UCL DEPARTMENT OF PHYSICS AND ASTRONOMY

UCL

ANNUAL REVIEW 2024

This year the annual review images showcase our departments teaching laboratories. Used by undergraduate students to learn core principles of physics experimentation, our images capture the beauty of basic equipment, and the experiments that physics is based on.

Front Cover

When electricity passes through a gas discharge tube, the atoms become excited. As these atoms return to their normal (ground state) energies, they emit electromagnetic radiation, which we perceive as different colours. Each gas produces a signature colour due to its unique electron transitions. An assortment of gas discharge lamps can be found in every physics laboratory.

COMMUNITY FOCUS Image (page 6)

A resistance box or variable resistor. Unlike older analogue multimeters, these resistance boxes are still widely used due to their ruggedness and durability. They can survive accidental misuse by inexperienced undergraduates.

ACADEMIC SHOWCASE image (page 41)

Close-up of the made-in-house lock-in amplifiers used in the second-year band gap experiment (CM4)

RESEARCH SPOTLIGHT image (page 46)

Close-up of the circuitry of the made-in-house lock-in amplifier used in the second-year band gap experiment (CM4). This experiment investigates the interesting relationship between the reflectivity of a material (an optical property) and its conductivity (an electrical property).

RESEARCH STATISTICS image (page 65)

Experiment boards for the E5 electronics project where second-year students build a digital thermometer from individual components. During this term-long project, students learn about transducers, analogue and digital electronics and programming.

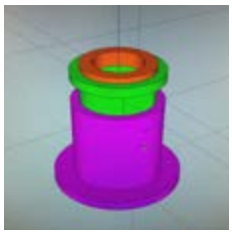
STAFF SNAPSHOT image (page 71)

This 3D-printed human hand was produced by third-year project students to test feedback control. Perfection of this device could enable natural manipulation of objects in hazardous or remote locations.

All images taken by Kelvin Vine, Experimental Development Officer in the Undergraduate Physics Teaching Laboratory.

Review edited by Lucy Keepking **lucy.keepking@ucl.ac.uk**

Contents



Welcome

The 2023/4 academic year has been another hugely productive and packed one. In the pages of this Annual Review we find examples of exciting research, education excellence, inspiring public engagement and broader initiatives that support the development and implementation of our aims. I've particularly enjoyed hearing first hand from our graduating undergraduate students as they advance in the department and develop exciting new connections beyond it.

Among the highlights this year was a departmental away day in July 2024, attended (in-person) by 90 staff, with representatives from every staff group finding their way to a café-style layout in the IoE. The facilitated sessions included 'Breaking Down Barriers' led by Lori Coletti Campbell. We were steered to find out what we had in common, and it turns out our department is full of swimming fans! I led a discussion on actions for improving our research standing for REF2029. Dialogue about research strategy focussed not only on central infrastructure investment, but also targeted investment of our time and focus. Louise Dash framed an interesting discussion on how to embed skills in our physics curriculum. Closing off the day, Lucy Keepking led conversations on EDI Values and Community, with outcomes that included over 60 ideas for inspirational departmental mottos. We aim to adopt the most popular one as part of our revamped departmental branding.

The department's successes in attracting prestigious research fellowships have this year included Luke Caldwell (lecturer in the Atomic, Molecular, Optical and Positron Physics, AMOPP, group) being awarded a UKRI Future Leaders Fellowship. His research is founded on building tabletop experiments - using the techniques of atomic, molecular and optical (AMO) physics - to test the fundamental laws of physics. In particular, Luke aims to build experiments that can shed light on why the universe is made of matter rather than antimatter. I am also very pleased to welcome to the department Valentina Zhelyazkova (AMOPP) and Valentina Cairo (High Energy Physics), who have been awarded Royal Society University Research Fellowships (URFs) in 2024.

This Review highlights the breadth and continued excellence of research in the department. During the past year there have been several media highlights founded in this activity, these include the discovery of a metal "scar" on a planet-consuming white dwarf (involving Jay Farihi); the detection of a neutron star in the dust of Supernova 1987A (involving Mike Barlow) and verifying the quantum nature of large masses (involving Sougato Bose). There has also been particularly heightened media interest and public engagement in a new theory developed by Jonathan Oppenheim. The excitement is that the theory takes an alternative approach by suggesting that spacetime may be classical—that is, not governed by quantum theory at all. Instead of modifying spacetime, the theory—dubbed a "postquantum theory of classical gravity"—modifies quantum theory and predicts an intrinsic breakdown in predictability that is mediated by spacetime itself.

The department had a UCL internal quality review (IQR) of teaching and education delivery this year. I am grateful to the IQR panel (chaired by Prof Parama Chaudhury, Pro-Vice Provost; Education - Student Academic Experience) for the time and effort they invested in this process. The IQR came at a juncture when we are as a community reflecting deeply on actions for improving our teaching performance and addressing our shortcomings in the NSS and TEF metrics. The recommendations of the IQR will be actioned during the 2024/5 academic year, charged by a newly formed Task and Finish group. The group will review teaching management structural changes, operationalise programme and module lead role descriptors, embed the role of year group leads, undertake an analysis of the department culture related to the provision of education and student engagement/experience, and evolve the workload allocation process.

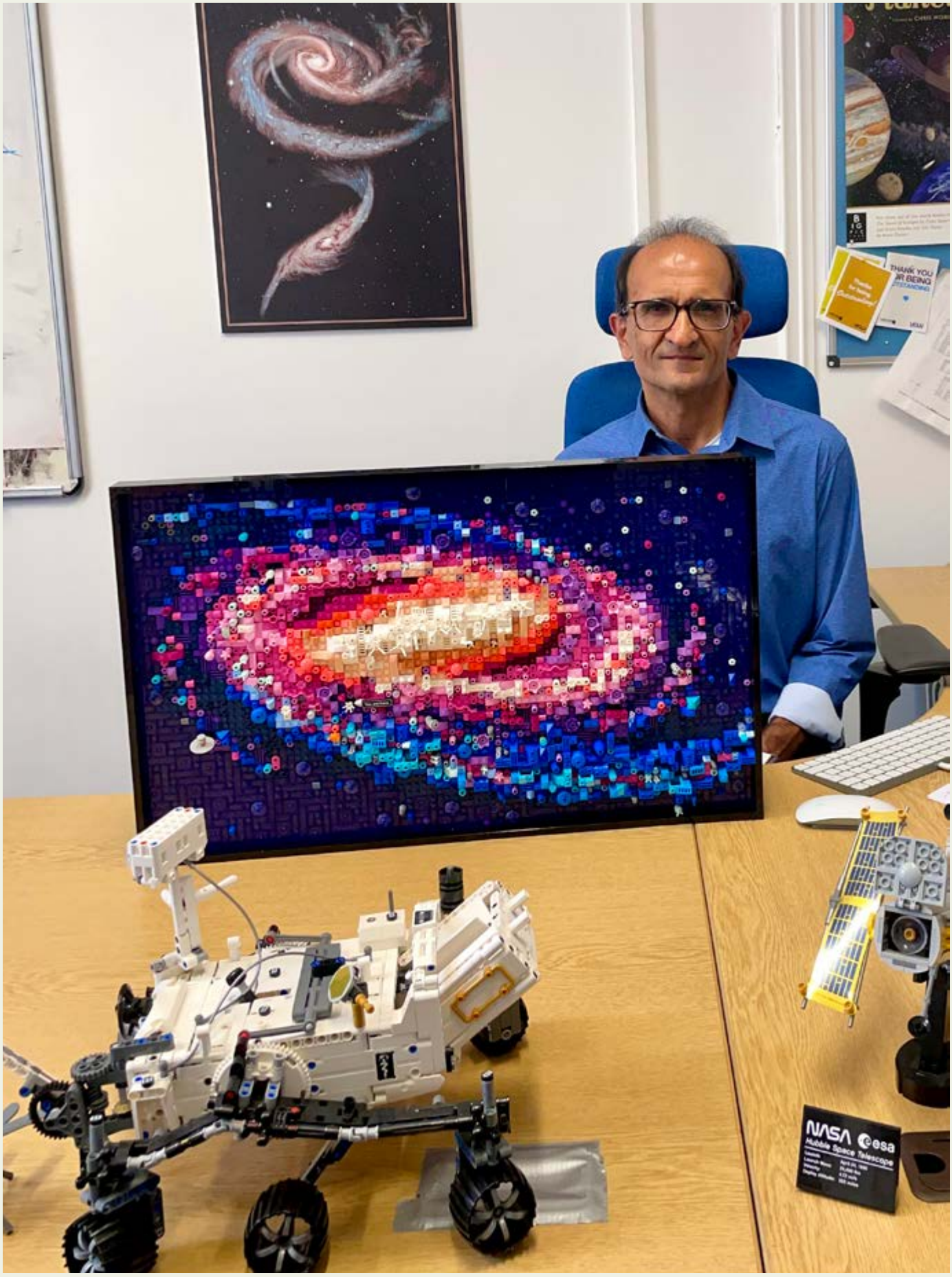
Another highlight of my calendar this year was the annual P&A Gala Dinner and Prize Award Ceremony, which brings together our alumni, students and staff for a celebration of what has fundamentally made this Department a success, was held on 1 December 2023. As in previous years, the programme of events began with our Annual Physics and Astronomy Lecture, delivered this year by Bart Hoogenboom. The departmental lecture was followed by the celebratory evening held in the Jeremy Bentham Room, Wilkins, with guess speaker, and alumni, Dr Sarah Beardsley (Director RAL Space).

Together, we are deeply motivated to combine excellence in research, education, innovation and creativity to achieve groundbreaking impact, from the realms of fundamental science to global scale challenges facing humanity. Our international reputation and ambitions are founded firmly on the talent, hard work and dedication of all our staff. The academic world can, however, be highly pressured at times; heavy workloads, short-term contracts, intense competition and rejections can place us under considerable strain. We continue to analyse and act on the results of our departmental surveys (staff and PhD students), as we work to address areas that need improvement and strive for the department to be a very supportive and welcoming place to work, for all of its diverse community.

Thoughts and planning are now also turning to UCL's bicentenary celebrations in 2026. This is a resonant landmark given that the Department of Physics and Astronomy was one of the founding departments of the London University in 1826, then known as the Department of Natural Philosophy & Astronomy, established on the first floor of the South Wing.

Rev Dr. Dionysius Lardner was elected as the Chair. The earliest attendance of women at a course of lectures at UCL was in May 1832 when Mrs Potter and Miss Rogers joined Rev William Ritchie's course of six lectures on electricity: they thus became the first two female university students in the country. Also, the first courses in practical physics arranged for undergraduate students in any English university were given at UCL in the session 1866-67 on the initiative of Prof. Carey Foster. I look forward in the coming year to inviting and welcoming a wide participation from colleagues (present and alumni) to help us shape a very special and memorable bicentenary.

