inherent



scalability and ability to operate at room-temperature could see two-dimensional materials become a leading quantum technology.

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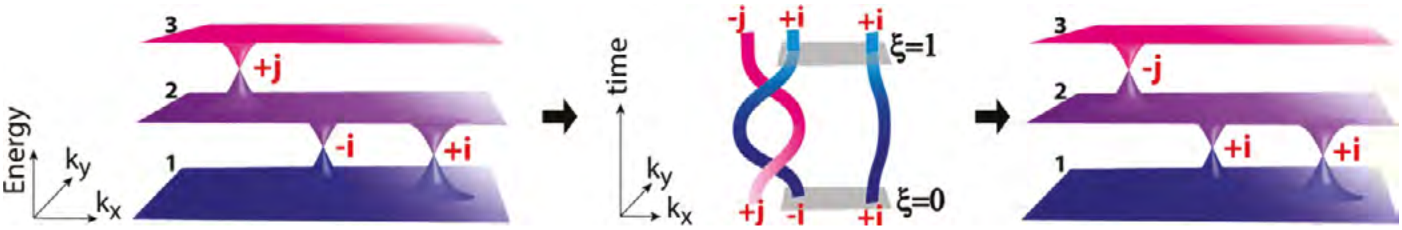
Topology Matters

We congratulate warmly ROBERT-JAN SLAGER on his award of an EPSRC New Investigator Award and an ERC Starting Grant. The contributions of his theory group range from out-of-equilibrium systems to magnetism and from non-Hermitian physics to lattice gauge descriptions of nematic phases of matter. They are particularly interested in how universal mathematical descriptions may emerge in condensed matter systems that are experimentally accessible, with a particular focus on the role of topology. Here he describes some highlights of their research.

Topology is a branch of mathematics that in essence characterises properties of objects that are preserved under smooth deformations and which can be related to deeper geometrical and analytical expressions. This is usually exemplified by the topological equivalence of a coffee cup and doughnut - without cutting or gluing one can be continuously deformed into the other. Their general class may be quantified in terms of characterising invariants, in this example the integer that counts the number of holes. Rather remarkably, this principle has been found to be of pivotal importance in phases of electronic matter, where the wavefunctions can tie distinctive collective knots, topologically distinguishing different classes of insulators and metals. These topological insulators and metals are not only appealing from a purely theoretical point of view, providing, for example, an exotic vacuum with illustrious axion electromagnetic couplings, but also exhibiting remarkable physical phenomena such as protected metallic edge states. The latter could shape next-generation electronics or excitations that can store quantum information, making topological materials a potential key component in quantum computing platforms.

Although it has been known that symmetries such as time-reversal facilitate such topological invariants, we were amongst the first to point out that crystal symmetries also play an important role [1], placing conditions on which topological phases can be formed and pinpointing that there is a rich landscape of different possibilities. Although this developed in an active field, we made another substantial step in 2017 finding that these phases can be related to deeper mathematical principles involving so-called K-theory by tracking simple symmetry properties of wave functions in the Brillouin zone [2]. This provides a road map for discovering topological materials and has been used by various groups to map out the different classes in momentum space for all types of symmetries [3]. These also enable us to check whether these classes have an atomic limit, the absence of which directly implies topological properties such as edge states [4]. From a more tangible perspective, these rules are also being employed to build topological material databases in a high-throughput manner and have resulted in various realisations of topological materials.

In the past two years we have discovered a radically new class of topological materials that cannot be described by this paradigm and depend on multi-gap conditions. The idea is that band nodes, that is, places where different bands touch in the Brillouin zone, can carry anti-commuting, or non-Abelian, charges when they reside between different pairs of bands. As illustrated in Fig. 1, when the nodes are then braided along each other in momentum space, the system undergoes a topological phase transition, quantified by a new multi-gap invariant that we refer to as Euler class [5]. Apart from initiating searches into new phases and novel mathematical multi-gap characterisations [6,7,8], these findings have resulted in the prediction of tangible physical consequences. For example, we predicted that when a system is quenched with a multi-gap Hamiltonian, the wave function should form linking patterns [9] that indeed were observed in March this year [10]. Moreover, we have formed a very productive collaboration with the Materials Science Department, which has resulted in several proposals to observe these new braiding mechanisms in systems that



range from phonon spectra [11] to electronic materials exhibiting structural phase transitions [12]. As a result, we have excitingly witnessed rapidly increasing interest in this new research direction the past few months.

We are excited about the feedback in terms of funding, interest from colleagues and other Universities, and are eager to further increase the momentum.