Professor Raman Prinja
Head of Department



Head of Department Professor Raman Prinja displays his selection of space-themed legos.

COMMUNITY FOCUS

Teaching Lowdown

Despite some significant challenges this year, the Department of Physics and Astronomy has demonstrated remarkable resilience and dedication to providing high-quality education for all our students.

Our staff have continued to embrace innovative teaching methods, combining excellence in face-to-face teaching with the best of our digital resources, ensuring that students get the best quality education we can offer. They've integrated of cutting-edge research into our delivery, enriching the learning experience, allowing students the opportunity to engage with the latest advancements in physics as well as develop critical thinking skills.

Members of the department, both academic and professional services, have gone above and beyond to support students, offering additional office hours, personalized feedback, and mental health resources to help them navigate the challenges of being a physics student – indeed the question about our mental wellbeing support services was our top-scoring question in this year's National Student Survey (NSS) results. We've also fostered a stronger sense of community through student events, including coffee mornings with guest speakers for students to socially connect. Our Year 1 study club has continued to grow this year, with many students finding it a useful resource both for social and academic support – we are hoping to expand this initiative to other year groups in the future. Our student reps have provided an exceptional service to their peers and to staff in the department via the Staff-Student Consultative Committees, and many thanks are due to them for their dedication and work this year.

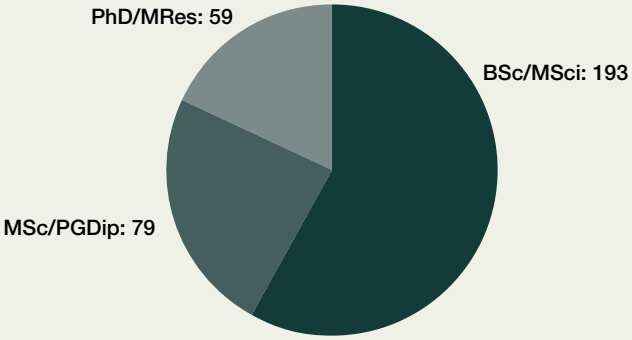
One new initiative at UCL for 2023/24 was the introduction of departmental education plans (DEP), designed to help departments tackle issues in a structured and supported way. Our DEP was centred around the provision of feedback, with an aim to improve both the timeliness and quality of feedback. We were able to make some significant headway here, with a noticeable improvement both to our NSS results in this area, and very positive feedback from student reps, who told us that students have both noticed and appreciated the positive changes we've made here. We also saw a very welcome improvement in our NSS "student voice" results, indicating that we're successfully developing two-way communications with our student body, and they are listened to.

In June our amazing Education Support Team were recognized by winning runner-up in the 2024 BEAMS Professional Services Awards category for "Outstanding team contribution to achieving UCL's mission", a very well-deserved accolade. Our annual Departmental Education Prize received a number of very strong nominations this year, with David Bowler being awarded the prize, for his long-standing contributions to excellence in education in the department – very many thanks to everyone who was nominated, and to everyone who provided a nomination.

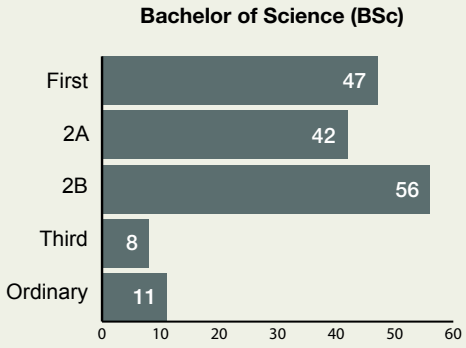
It has certainly been a challenging year for education within our department, but we are confident that we are on a path that will lead us onwards and upwards!

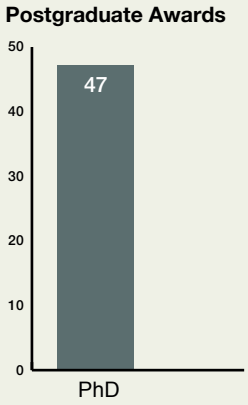
Dr Louise Dash
Director of Teaching

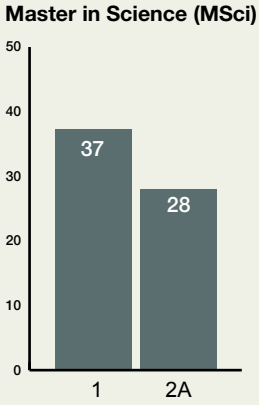
Intake



Awards







Student Accolades

UNDERGRADUATE PRIZES 2023/24

Oliver Lodge Prize
Best performance 1st year Physics
Bowen Yu

Halley Prize
Best performance 1st year Astrophysics
Yuxi Chen

C.A.R. Tayler Prize
Best performance in Communication Skills, 1st/2nd year
Mondo Lee

Wood Prize
Best performance 2nd year Physics in Yan Ryan Mok

Huggins Prize
Best performance 2nd year Astrophysics
Kirill Batrakov

David Ponter Prize
Most improved performance in department, 1st to 2nd year
Ren Wang

Dr Sydney Corrigan Prize
Best performance in experimental 2nd year work- PHAS0028
Emily Napper

Best Performance 3rd Year Physics Prize
Yutong Zheng

Best Performance 3rd Year Astrophysics Prize
Gregor Čavlović
Burhop Prize

Best performance 4th year Physics
James Henderson

Herschel Prize
Best performance 4th year Astrophysics
Charlie Drury

William Bragg Prize
Best overall undergraduate
Luo Long

Software Prize
Best use of software in a final year (astro) physics project (Jointly awarded)
Harvey Bermingham


Bowen Yu


Yuki Chen


Mondo Lee


Kirill Batrakov


Luo Long


Harvey Birmingham

Harvey Bermingham was one of the first group of MSci students to undertake a 4th year project in the area of Renewable Energy Resilience. He learned how to access, interpret and analyse large multi-year meteorological datasets, and apply a detailed model of wind-turbine power output and transmission. The core part of Harvey's project was the optimisation of off-shore wind farm locations to maximise the reliability of wind power in providing electricity to the UK, and he used novel genetic algorithm machine learning approaches in order to achieve this. He developed metrics for assessing the effectiveness of a given wind-farm spatial distribution and identified some key trends such as the importance of having geographically distributed locations.

Harvey presented his results in the first Physics & Astronomy Department workshop on Climate, Sustainability and Net- Zero, where it was noted by a member of the Climate Change Committee and others present. Harvey's work has laid the ground for further research in future energy scenarios for the UK, and illustrates how our students can use their physics knowledge and computational skills to tackle critical real-world challenges.

Software Prize
Best use of software in a final year (astro) physics project (Jointly awarded)
Shaun Mohamed Rafi Boodram

Shaun Boodram's MSci project, supervised by Dr Carla Perez-Martinez and Dr Aydin Sabouri (UCL), was to optimise the design of an electrostatic lens to focus the beam emitted from a novel ion source. The focused beam of ions could be implemented in nanopatterning, for example, for carving nanopores useful in DNA sequencing.

Shaun optimised the operating parameters of the lens by simulating various geometries on COMSOL Multiphysics. COMSOL uses the finite element method to calculate the electric field around the lens, and then the software traces the paths of the ions as they travel through the lens and towards a target. Shaun developed his own Python routine to calculate the spot size of the ions on the target from the COMSOL simulation results. Shaun was able to figure out how to perform a parametric sweep for this complex simulation in COMSOL.

This breakthrough was key to this project, allowing us to perform hundreds of simulations automatically and study many possible lens geometries. Shaun not only managed to find an optimal lens geometry within our design space, but he also simulated the performance of different particle populations in the beam and started a simulation of an array of lenses for multiplex patterning. Shaun not only did a simulation of the base array, but he analysed the initial results and found that by introducing larger grounding electrodes he could suppress artifacts due to leaking fields. Shaun's work will be of utmost importance as we work towards making arrays of lenses for nanomanufacturing.


Tin Ran Ryan

Brian Duff Memorial Prize
Best 4th year project
Yasona Neucleous

As part of his MSci thesis, Yasona worked on ML/AI models for skin lesion image classification for early non-invasive diagnosis of melanoma and other types of skin cancer. Improving the performance and interpretability of such models has the potential to save thousands of lives due to the high incidence rate of skin cancers and the difference that early detection makes on patient survival.

Using data augmentation and transfer learning methods, Yasona produced deep learning models that rival state of-the-art approaches -even without the use of obvious methods expected to further improve results, such as external datasets, ensemble methods or extensive hyperparameter optimization.

Yasona's exploration identified several forms of -until now underexplored bias introduced in the data during the imaging stage. Such an investigation and its findings are entirely novel in this context (AI/ML-based skin lesion classification) and quite informative.

His investigation provides new insights for the field, paving the road for further exploration. All this makes Yasona's work highly relevant to the AI/ML medical imaging field, novel, publication-worthy and award-worthy. He is currently working on publishing the results in a top-tier ML conference.


Saad Sheikh

Sessional Prize for Merit
Best 4th year project achieving balance between theoretical and practical physics
Hiba Noor

Hiba tu Noor succeeded in an MSci project that went far beyond the task provided. The goal was straightforward, to use the Gaia satellite to determine if 'polluted' white dwarfs are single stars, or more often gravitationally bound to another star. This was a direct test of hypotheses where stellar companions are responsible for dynamics that results in the deposition of planetary material onto the white dwarf surface. Hiba finished the project goals in only a few weeks, and then initiated a series of major improvements over the course of the next few months. These include, identifying additional samples to test and corroborate one of her early findings, robustly characterizing the likelihood that pairs of stars are actually gravitationally bound, and simulating false positives.

Ultimately, her work showed that polluted white dwarfs are a population of single stars, thus favouring major planets as responsible for the inferred dynamics around polluted white dwarfs. Her work is currently being prepared for publication in the Monthly Notices of the Royal Astronomical Society.

POSTGRADUATE PRIZES

Harrie Massey Prize
Best Astrophysics and Planetary Science MSc Student
Hiu Laam Lee

Harrie Massey Prize
Best Physics and Quantum Technologies MSc Student
Natasha Siow

Harrie Massey Prize
Best Scientific and Data Intensive Computing Prize MSc student
Runyang You

Biological Physics Prize
Outstanding postgraduate physics research in Biological Physics
Matej Sebek

Outstanding postgraduate physics research in Biophysics was awarded to Matej Sebek in recognition of the exceptional contributions to the interdisciplinary fields of materials science, optoelectronics, and biophysics through his thesis “Transition Metal Dichalcogenides for Optoelectronic Applications”

High Energy Physics Prize
Outstanding postgraduate physics research in High Energy Physics
Jamie McGowan

Jamie McGowan obtained his PhD in Particle Physics in 2024 for his thesis on “Approximate NLO Parton Distribution Functions - In the pursuit of theoretical uncertainties”.

The main content of the thesis is the production of the first approximate set of N3LO parton distribution functions (PDFs), which were presented in the extremely substantial publication Eur. Phys.J.C 83 (2023) 3, 185. This was the first article to produce results on the structure of the proton in terms of the constituent quarks, antiquarks and gluons at this unprecedented level of precision, i.e. next-to-next-tonext- to-leading order in a perturbative expansion in terms of the strong coupling constant.

Jon Darius Memorial Prize
Outstanding postgraduate physics research in Astrophysics
Catarina Alves

The Vera C. Rubin Observatory serves a vast diversity of science goals ranging from static-sky cosmology to the study of transient phenomena on a variety of timescales. The observing strategy of Rubin’s Legacy Survey of Space and Time (LSST) is therefore a “make or break” consideration for maximizing its science output. LSST will generate about 10 million alerts a night of transient and variable sources.

The open question which Catarina’s thesis work answered was to identify the key levers in the LSST observing strategy allowing us to cleanly separate scientificallyimportant classes of transient sources (supernovae) in the firehose of its alert stream; this is the critical step that enables supernova cosmology with LSST. To do this she had to solve a highly non-trivial optimization problem involving delicate trade-offs in the observing cadence design, since the supernova science must be optimized with no detriment to the multitude of other science cases.

The resulting thesis research has been highly impactful within the LSST Dark Energy Science Collaboration, and for optimising science with the Vera C. Rubin Observatory more broadly. Her valuable contribution led to her election as a Builder of the 1000+ person LSST DESC Collaboration, an honour granted to less than 50 scientists to date.

Christopher Skinner Prize (Astro)
Outstanding postgraduate physics research in Astrophysics
Lucy Hogarth

Lucy’s thesis entitled “Going with the radial flow: how molecular gas flows affect the large-scale evolution of galaxies” explores several key components of modern galaxy evolution models. In these models, the evolution of galaxies is driven by flows of gas in and out of galaxies, and by the formation of new generations of stars from this gas. A key limitation however is that directly observing these gas flows is extremely challenging. Lucy addressed this complex challenge


Natasha Siow

Jamie McGowan


Catarina Alves


Camilla DiMino

head-on by looking for the signatures of molecular gas in- and out-flows in samples of nearby galaxies observed with the Atacama Large Millimeter Array (ALMA) and with optical spectroscopic instruments.

In addition to her outstanding research, Lucy has used her time as a PhD student to engage in education and public outreach deeply and meaningfully, not just on the topic of Astrophysics, but also on climate science and neurodiversity, reaching large audiences across the UCL community, the UK and Europe.

Marshall Stoneham Prize
Outstanding postgraduate physics research in Condensed Matter and Materials Physics (experimental) (Jointly awarded)
Camilla DiMino

"Weak Intermolecular Interactions in Bulk Liquids and at Liquid/ Nanomaterial Interfaces"

Dr Camilla Di Mino's PhD thesis describes very significant advances in our understanding of how weak intermolecular interactions can play a key role in determining structure and properties in a variety of soft-condensed matter systems, ranging from simple liquid mixtures to complex dispersions, and nanoscale confinement and interfaces. In particular, during her PhD studies, Camilla developed and exploited state-of-the art neutron scattering and computer modelling techniques on a wide range of liquid and colloidal systems, and she has published her work in high-profile peer reviewed journals. Camilla's research has led to a number of important fundamental discoveries, for example: ideal local mixing in organic liquids, new solvation motifs around π-electron systems, and the underlying nature of solvent ordering that leads to nanoparticle dissolution and stability. In addition, Camilla's research has a variety of important practical applications with far-reaching impact,from energy storage systems through to biochemical assembly and molecular recognition.

Marshall Stoneham Prize
Outstanding postgraduate physics research in Condensed Matter and Materials
Physics (theory) (Jointly awarded)
James Dborin

"Implementing Tensor Network Algorithms on Quantum Computers"

Jamie worked on the application of tensor networks to structure quantum software. He was independent and resourceful from the start of his PhD. His thesis led to 5 publications – in high-impact journals. I believe that these papers can have a long-term impact on the field. Indeed, some have already become very influential; a work led by Jamie on using matrix product states to initialise quantum circuits for a range of applications has led to an entirely new direction for at least one quantum software company. His work running code on Google's quantum computer stands as the current state of the art. Beyond the long-term academic impact of this work, Jamie is taking ideas born in his PhD to successful technological application. His company – TitanML – have demonstrated that tensor network ideas can be used to compress large language. Given the largescale use of these codes, this will yield significant energy and cost reductions.

Carey Foster Prize
Outstanding postgraduate physics research in Atomic, Molecular, Optical and Positron Physics
Thomas Mellor

Thomas Mellor's PhD thesis is a theoretical and computational work entitled "Method Development in Ro-Vibrational Calculations of Polyatomic Molecules" done under supervision of Prof Sergey Yurchenko. It has resulted in 8 papers: 4 as first authors and one as a single author. In, fact his solo-author manuscript in Mol. Phys. 120.18 (2022), e2118638 on "Molecular frames for a symmetry-adapted rotational basis set" was awarded the prestigious Longuet-Higgins Early Career Researcher Prize for "a significant contribution to a top quality paper which has been published in the journal the previous year".

One of Tom's scientific inventions is the new theoretical approach called "artificial symmetry" – applying the well-established irreducible representation technique to treat systems with no or low symmetries. This novel technique has now been adopted and used for highly accurate calculations of spectra of polyatomic molecules. Another his heroic development is the full set of irreducible representations for one the most complex molecular symmetry groups, G36(EM), required for the spectroscopic description of the rovibrational spectra of Ethane (C_2H_6), which nobody has managed before Tom despite Ethane being one of the key atmospheric molecules.

Spreadbury Prize
Outstanding postgraduate physics research in High Energy Physics
Saad Shaikh

"A Quality Assurance Range Calorimeter for Proton Beam Therapy"
Saad's PhD work focused on the development of a novel detector for making Quality Assurance (QA) measurements for proton beam radiotherapy (PBT). QA is a critical part of the treatment process when treating cancer patients with PBT. QA measurements of the proton beam spot size, position, absolute dose and range need to be made every morning to ensure the machine is safe for treatment. There is a detector under development within the High Energy Physics group at UCL that aims to make faster and more accurate measurements of the proton range to improve the quality and reduce the time needed for daily QA.

He played a critical role in all of the experimental tests that demonstrated the successful operation of the detector and was singularly responsible for the complete data analysis of all the subsequent results. He is currently drafting the first two papers describing the detector and world-first proton range measurements at ultra-high (FLASH) dose rates. He was also able to present the results from the group at a number of prestigious international conferences, including PTCOG. There is no question that the successes achieved with the project would not have been possible without Saad's work.

Alumni Matters

The Physics and Astronomy Prize Giving Ceremony 2023 was held in the Jeremy Bentham Room on 1st December 2023.

Professor Raman Prinja, Head of Department, opened the award ceremony and welcomed all the staff, students and guests at the event, including Dr Sarah Beardsley, Director of RAL Space Research Institute as our guest speaker.

We are incredibly proud of our remarkable community of over 7000 alumni, living in over 60 countries worldwide and always enjoy hearing from you.

Please do reach out to share your news and connect with us at UCL.

As UCL alumni, you are a crucial part of UCL's vibrant global network and there is a huge range of useful services and exclusive benefits available to you.

Please visit the UCL Alumni website to view services available to you, lifelong learning opportunities and opportunities to volunteer and support UCL students: www.ucl.ac.uk/alumni

Sarah Beardlsey

Group photo of all 2023/24 Prize Winners

Equality, Diversity and Inclusion

Rewarding EDI work within Physics & Astronomy

In December 2023 the department awarded our inaugural Equality, Diversity and Inclusion Prize to Vinooja Thurairethinam.

Vinooja Thurairethinam

The EDI Prize was suggested in 2022, with Benjamin Joachimi, the previous chair of the EDI Committee, working with Lucy Keepking to draft a proposal for departmental approval. The EDI Prize was proposed to reward staff and students using the following criteria:

- embedding EDI into mainstream work through their approach and undertaking of all tasks, be it day-to-day tasks or larger projects.
- doing things differently by incorporating EDI values into the way they work resulting in a positive shift in UCL culture.
- taken the opportunity to engage with staff, speaking openly about their personal experiences in a visible forum that encourages and champions diversity and inclusion in a way that our students and staff can relate to
- voluntary contribution to a staff equality network / EDI Group, recognising impactful activities and commitment to EDI.

With the Head of Department, and the EDI Committees full support, nominations opened for the first prize in Autumn 2023. Nominations came from across the department, with both staff and PhD students nominated for the prize.

Vinooja Thurairethinam was named the prize winner in November 2023, and attended the departments annual prize giving event in December 2023.

With the help of the Anti-Racism Action group, Vinooja has collaborated with a TV producer to create outreach videos for schools to promote racial diversity in physics students from underrepresented backgrounds in science do not always see themselves represented in outreach activities. These videos seek to bridge the gap between these students and a career in physics, while also informing families of available career trajectories that may be considered unconventional within their cultures.

In addition, with the help of other PhD students, Vinooja is creating a gallery of posters within the Astrophysics group, focusing on highlighting physicists with diverse protected characteristics. These posters aim to demonstrate active inclusivity and create a welcoming environment for individuals with various backgrounds and identities, promoting the idea that the department is committed to supporting and celebrating all members of our community.

Recognising and rewarding EDI work in the department is just one mechanism to increase engagement in EDI work. There are more plans underway in the upcoming year to raise awareness of EDI, and encourage all members of our department to play their part.

Mrs Lucy Keepking
Departmental EDI Co-Lead

Students in Action

Women in Physics

The UCL Women in Physics group (WiP) has been championing and celebrating women and their achievements for many years now. We have expanded our coordination team over the last year, and we are excited to continue growing and supporting the departmental Equality, Diversity & Inclusion (EDI) efforts.

We are delighted to have Dr Abbie Bray return to WiP, this time as the Academic Chair. Abbie was previously the WiP Group Coordinator and is currently a Lecturer for the London Centre of Nanotechnology (LCN). Having pioneered many EDI, as well as outreach and public engagement, activities for both the physics department and the LCN, we are incredibly excited to have Abbie on the team.

When I took over as Group Coordinator, a primary objective was to increase our engagement with undergraduates. To achieve this, WiP introduced new Student Lead positions dedicated to organising a variety of academic and social events throughout the year. The response to our call for applications was overwhelming, and I am delighted to announce that we now have a wonderful team of six Student Leads:

- Sarah Littlejohn, MSc Quantum Technologies
- Mina Sibay, MSci Physicsm
- Mariam Fadel, MSci Physics
- Artemis Song, MSc Quantum Technologies
- Kaushkee Vats, MSc Astrophysics
- Vidthya M Adthisaya Ganesen, MSci Physics

The appointment of our Student Leads should allow for the group to keep its momentum throughout the year and provide more points of contact for those wishing to interact with WiP.