Brief Curriculum vitae

Robert-Jan studied physics and mathematics at Leiden University, obtaining his PhD with the highest distinction awarded to only 5% of all doctoral students. His achievements during his studies were recognised with several prizes, including a national Shell award from the Royal Holland Society of Science and Humanities. After postdoctoral appointments at the Max Planck Institute for complex systems and Harvard University, he joined Cambridge as a Winton group leader in December 2019. While at Cambridge he has published over 25 papers, including several Physical Review Letters, a Nature, two Nature Physics and two Nature Communications articles.

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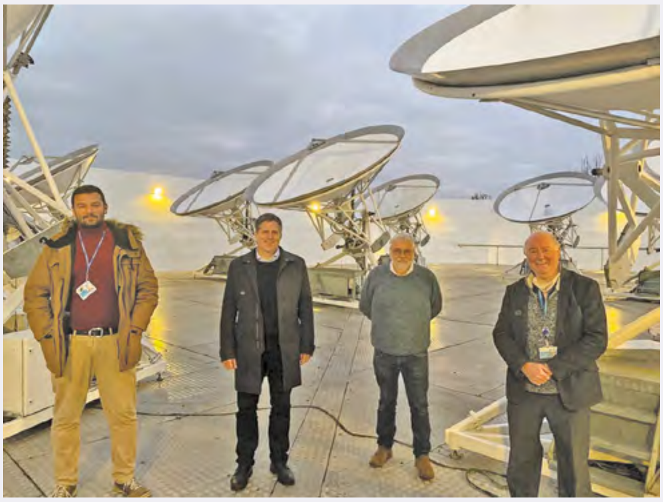
FIG. 1 (LEFT). Multi-gap topology. The left panel shows three energy bands as a function of momentum and band nodes with charges i and j that are non-Abelian quaternions. After the momentum-space braiding process illustrated in the centre panel, the resulting band structure features similarly-charged (+i) band nodes in 'gap 1' (final panel). The obstruction to annihilate nodes with similar charges in this 'gap' is quantified via a non-trivial Euler invariant ξ defined over Brillouin zone patches containing them, such as the grey planes.

Local MP's Visit to the Mullard Radio Astronomy Observatory



In December 2021, we were pleased to welcome local MP **Anthony Browne** to the Mullard Radio Astronomy Observatory (MRAO). Observatory Director **Paul Alexander, Eloy de Lera Acedo** and your editor had the pleasure of showing him around, recalling all the discoveries that took place here and discussing plans for the future. Browne studied quantum relativity at Cambridge under John Polkinghorne and wrote an extensive post on Facebook on his visit to the Observatory. He paid tribute to the many breakthroughs that had taken place and continue to take place at the MRAO.

ABOVE: The visit of local MP Anthony Browne to the Arcminute MicroKelvin Imager (AMI) at the Lord's Bridge Observatory. (left to right) Eloy de Lera Acedo, Anthony Browne, Paul Alexander and Malcolm Longair. The photograph was taken within the enclosure of the small array of ArcMinute Imager (AMI) which continues to make wide-field surveys of the sky at 15 GHz and monitor the variability of transient and variable radio sources.

Tackling non-equilibrium fluctuations in soft materials

Many congratulations to ALICE THORNEYWORK for her success in winning both a Royal Society University Research Fellowship and an ERC Starting Grant. She introduces her research on the non-equilibrium fluctuations in soft materials

Natural phenomena are governed by a complex interplay of physical and chemical factors. At the molecular level, however, unravelling experimentally such behaviour is very challenging as the short length and time scales make it difficult to visualise and manipulate systems directly. Significant insight can be gained by studying experimental models that capture relevant behaviours which are much more experimentally accessible. In my group we use the unique toolbox provided by soft matter to build these models across a wide range of length scales. Our current focus is to exploit this approach to understand noise and fluctuations in non-equilibrium scenarios.

Noise is a universal aspect of experimental science, typically viewed as a problem to be overcome. Indeed, we often talk about looking for the signal in the noise. Yet fluctuations contain significant information about a system's underlying features. This is not a new idea: it was famously captured by Onsager nearly a century ago, and the Nobel Prize-winning discovery of cosmic microwave background radiation came from a careful analysis of residual noise from a communications antenna. Noise is often overlooked as a source of information, however, because it can be prohibitively difficult to interpret fluctuations in experimental data. Many factors need to be disentangled which are individually difficult to interpret, especially in non-equilibrium systems where microscopic fluctuations remain poorly understood. For example, noise scaling as 1/f in the power spectral density is observed in diverse physical scenarios, from tidal patterns to the brain, but the associated underlying molecular mechanisms are widely debated.