This year, we successfully organised a Women in Technology panel event, chaired by Student Lead Sarah. The event featured an impressive lineup of speakers from various tech sectors—Megan Slattery from Trainline, Taliah Horner from AND Digital, Natasha Siow from The Hut Group, and Constance Laine from Quantum Motion. These experts shared their diverse experiences in software, data science, and quantum computing, providing valuable insights to our members. Scheduled during the peak of internship application season, the event sparked an engaging Q&A session, reflecting the audience's enthusiasm and keen interest in the topics discussed.

To maintain an active presence over the summer and enhance our collaboration with other London-based Women in Physics groups, we organised a Rounders and Picnic social event in partnership with Imperial College London and King's College London. This event aimed to focus on the health and wellbeing of our members by promoting physical activity and social interaction in a relaxed setting, ahead of the start of the new academic year. Additionally, the group hosted a bar night at the Institute Bar, which provided an excellent opportunity for newer members to connect with our Student Leads.

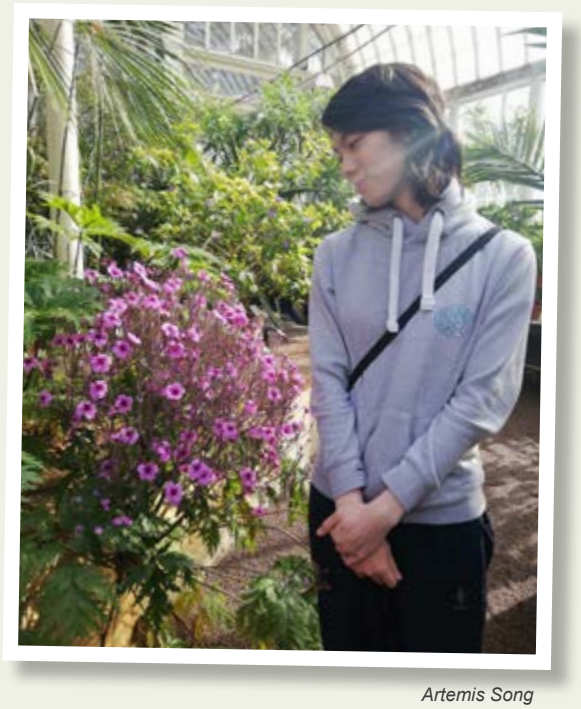
With fresh energy and perspectives in the team, our group is eager to adapt and expand our activities based on the interests and needs of our members. We are open to all suggestions and are committed to organising events that you would like to see. Whether you have ideas for future events, questions about how to get involved with EDI efforts, or need support in any way, we encourage you to reach out to us.

All the best for this coming academic year.

Fern Pannell
UCL WiP Group Coordinator

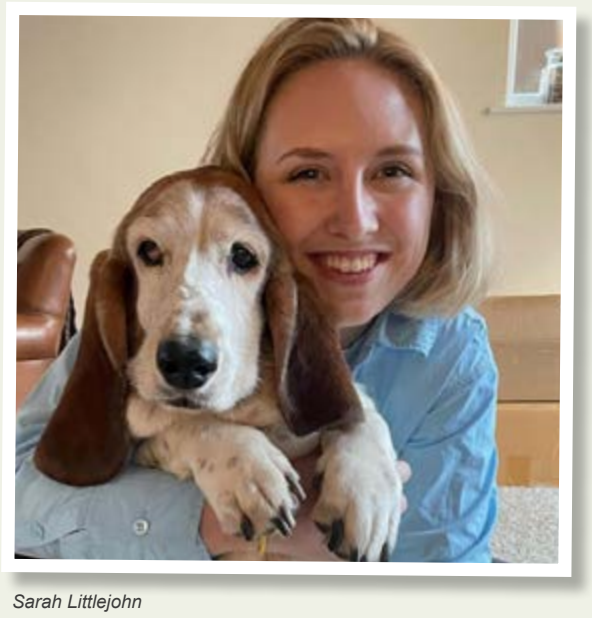
Fern Pannell

Abbie Bray



Artemis Song

Vidthya Adthisaya Ganesen



Sarah Littlejohn

Teaching

Computed Tomography

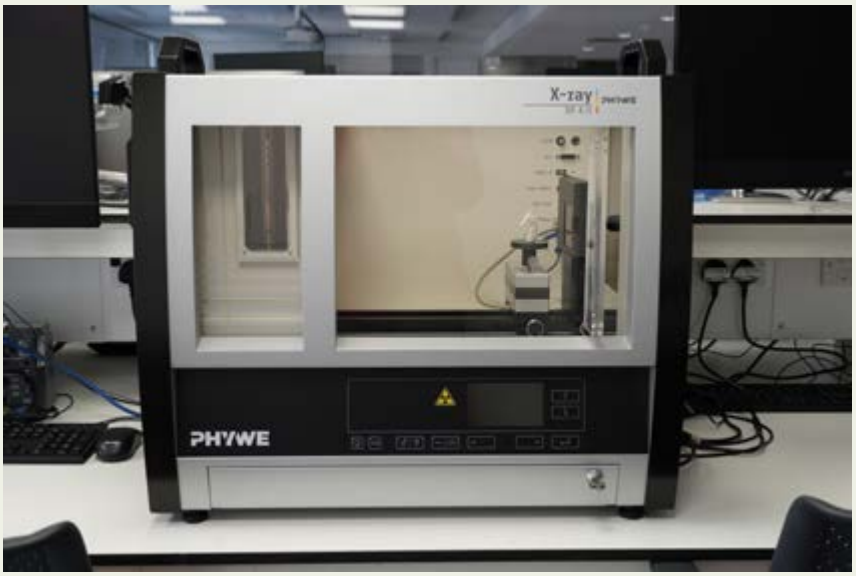
The Physics Lab bridges the gap between theoretical knowledge and practical applications significantly contributing to the understanding of fundamental principles. There really is no substitute for deriving the laws of physics using your very own measurements. As knowledge of our physical world advances, the experiments we provide to students must be constantly developed to maintain a high standard of teaching. A good example of this continuous improvement is a newly developed experiment teaching the principles of Computed Tomography (CT).

CT scans offer several valuable benefits in medical diagnostics. CT scans quickly capture detailed images of internal structures, aiding in swift diagnosis and treatment planning. Unlike conventional X-rays (radiographs), CT images (tomographic images) eliminate overlapping structures, providing a clearer view of anatomy. Physicians can assess shape, size, density, and texture with precision.

CT helps determine when surgeries are necessary, reducing the need for exploratory procedures. It also guides treatment for injury, cardiac disease, cancers and stroke. Overall, CT scanning combines speed, accuracy, and versatility, making it a vital tool in modern medicine.

Dr Nick Nicolaou (Module Lead) and Miss Fern Pannell (Post Graduate Teaching Assistant) recognised the potential for more interdisciplinary experiments with an emphasis on Medical Physics. Fern worked tirelessly on this new experiment which uses the PHYWE XR 4.0 commercial X-ray generator (figure 1). This unit has been in our inventory for a while, used to teach X-Ray spectroscopy. However, we were one of the first labs in the world to upgrade these machines to perform CT Scans and the usual challenges with any new system integration had to be overcome. Dealing with prototype hardware, such as a faulty CMOS sensor, and beta software is always a challenge and this was no different.

Once initial teething problems were rectified, then commenced months of testing, validating the physics and of course writing a lab script compliant with the pedagogical requirements of the module.



3D printed CCC camera housings

3D printed CCC camera housings

It is ultra important that teaching experiments get it right so as not to frustrate the students. While we do want them to learn basic troubleshooting, they are not at the level where they can problem-solve things like breaking hardware or crashing software.

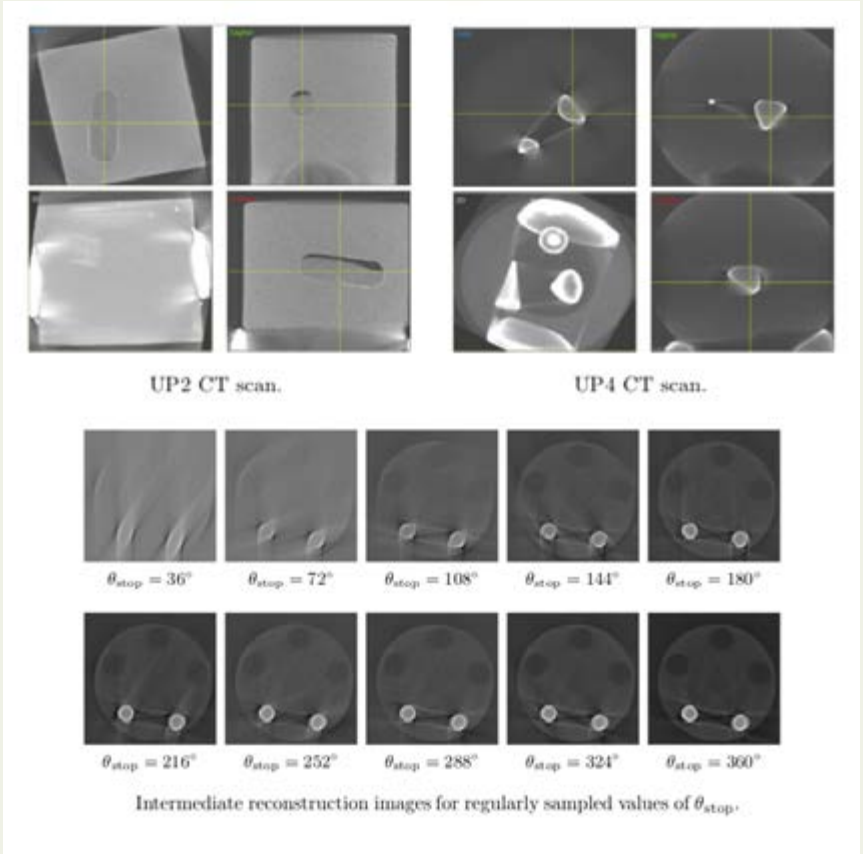
Although the mathematics use to reconstruct tomographic images is beyond the scope of undergrads (and this author), this experiment teaches the principles of X-ray imaging and CT Scans, beam setup, parameters affecting beam intensity, imaging contrast and resolution. The students then proceed to perform CT scans on mounted and 3D printed phantoms which they then must interpret (figure 2). One of these tests requires them to identify a foreign body embedded within another (figure 3). A few examples of images obtained by one student are shown in figure 4.

Finally, but of great significance, is that Fern does not work in the Teaching Labs but is currently a PhD student with the HEP group here in the department. This is not the first time that we have had collaborations with research groups to develop teaching experiments and so far, these have all been positive experiences both for the labs and the groups involved.

Overall, collaboration ensures a holistic educational experience that combines a research-informed curriculum with effective teaching practices. When research and teaching are closely linked, we can address skills and knowledge gaps in the local and national economy, contributing to broader societal goals. Exposure to research prepares students for real-life social and employment situations.

The suite of experiments in lab 3 gives our undergraduate students their first taste of research level practical experience. Collaborations with research groups to develop teaching experiments have been positive experiences, both for the labs and the groups involved and we hope that these kinds of collaborations continue.

The updated low-temperature calorimetry experiment



The two instruments above replaced the three below.

Science in Action

What is PandA?

PandA is an annual Physics and Astronomy (P&A) festival featuring a big show with music, theatre, dance, songs, and an art and science exhibition. This truly unique event celebrates all the talents of our community. The PandA show was inspired by the long tradition of the Physics plays, which were written, directed, and performed by second-year students, usually led by the Physics Society, for P&A freshers during the Cumberland Lodge away-days. These amazing weekend retreats, held in a beautiful 17th-century country house in Windsor Great Park, allowed students and academics to meet and get to know each other—a cherished tradition.

While not much evidence of these masterpieces remains in the public domain, a very short recording can be found on the UCL PandA YouTube channel. In 2019, a group of enthusiastic PhD students and staff decided that these jewels of humour and performance deserved to be promoted and shown to the entire department. It would be a crime not to. We knew the department harboured many talents beyond just the play and aimed to create a full Physics and Astronomy talent show.

Already by mid-February 2020, just before the pandemic hit, we had a full-scale show in the Logan Hall of IoE with even more content. The event began with a reception and ended with karaoke, solidifying its status as a festival and giving rise to the name "PandA"—a perfectly fitting title that seemed to appear out of thin air. This year, we celebrated the 5th anniversary with the 5th show, despite pandemic and post-pandemic challenges. Since 2023, the show has been hosted in the beautiful Bloomsbury Theatre, although we remain grateful to the Logan Hall for hosting two amazing shows before. Since 2021, when PandA was held online, the shows have been recorded and can be found on the PandA UCL YouTube channel.

PandA consists of two parts: the show and the exhibition. This year, the art and science exhibition was held in the Wilkins cloisters. The Physics meme competition, always a traditional part of the exhibition, showcased hundreds of original memes from members of the department. Our collection from 2020 has grown so large that we barely have enough space for all the memes. Apart from the memes, we presented books written by P&A academics, and featured art, science, library and pop-science stalls.

The PandA show, the jewel of the festival, was presented on the stage of the Bloomsbury Theatre with the sensational host, 3rd-year student Leyla Iskandarli, who had a few tricks up her sleeve (and two beautiful songs). Not many believed our magician-on-campus, an MSci 4th-year student T.K., could travel back in time to take a photo of his playing cards (or their permutations). But he did, with the spell "Physics unites," much to the audience's amusement.

The Physics play featured Barbyhiemer with a dramatic retelling of true events, highlighting heroes who bravely said "No more" and destroyed DevComm 2 from the Provost's computer. Because "physicists are not meant to be shy, socially

awkward, and stay in the library all day studying and doing equations and things, troubled by visions of a hidden Universe or useless in the lab." And as they said, "Communication is a lot like casting a spell. If you're overthinking it, you're probably doing it wrong!" The play was written, directed and starred by Max Henderson, Kirill Batrakov, Kefala Kyriaki, Rui Rui Xie, Francisco Diego, Ziqi Huang, Uddhav Venkatesh, Neil Booker, Oleksiy Smola, Ayato Yamazaki and Mondo Lee.

The infamous PandA Game Show was created and hosted by the brilliant 3rd-year students Jonah Donaldson and Uddhav Venkatesh and featured two teams of contestants: Team A (Abbie Bray, Dan Browne, Kate Pattle) and Team B (Jon Butterworth, Elinor Ashgrove, Chris Howard). The creative and funny contests included rounds of general knowledge/useless facts questions, betting and trivia (e.g., which book weighs more, Landau vol 4 or Griffith's, or how many affairs Einstein had) and Physics Charades. Spoiler: Team B won! The PandA prize can be seen on display on the ground floor of the Physics building.

The music performances were, as usual, affecting, passionate, and of exceptionally high quality. Our brilliant talents are Sushuang Ma, Alex Thompson, and Lin Qiao (voice, cello), Eva Aw (song/piano), Leyla Iskandarli (piano, guitar, songs), Alex Lukov (classical guitar), Francisco Diego (Mexican songs), and Sovann Pandit (piano performance). The show concluded with the Physics Sea Shanty band (Sergey Yurchenko and Alex Thompson) performing "What do we do with a drunk professor, early in the morning?" joined by the full PandA cast and the audience.

Planning for the next festival will start in October 2024, as soon as the new term begins. PandA is always looking for organizers, performers, creators of ideas, entertainers, and artists. Join us by contacting **uclphysicspanda@gmail.com**.

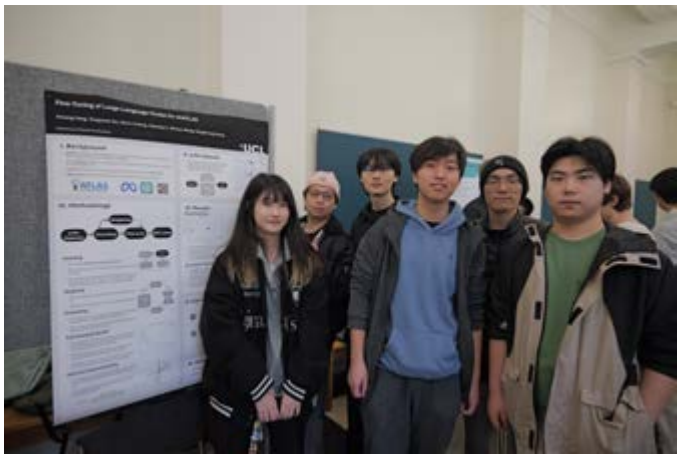
Sergey Yurchenko and the PandA team

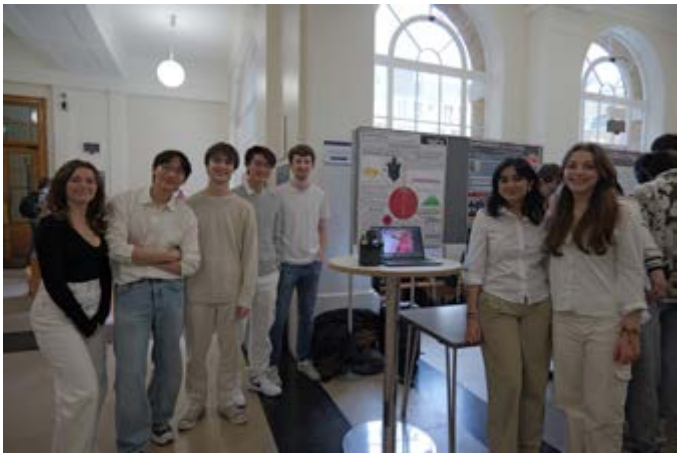
Physics Group Project – Poster Session

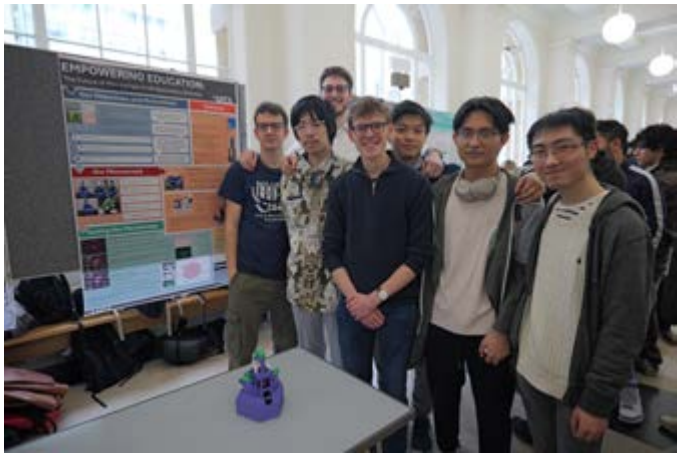
In this course, students participate in a demanding, long-term, open-ended project within small teams. The course concludes with a poster day, where the teams showcase their project work during an event in the North Cloisters. The students displayed great enthusiasm and engagement with posters demonstrating excellent scientific content and presentation skills. This event was a standout feature of the course. Prizes were awarded to the top three posters with the highest scores, and we extend our gratitude to all the staff who served as board members for the group projects.

The Group Project module was led by Dr. Daven Armoogum and Dr. Nick Nicolaou, with all photos credited to Kelvin Vine.

Prof. Thanh Nguyen







Outreach & Public Engagement

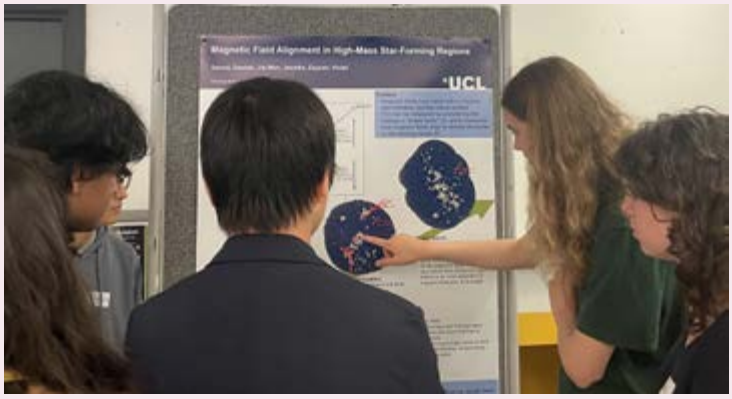
HEP Masterclass

On the 26th March 2024 the High Energy Physics Group hosted 50 A-level students in a Particle Physics Masterclass culminating with a live link up to CERN and three other institutions across Europe. Huge thanks to Ben Waugh for hosting the session, to Alex Martynwood for delivering an amazing talk about working as a researcher at the Large Hydron Collider and especially to the postgraduates Margot MacMahon, Lucy Bailey, Adam Scaachi and Marcin Jastrzebski who acted as mentors and helpers to the student as they completed their task of hunting for the Higgs Boson in data provided by CERN.

Year 12 students using data provided by CERN to hunt for the Higgs Boson

Public Engagement with Research

The department continues to be at the forefront of some exceptional projects that bring physics research to public audience. Targeting students from under-represented backgrounds, projects such as Orbyts bring postgraduate researchers into communities to develop long-term links where school pupils solve real research problems. An end of year conference brings over 300 pupils to the Bloomsbury campus to perform lightning talks and present posters on their research findings. The plan is to engage with all aspects of physics research through integrating public engagement in grant proposals, so more pupils can gain an understanding of cutting-edge physics and our postgraduate community can develop research and project management skills that will support them in their future careers.