By exploring different classes of fluctuations in a suite of soft matter models, we aim to develop novel methods to extract useful information from experimental noise. For example, we

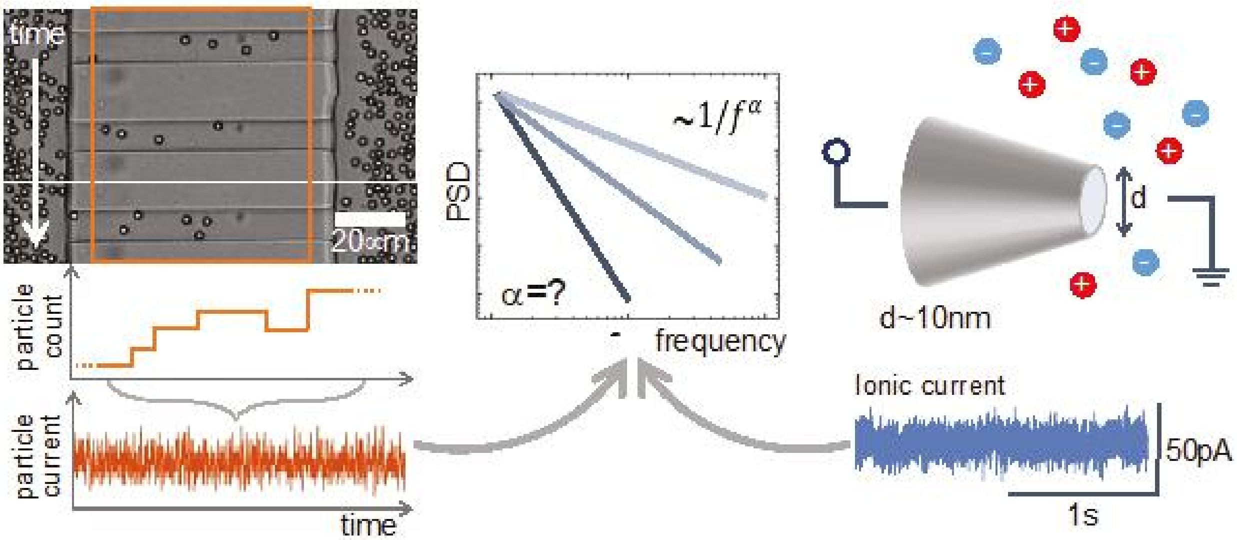


FIG. 1. Understanding noisy currents and the power spectral density (PSD) scalings they produce by (left) counting colloidal particles driven through microfluidic channels and (right) probing ionic currents through nanopores.

are studying noise in currents at both the mesoscale, with observable currents of colloidal particles driven through microfluidic channels, and at the nanoscale, with ionic currents through precisely fabricated and functionalised nanopores. Furthermore, to probe the role of fluctuations in more complex flexible structures inspired by biological molecular machinery, we are using DNA to self-assemble nanoparticles into complex structures with tuneable rigidity and well-defined features.

Our work will not only provide exciting new insights into physicochemical fluctuations at a fundamental level but will also underpin the many applications of soft materials in emerging technologies that require specific noise characteristics. Moreover, by developing transferable analysis methodologies applicable to diverse experimental scenarios, we hope in the future to help others transform their noise into a signal in its own right.

Brief Curriculum vitae

Alice completed her undergraduate studies and DPhil in the Department of Chemistry, University of Oxford. She joined the Cavendish Laboratory in 2016, and in 2018 was awarded an Oppenheimer Research Fellowship in the department. In October 2021, she became a Royal Society University Research Fellow and from later this year her group's research will be supported by an ERC Starting Grant.

Professor Mark Warner FRS (1952–2021)

Readers will be very sad indeed to learn of the death of Mark Warner after a period of ill-health. Mark was a theoretical physicist of the highest distinction and a pioneer in the field of liquid crystal elastomers. His research achievements are well summarised in the citation for his election as a Fellow of the Royal Society in 2012.

> 'Mark Warner is one of the founders of the field of Liquid Crystal Elastomers and has thereby predicted new phenomena hitherto unknown to classical elasticity, liquid crystals and rubber, for instance large thermo and opto-mechanical effects, liquid-like shape changes, mechano-chiral response and soft ferro-electric solids. He has pioneered much of the statistical mechanical understanding of polymer liquid crystals. His work has inspired experiment and theory in a large number of groups internationally in chemistry, physics, mathematics, engineering and industry pursuing novel mechanics, photo-actuation, rubber lasers and optically-driven ferro-electric rubber.'