Students aged 15 to 17 talk about their research posters produced during a 12-week project partnering with a PhD researcher

Student Public Engagement Awards

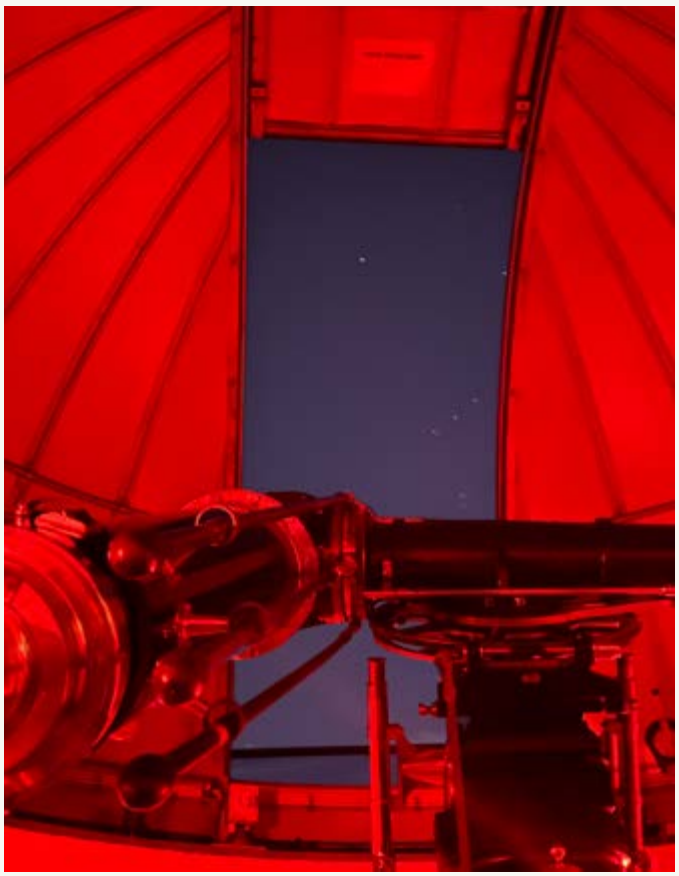
A number of our students have won awards this year for their excellent work in science communication and outreach. UCL PhD researchers Alex Thomson won first place and Conor Ballard was runner-up at the Centre of Planetary Sciences Outreach and Engagement Awards 2024. Amara Mighty won an Ogden Trust Award for her work with under-represented groups, and Max Henderson as an undergraduate ambassador at summer schools and astronomy tours for the public. The Mathematical and Physical Sciences Early Career Researcher Forum award for Outreach and Communication went to PhD researcher Fern Pannell. Congratulations to everyone for their well deserved awards.

Alex Thompson receives her prize at the Centre of Planetary Sciences Outreach and Engagement Awards 2024

Student Projects: U-kNOw Feynman

A team of third-year undergraduates supervised by Roger Johnson created a new card game as part of their group project to help the public understanding of Feynman diagrams. The game was tested on a groups of students and received great feedback, the plan is to take the game forward and see how it can be used in schools to promote curiosity and understanding of particle physics in a fun gamified way. The third year undergrads involved in the project were Zara Ercan, Sanjey Kumaravel, Ben Elliot, Leyla Iskandarli, Nadia Selimovic, Matt Cullingworth and Daniyal Khan.

A-level students playtest the U-kNOw Feynman game developed by third-year undergrads as part of their group project



Observatory Tours

We had another successful year of observatory tours held at UCL Observatory in Mill Hill. We hosted school groups, scouts, astronomical societies and community groups alongside our free to the public weekend evening tours for families. Overall, we welcomed more than 1000 people though the gates, and for many it was the first time they had ever visited an observatory. A huge thank you to all the student tour guides that helped make every event a success. Their enthusiasm and knowledge was a joy to see, and made even the nights when the clouds didn't allow us to observe, shine for all our guests.

A view through the open shutters of the observatory during a astronomy session. Red light is preferred as it protects night vision.

Science Centre Lectures

The science centre lectures continue to draw an audience for their regular Friday early evening slot. Thanks to Sadiq Kadifachi the founder of the lectures who is still finding new speakers and the hosting by Iga Zacharewicz who keeps everything running online. The geographical reach of our online lectures is phenomenal, but we do hope next year to bring back one or two in-person events to the calendar. Always looking for new talks on subjects across all of Science, Mathematics and Engineering, aimed at knowledgeable pre-undergraduate level, do get in touch if you would suggest a speaker or be in the audience for one of our talks starting again late October 2024.

Your Universe

The 18th edition of Your Universe festival took place on March 14th, 15th and 16th, 2024. This time, the festival included Astronomy and Planetary Sciences.

As usual, the festival displayed more than 10 stations along the UCL North and South Cloisters, the front Quad, the Wilkins Terrace and for the first time,the new Object Based Learning Laboratory, located betweeen the North and South Cloisters.

An important addition to the festival has been the participation from the UCL/Birkbeck Centre for Planetary Science, with amazing displays, materials end presentations. In particular, the CPS Juice stand led by CPS Marketing and Outreach Officer, Karen-Anne Devoil, who gave a talk on the subject 'The JUICE Mission -exploring the icy moons of Jupiter', enjoyed by school groups and the public.

We received nearly 300 primary and secondary school children from the Canary Wharf College and the Azhar Academy Primary School. Saturday was the family day, attended by about 100 adults and children.

North cloisters during secondary school group visits'

PUBLIC LECTURES

Evening lectures took place in the Harrie Massey lecture Theatre and the Gustave Tuck Lecture Theatre.

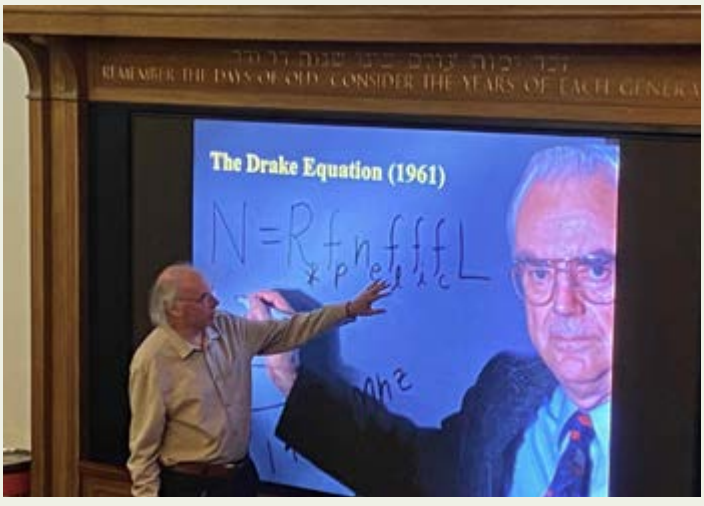
The Thursday theme was THE AURORA by Phil Halper, an enthusiastic alumnus of our Certificate in Astronomy, who has become an expert in the effect of solar storms on our high atmosphere. Phil showed his own spectacular pictures and videos recorded in recent years from Iceland and Scandinavia.

UCL Certificate alumnus Phil Halper delivers his spectacular talk on the aurora in the H Massey Lecture theatre.

The Friday lecture was Paradise Planet Earth by Francisco Diego, who introduced a wide range of disciplines related to the origin of the Universe, atoms, solar systems, the Earth and life, in order to enhance the relevance of our natural environment and the need to preserve it.

On Saturday, there was the traditional Gustave Tuck Panel Discussion, this time on the theme of Life in the Universe.

Matthew Powner, Professor of Organic Chemistry at UCL, opened the session with a detailed account of the origin of life, from a combination of chemicals, including hydrogen cyanide, offering a new perspective on a process that started almost 4 billion years ago.



Prof Ian Crawford, planetary and astrobiology scientist at Birkbeck, University of London, explored the topic of intelligence in the Universe and the lack of evidence for aliens.

The discussion was introduced and moderated by Dr Francisco Diego from our department. The Q&A session went for almost an hour, with important participation from some chidren in the audience, who asked really insightful questions.

GENERAL

This has been one our best festivals thanks to a very enthusiastic, efficient and professional team (YUF Committee), mainly: Jo Fabbri, Karen-Anne Devoil, Mark Fuller, Sarah McGrath, Wakami Soh and Noah Bensoussan. They organised communications, venue bookings, school groups promotion, demonstrator/explainer recruiting/training and most important, day preparations, logistics and adaptation to last minute contingencies related to school visits and room booking alterations.

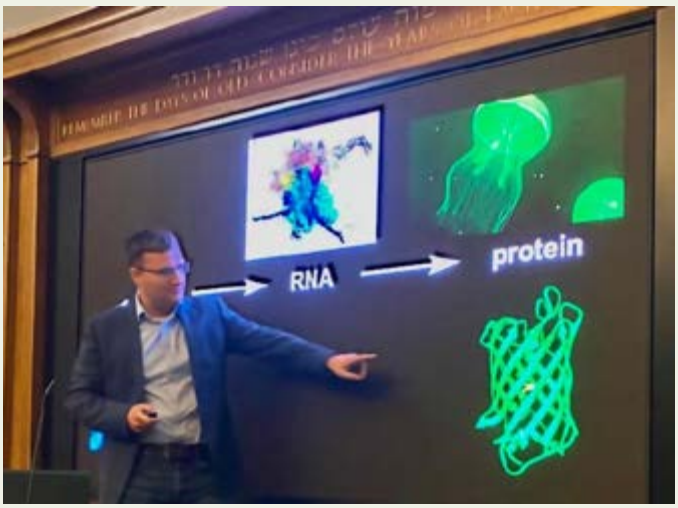
Looking ahead, there are major challenges, specially in the area of prioritised and reliable room bookings, more participation and support from our academic staff as demonstrators and lecturers and additional help in promotion, social media and website maintenance.

It is gratifying to see how Your Universe Festival is entering a wider context, just in time for the UCL Bicentenary celebrations.

The iconic interactive Hertzsprung-Russell diagram was again a major attraction, explained by volunteer Tony Law.

The CPS stand in the cloisters with Karen, Noah and Jo'

Michelle McGrath, volunteer from one of our CityLit courses, explains the orbits of extra-solar planets



Prof Powner explains the early stages on the origin of life

Postgraduate Society

The Physics & Astronomy postgraduate society is on a mission to create a lasting legacy that future students will rave about. Following the thrill of last year's research group competition, we've kept the momentum going with exhilarating outdoor summer events, including intense games of rounders and a variety of fun activities.

We're also diving into important topics over pizza and drinks, covering everything from writing upgrade reports and finishing your thesis to conference prep and career development. Whatever you need, the society is here to help!

Prof Crawford describes in detail the possibility of alien civilisations in our galaxy

But it's not all about competition—we're passionate about building a tight-knit community of postgraduate researchers. Every fortnight on Tuesday, we invite you to join our lively lunch and coffee club! This new initiative is the perfect chance to mingle with fellow students from different research groups, share stories, and enjoy delicious snacks and coffee.

We're always buzzing with fresh ideas for events and activities, and we'd love for you to get involved. No matter your background, there's a place for you in our vibrant postgraduate community. Come join the fun and help us make every moment unforgettable!

Teo Cobos
On behalf of the P&A Postgraduate Society

HSE Updates

Leaf Labs and sustainability

LEAF (Laboratory Efficiency Assessment Framework) is a standard set by UCL to improve the sustainability and efficiency of laboratories. 85 global institutions have joined and are taking part to help address the climate and ecological emergencies through your science

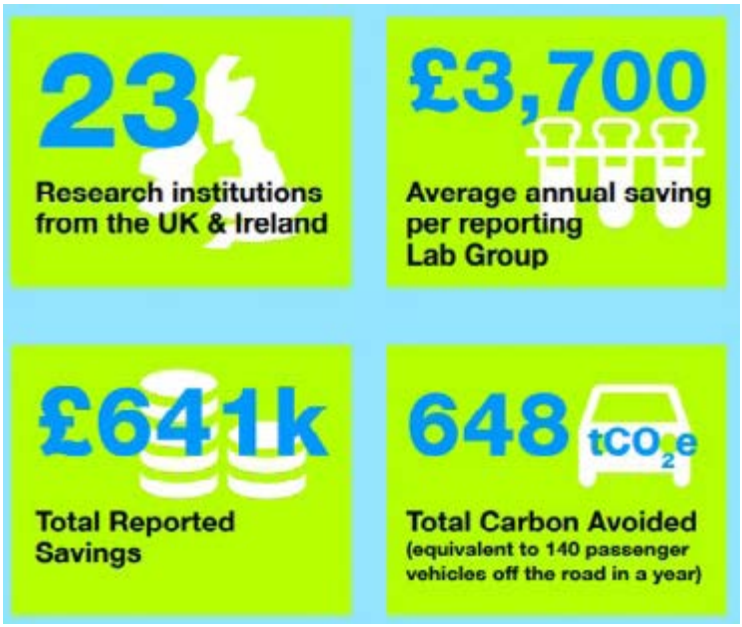
Laboratory-based research is essential for advancing society but it is also extremely energy and resource intensive. It's estimated that laboratories are responsible for around 2% of global plastic waste and use 3-10 times more energy per meter squared than a typical office.

By joining the LEAF programme, P&A laboratories can reduce their carbon emissions and create an environment that supports research quality.

Laboratories are awarded either a Bronze, Silver, or Gold level depending on how many sustainability actions they take. Currently P&A UG Laboratories are piloting LEAF in the department led by Lee Bebbington and Derek Thomas. To date UG Lab 1 has just been awarded a bronze award with Silver in our sights

As funders are taking action in driving sustainability into science, and institutions work towards impressive carbon targets, we hope LEAF can serve as a means of getting us where we need to be a bit quicker!

LEAF's pilot savings



Before making LEAF widely available, UCL piloted LEAF for 2 years with 23 other universities and research institutes from 2018-2020.

- 235 Lab groups took part;
- £3700 average annual saving reported by Lab group;
- £641k total reported savings;
- 648t CO2e total carbon avoided (equivalent to 140 passenger vehicles off the road in a year);
- 99% of those surveyed said they would use LEAF again.

Lee Bebbington, Departmental Safety Officer and Facilities Manager

T-100

T-100 stands for Target 100, a transformational safety program introduced by the Provost to be implemented by all departments at UCL. T-100 consists of 4 stages (baseline, stages 1,2,&3) And is a structured approach to managing health and safety to minimise the risk of injury and illness. It involves identifying, assessing and controlling risks in all UCL activities. The program represents a significant shift in the way we work, introducing focused regulation, new policies, monitoring and reporting structures.

T-100aims to improve safety cultures and protect UCL against financial and reputational damages. Due to the nature of the hazards and risks in laboratory based subjects, our department is subject to a more extensive version of T-100, compared to lower risk, non-scientific departments.

In order to qualify for an award, departments are audited by an advisor from safety services who must be satisfied each department has fulfilled all of the requisite criteria for each stage. This involves the implementation of over 65 separate pieces of work such as new frameworks and processes, monitoring and reporting, new or improved policy implementation and more. These are then examined and given either a pass or a fail. P&A has passed the baseline stage and have become the first department in MAPs to be awarded level 1. Our next stop? Completing Level 2.

Lee Bebbington, Departmental Safety Officer and Facilities Manager

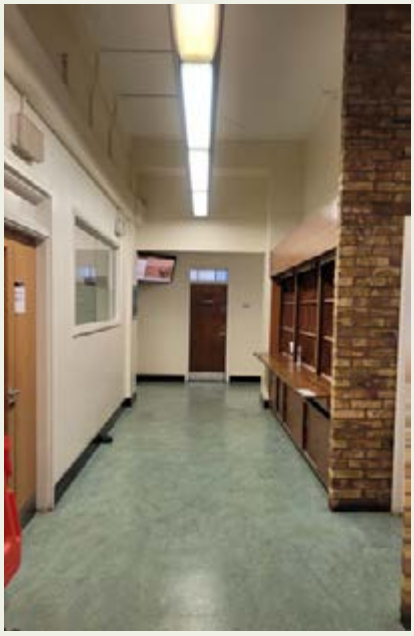
Physics Building Corridor Refurbishment Summer/Autumn 2023

In 2022 P&A applied for funding to refurbish the ground corridor in the Physics Building. The corridor was dark, and well worn, with fixtures and fittings not quite befitting a grand building such as Physics.

The refurbishment process was slow, as the Physics Building is listed, and previous works meant there was risk of asbestos. Work was carried out over the summer of 2023, leaving us with a sympathetically renovated corridor, far brighter and in better shape for many years to come!

Lucy Keeping

Before...



After...

Data Intensive Science and Industry (DISI) Centre and Centre for Doctoral Training in Data Intensive Science (CDT DIS)

The Centre for Data Intensive Science and Industry (DISI), including the Centre for Doctoral Training in Data Intensive Science (CDT DIS), has experienced another year of growth, innovation, and achievements.

The DIS CDT has now been running since 2017, and we welcomed our 7th cohort to UCL last September. We have now overall enrolled 75 PhD students, with 29 of them graduated. The popularity of the programme has continued to grow, and we received a record number of applications to join the 8th cohort, who we look forward to welcoming in the new academic year. In addition to our new students, there have also been some changes in the management team. Nikos Konstantinidis, who has been a co-director since the DIS CDT launched, is taking a step back to focus on alumni engagement for the Centre and will be replaced by Tim Scanlon. Minh Cao, the CDT Manager, has moved onto a new job and will be replaced by Ran Xu. We would like to welcome both Tim and Ran to their new roles, and thank Minh and Nikos for their hard work and dedication over the years, which has been pivotal to the success of the Centre.

The Centre has continued to be at the forefront of cutting-edge research and the excellence of the student's research has been international recognised by the receipt of several prestigious awards during the last year. This includes:

- Johannes Heyl, supervised by Prof. Serena Viti, won the very prestigious MERAC prize from the European Astronomical Society for the best computational astrophysics PhD thesis. This is a highly competitive prize, which is only awarded every other year, and open to all students in Europe. Johannes pioneered the use of machine learning in astrochemistry, revolutionsing the field, and leading to six novel and ground-breaking papers.
- Sam Van Stroud, supervised by Prof. Tim Scanlon, won the prestigious ATLAS Thesis Award, which is awarded to only 6-7 students a year from over the 300-400 PhD students who graduate on the ATLAS experiment every year. Sam won his award for his ground-breaking work in using graph neural networks, a machine learning technique, to revolutionise ATLAS's ability to identify b and c-quark jets, which is pivotal to the vast majority of ATLAS's physics programme.
- Jackson Barr, Nikita Ivvan Pond and Samuel Van Stroud, were also jointly awarded the ATLAS Outstanding Achievement Award, for their outstanding contributions towards developing and deploying Graph Neural Networks in ATLAS, leading a paradigm shift in both the performance of reconstruction algorithms and the way researchers collaborate on algorithmic development.

We would like to congratulate all the above students on their achievements. These awards demonstrate the dedication, innovative nature and unique skillset of the students, which allows them to fully exploit the power of machine learning to transform our understanding of the Universe!

Student wellbeing continues to a central priority of the Centre. We have started a student-led 'CDTea' session which are held weekly, with tea/coffee and pastries as an extra incentive. This is overseen by three volunteer student coordinators, who also organise termly social activities. The CDTea sessions includes talks by students on their industry placements, discussions on ethics and invited talks from industry. These events have proved very successful, with high attendance, and have built strong links, both within and across the years. We have continued to run events to widen participation and increase engagement, including our In2Science work placement scheme to encourage secondary school pupils from underrepresented groups and from disadvantaged backgrounds to consider careers in STEM, welcoming another 15 students into the department this summer

A key part of DISI and the DIS CDT, is the strong links and interactions we foster with partners. We have now engaged with over 45 partners, including hosting 31 industry group projects and our students have undertaken over 48 6-month placements. This has brought in over £1M of additional funding and resulted in over 15 papers jointly published with industry partners. Over the last year, our students have continued to engage with industry, with a further eight placements underway and four group projects undertaken with the Guardian, MediaTek, PeakAI and UCL Oncology, which produced some very impressive outcomes. We also hosted our inaugural Data Science Careers Fair, with over 100 students in attendance and representatives from over 20 partners, highlighting the demand for skilled professionals in the data science landscape. There is a very strong desire to directly collaborate with the Centre from our partners, with two of next year's students co-funded with the CERN NextGen trigger project (funded by the Schmidt foundation) and one from the Alan Turning Institute. Our LinkedIn page, also continues to grow in popularity and acts as a great showcase for the work of the Centre and a way to link with students, industry and beyond, so please follow-us if you are on LinkedIn (https://uk.linkedin.com/company/ucl-centre-for-data-intensive-science)!

Centre for Planetary Sciences

The Centre for Planetary Sciences at UCL/Birkbeck (the 'CPS') is one of the UK's leading centres for planetary and exoplanetary science, based on a collaboration of the UCL departments of **Earth Sciences, Physics & Astronomy, and Space and Climate Physics** (the Mullard Space Science Laboratory, MSSL, in Surrey), and the **Birkbeck Earth & Planetary Sciences** group within the School of Natural Sciences.