Mark was also a brilliant teacher who had a particular interest in introducing young people to the power of mathematics in physics. He won a major grant from government to enhance the teaching of mathematical physics in schools and this evolved into the extraordinarily successful international Isaac Schools Project. Mark received a number of awards, including the Alexander von Humboldt Research Prize in 2000, the Europhysics Prize of the European Physical Society in 2003, and the G. W. Gray Medal of the British Liquid Crystal Society in 2014. In addition to being a Fellow of the Royal Society, he was elected as an Honorary Fellow of the Royal Society of New Zealand in 2002.

Colleagues like Mark are irreplaceable. We pass on to his family our sincere condolences.

Research Grant successes

EPSRC has awarded a **Critical Mass Grant to the Theory of Condensed Matter Group**. The £3.67million grant will bring together cross-disciplinary collaborators from the Cavendish Laboratory, the Department of Materials Science & Metallurgy and the Department of Applied Mathematics and Theoretical Physics (DAMTP) to advance their world-leading research and innovation on dynamical phenomena.

Diana Fusco has won a prestigious 2022 Human Frontier Science Program (HFSP) collaborative Research Grant to investigate biofilm heterogeneity as an evolutionary mechanism for resilience to complex environment. The project is a joint project with two other young investigators – Luis Ruiz Pastena from the University of Miami (USA) and Carolina Tropini from the University of British Columbia, Vancouver (Canada).

Congratulations to **Ulrich Schneider**, for being among the 313 winners of the latest round of European Research Council's Consolidator Grants. Ulrich leads the Many-Body Quantum Dynamics group at the Cavendish Laboratory. He has secured a grant of €2 million (£1.6 million) to build the first Quantum Gas Microscope for the Kagome lattice in order to study the rich physics of frustration, flat bands, and novel strongly-correlated states.

The Cavendish's **High Energy Physics group** is to receive £2.67 million funding from the Science and Technology Facilities Council (STFC). The group is one of the 18 beneficiaries of the £60 million investment as part of its continued support to the UK particle physics research community.

Congratulations to the **Keyser Lab** for their €150k Proof of Concept grant awarded by the European Research Council (ERC). This top-up funding will help them bridge the gap between the results of their pioneering research on early detection of cancer biomarkers using nanopores and the early phases of its commercialisation.

New funding, provided jointly by STFC and the UK Space Agency has been awarded to 10 UK projects to develop technologies for the next generation of space science missions. One of these projects is from the **Cavendish Radio Cosmology group** led by **Eloy de Lera Acedo**. The initial funding is part of a project to design, build, deploy and operate a CubeSat to the far side of Moon's orbit, to look for signals that originated in the Dark Ages of the Universe.

UN's International Day of Women & Girls in Science

Discover inspiring women at different points in their careers in physics at the Cavendish and elsewhere in *The Making of a Physicist* film series. Cambridge researchers include **Carmen Palacios-Berraquero,** CEO of Nu Quantum, **Maria Ubiali** (now a Lecturer in DAMTP) and **Val Gibson** (Head of the High Energy Physics Group). You can watch all four films on the Cavendish's YouTube channel: youtube.com/c/CavendishLaboratoryUniversityofCambridge. The films, created by artist Miranda Creswell and Ashleigh Griffin of the Department of Zoology, University of Oxford, were commissioned by the Cavendish Laboratory to celebrate and recognise the important role women play in science and technology. More films are in preparation and will be released in the next few months.

New Lectureships in Extragalactic Astrophysics and Experimental Astrophysics (Exoplanets)

We are delighted to report that **Sandro Tacchella** will join the Department as Assistant Professor in Extragalactic Astrophysics from April 2022. He is a well-known expert in the field of galaxy formation and evolution. We are equally delighted that **Paul Rimmer** has been appointed Assistant Professor in Experimental Astrophysics (Exoplanets) starting in July 2022. He is planetary astrochemist, working on both experiment and theory concerning the principles of chemical kinetics to describe atmospheres and surfaces of other planets (for photographs, see page 4).

Sustainability award for the Ray Dolby Centre

Congratulations to the Cambridge construction team, who won first prize in the Bouygues Annual Sustainability Awards Ceremony, for their exceptional commitment to sustainability on the RDC site. A special mention went to a number of different sustainable initiatives; from partnering with Community Wood Recycling and Protec to reduce waste on site diverting it from landfill, to using Eco360 Group's cardboard desks in onsite offices and repurposing site materials to be converted into sheds, hedgehog homes and more.

West Hub coming soon

The **West Hub**, Ray Dolby Centre's nearest new neighbour, is set to open on April 26th 2022. It will provide the West Cambridge Campus with a wide variety of services such as a new Library service as well as spaces in which teaching, events, seminars and meetings can take place. Open workspaces are available throughout the building, designed for a range of working styles from group collaboration to focused work. The ground floor is given over to catering and retail, providing a much needed base for socialising.

IOP Tom Duke Prize 2022

Congratulations to **Pietro Cicuta** on being awarded the Tom Duke Prize 2022 by IoP's Biological Physics Special Interest Group. The prize confers the role of ambassador to disseminate the importance of physics in the life sciences. Tom Duke was a brilliant theoretical bio-medical physicist and former member of the Cavendish who tragically died at an early age of cancer.

IoP James Clerk Maxwell Medal and Prize

We are delighted to announce that **Bartomeu Monserrat** has won the prestigious Institute of Physics (IoP) James Clerk Maxwell Medal and Prize for his outstanding early-career contributions to theoretical physics.

Postgraduate Student Prizes 2021-22

Many congratulations to the winners of the Cavendish Annual Thesis Prizes for Postgraduate Students, awarded annually to recognise outstanding work by PhD students, based on a peer-reviewed paper reporting research undertaken during their PhD at the Cavendish.

Cavendish Prize in Experimental Physics - **Alice Merryweather** (Optoelectronics) for her paper "Operando optical tracking of single-particle ion dynamics in batteries" (Nature, June 2021)

Cavendish Prize in Computational Physics - **Bo Peng** (Theory of Condensed Matter) for his paper "Topological phonons in oxide perovskites controlled by light (Science Advances, November 2020)

Abdus Salam Prize in Theoretical Physics - **William Barker** (Astrophysics) for his paper "Systematic study of background cosmology in unitary Poincaré gauge theories with application to emergent dark radiation and H_0 tension" (Physical Review D, July 2020).

Abe Yoffe (1919–2022)

Readers will be saddened to learn of the death on 22 March 2022 of Abe Yoffe, Emeritus Reader in Physics and Emeritus Fellow of Darwin College, at the age of 102. A brief biography of Abe was published in CavMag23 on the occasion of his 100th birthday in 2019[1].

Fellowships

We are delighted to welcome the following winners of distinguished Research fellowships.

Adrien Bouhon (Mott/TCM) and **Natsumi Taniucki** (Rutherford/HEP) as Marie Curie Fellows; **Jan Behrends** (Mott/TCM) as a Leverhulme Early Career Fellow; **Pedro Vianez** (Mott/QM) as an EPSRC Doctoral Fellow.

New Appointments & Promotions

We are very pleased to welcome the following administrative and support staff members to the Laboratory and congratulate colleagues who have recently been promoted in the Department.

We are delighted that **Leona Hope-Coles** has been promoted to the new senior post of 'Executive Assistant to the Head of Department'

Matthew Rihan (Isaac Physics) Content Developer & Programmer
Jonathan Waugh (Isaac Physics) Content Developer & Programmer
Sam Lambrick (Isaac Physics) Content Developer
James Dolan (Isaac Physics) Senior Teaching Associate
David Ansell (NanoDTC) Teaching Associate
David Ward (Mott/SMF) Knowledge Transfer Associate
Jonathan Donaldson (IT) Windows System Developer/Administrator (secondment)
Thu Ra (IT) Systems Developer/Administrator
John McKay (IT) IT Customer Service Representative
Will Alcock (IT) Linux Systems Developer/Administrator (secondment)
Cheng Liu (Maxwell) Research Laboratory Manager (Promotion)
Gayani (Kosala) Kariyapperuma (Rutherford/HEP) Research Lab Technician
Stephen Melbourne (Facilities) Maintenance Assistant
Dylan Hutton (Workshop) Apprentice
Zinan Zhou (Kapitza) Hub General and Finance Administrator
Chris Wrycraft (Kapitza) HR & Events Administrator (Promotion)
Rafia Durrani (Rutherford) Hub Administrator (transfer from Kapitza)
Hannah McGhee (Rutherford) Hub General & HR Administrator
MiYoung Kim (Rutherford) Hub General and Finance Administrator
Alison Read (Rutherford/Battcock AP IPLU) Administrative Assistant - IPLU

1. www.phy.cam.ac.uk/files/documents/cavmag-23-2020-main-layout-online.pdf, page 16.

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 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 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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