CENTRE FOR PLANETARY SCIENCES
at UCL / Birkbeck

Our expertise includes astrobiology, lunar geology and lunar resources, planetary interiors, planetary physics and plasmas, small bodies and dust, and planetary surfaces, with researchers from the P&A department's Astrophysics group specialising in exoplanets, planetary magnetospheres, and proto-planetary and evolved planetary systems.

CPS members also play key and leading roles in planetary space missions such as the ESA Ariel (Atmospheric Remote-sensing Exoplanet Large-survey) mission led by Professor Giovanna Tinetti (P&A, Astrophysics), ExoMars Rosalind Franklin, Juice (Jupiter Icy Moons Explorer) and Comet Interceptor. The Centre has also been involved in the European Union-funded Europlanet RI project that brings together Europe's major planetary science centres.

CPS Director, Professor Nick Achilleos

The CPS is currently led by Director, Nick Achilleos, Professor of Planetary Physics in the Astrophysics Group and MAPS Vice Dean for EDI, with support from the CPS Board: Andrew Coates (MSSL), Ian Crawford (Birkbeck), Dominic Papineau (ES), Andrew Rushby (Birkbeck) and (outgoing) Ingo Waldmann (P&A Astro). Jo Fabbri (P&A Astro) is the Centre Coordinator, managing the day-to-day running of the CPS and its activities, assisted for specific tasks and outreach events by CPS Marketing and Outreach Officer, Karen-Anne Devoil.

APEX seminars

Regular CPS activities include the long-running and successful APEX - Astrobiology and Planetary Exploration - seminar series established and directed by Professor Ian Crawford for many years, and now led by Dr Andrew Rushby. The seminars take place in teaching terms 1 and 2 and have recently moved to Birkbeck on Friday lunchtimes but are also streamed online. They are advertised to our CPS colleagues, P&A undergraduates, Planetary Science MSc students and others – but everyone interested in these topics is very welcome to attend!

Outreach activities

Two years ago, we launched 'Adventures in Planetary Science', a series of free public online engagement events with talks by CPS experts and associated guests on topical planetary themes, including Q&A with the audience. This year, our AIPS event **'Asteroids and Meteorites: Unlocking the Secrets of the Solar System'**, timed to follow on from the successful launch of NASA's mission to asteroid Psyche and the Osiris-Rex mission sample return from asteroid Bennu, drew a fantastic audience of over 120 with some great discussion. Last year, our third event, **'The JUICE mission: Revealing the mysteries of Jupiter's icy moons'**, followed the successful launch of ESA's Juice mission and included a talk by Nick Achilleos, a Co-I for the Juice JMAG magnetometer team. In the new academic year, we hope to highlight what's hot in the field of exoplanet research and reveal the latest updates from the forthcoming Ariel mission, showcasing our experts from the P&A Astrophysics group and MSSL.

In March, the CPS took part for the second year, in Mars Week, a national engagement programme led by ESERO, ESA's European Space Education Resource Office, and STEM Learning UK. Our topical online debate: **Exploring the Moon and Mars: Are human missions essential or are robotics the future?'** was attended by over 100 members of the public and featured a lively Q&A session as well as some fun, interactive voting. The result was a dead heat between Team Human Exploration (presented by Birkbeck's Ian Crawford and Lucinda Offer from the RAS) and Team Robotic Exploration (presented by MSSL's Andrew Coates and Priya Patel), with both teams making excellent cases and underscoring why both forms of exploration will be important for future space exploration.

Promotional images for the CPS Mars Week 2024 Debate (left) and the Adventures in Planetary Science: Asteroids and Meteorites public outreach events this year

Also in March, the CPS took part in the department's Your Universe Festival of Astronomy and Planetary Science, with a dedicated CPS stand about the Juice mission and accompanying talks from our Outreach Officer Karen-Anne Devoil. Thanks to ESA and MSSL we had some wonderful Juice resources to share with the school pupils and public, including MSSL's hand-held scale model of the satellite! CPS MSc courses related to Planetary Science were also promoted at the stand. Jo and Karen-Anne also formed part of the YUF 2024 Organising Committee helping Francisco Diego and Mark Fuller to coordinate the main event.

The CPS Juice stand at the Your Universe Festival of Astronomy and Planetary Science 2024. Top: Karen-Anne Devoil giving a talk to school pupils about the mission to Jupiter and its icy moons. Bottom: Karen-Anne and Jo Fabbri with the Juice stand.

Group photo: CPS colleagues at the Summer Meeting 2024

Summer Science Meeting

The CPS's annual Summer Meeting is the highlight of our calendar, bringing colleagues together for a day of research sharing, networking, and socialising. This year, the event took place at UCL on 4th July (a significant day for the UK!) and featured 16 talks and 9 poster presentations, with nearly 40 attendees from all four CPS departments. It was a fantastic opportunity to connect in person and celebrate our work together.

CPS Outreach Engagement Awards 2024

At the Summer Meeting, we had the pleasure of announcing the winners of the CPS Outreach and Engagement Awards 2024, initiated last year to recognise and reward those who have given their time and expertise to planetary science outreach and engagement. The winners were awarded certificates and gift vouchers.

Connor Ballard receiving his Outreach & Engagement award from Karen-Anne Devoil at the Summer Meeting 2024.

The overall winner was Astrophysics PhD student, **Alexandra Thompson**, for founding and implementing the incredible Orbyts STAR (STudents Advancing Research) programme, which aims to create scientific projects for students with long-term health issues, in partnership with Great Ormond Street Hospital. Connor Ballard (PhD student, MSSL) was awarded Runner up for his Orbyts research work with an all-girls school in Essex, leading the group on an exciting Mars Balloon astrobiology project, in conjunction with Thales Alenia.

In addition, the panel awarded five individuals with special recognition for their outreach and engagement activities this year: Anna Parsec-Wallis (PhD student, MSSL), **Sushuang Ma** (PhD student, P&A-Astro), **Jorge Pérez González** (MSci Astrophysics, P&A), Becky Warrilow (PhD student, MSSL) and **Anna Thomas** (PhD student, P&A-Astro).

Special thanks to Mark Fuller for supporting the awards on the review panel. We hope the awards inspire others who are thinking of getting involved in planetary science outreach and engagement.

Summer Meeting Presentation Awards

Following the meeting, we had the pleasure of announcing the Summer Meeting Student Presentation Awards. UCL P&A's **Jack Davey** was overall Winner in the PhD student category with his talk 'The Effect of Spectroscopic Binning on Atmospheric Retrievals', with **Hiba Noor,** one of 4 Runners-up for her talk 'White Dwarf Pollution: One Star or Two?'. **Leyla Iskandarli**, soon to be starting an MSc in Astrophysics, won in the Undergraduate/Masters category for her talk 'Investigating Companions to the Helix Nebula Central Star', impressively based on her research project during her BSc in Physics at UCL. They each received a gift voucher and certificate.

Further details about the CPS Outreach & Engagement and Presentation Award Winners 2024 can be found on the CPS website.

Planetary Science MSc

The MSc in Planetary Science, hosted by the P&A department, is another offering of the CPS, with modules provided by the four contributing departments, including Birkbeck's Foundations of Astrobiology, Earth Science's Earth and Planetary Materials, MSSL's Planetary Atmospheres and P&A's Physics of Exoplanets. This year we congratulate 9 full-time and 4 part-time students on their graduation!

Join us!

P&A staff and postgraduate students conducting research related to planetary science are automatically members of the CPS, but if you are not on our current mailing list and would like to be involved, please do get in touch!

Website: https://www.ucl.ac.uk/planetary-sciences/

Enquiries: joanna.fabbri@ucl.ac.uk

Astro Bake-Off 2024!

The Astro Bake-Off took place on Thursday 18th April in the beautiful Haldane Room. We were presented with 9 entries, all of which were absolutely stunning, captured the theme wonderfully and were out of this world - pun intended!

The fun competition was open to all within the group, we had nine entries in total on the day, whilst the rest of the group were the official "judges". There were two prize categories: "Aesthetics" and "Taste", with 1st, 2nd and 3rd prize in each (Amazon vouchers of different values). A huge thanks to all those who entered the competition - each bake was unique, amazing to look at and delectable in taste!

Winners

"Aesthetics":

1st prize - Alex Thompson - The TRAPPIST-Yum System

2nd prize - Jack Davey - Mocha Cake

3rd prize - Kay Nakum - Beyond The Moon

"Taste":

1st prize - Kay Nakum - Beyond The Moon

2nd prize - Lorne Whiteway - Cosmological Banana Bread and Sam Wright - Total Eclipse of the Cookie (received the same number of votes)

3rd prize - Kate Pattle - Galactic Dynamics 2 Edition and James Ray - A Slice of Hertzsprung-Russell (received the same number of votes)

Alex Thompson - The TRAPPIST-Yum System

Kay Nakum - Beyond the Moon

Nick Achilleos - Auroral Oval Cheesecake

Sam Wright - Total Eclipse of the Cookie

James ray - A Slice of Hertzsprung-Russell

Lorne Whiteway - Cosmological Banana Bread

Laura Aguilar - Eagle Nebula

Kate Pattle - Galactic Dynamics 2 Edition

Jack Davey - Mocha Cake

A few words from some of the bakers and judges:

"With the first announcement of the Astro bake-off, I was excited but hesitant to enter. It's been quite a while since I last made a cake and I didn't want to embarrass myself by putting out a poor display. However, as soon as I had committed to entering and I had begun the process of trying to decide what to make, it was nothing but an enjoyable experience. On the tasting morning, the event brought us all together and we had a great turn out! Some weeks in the office, it can be rare for us all to be in the same place at the same time so that was the best part about the whole experience. It was a great opportunity to catch up and enjoy a relaxing morning. I was really pleased to be voted as one of the winners. It was quite unexpected but I'm hoping it will give me the confidence to return to baking in the future!"

PhD student, Jack Davey (baker)

"Approaching my final year now, I've always appreciated how often we as a department have activities and events that are designed to get everyone together for something fun and light-hearted so as soon as I saw the bake-off announced I knew that I wanted to participate in some shape or form. Personally, I am not a great baker or a particularly good cook of any kind but I do have an artistic streak so I decided early on that my 'strategy' as it were, should be to focus on the aesthetics side of things while also entering something that was at least edible/wouldn't poison my colleagues. I also do a lot of outreach and thought that the Astro theme could be used to make something colourful and engaging with 'real' physics at the core that could maybe be re-used as part of future outreach materials (providing that it didn't turn out absolutely terrible). My PhD research focuses on the stellar activity of exoplanet host stars and almost immediately I realised I wanted to do something related to the TRAPPIST-1 system (a highly active red dwarf star with 7 transiting super-Earths). I put a lot of effort into thinking how the stars surface activity could be represented in a tasty and aesthetically-pleasing way. Red and yellow '100s and 1000s' sprinkles made for great all over surface granulation and faculae with big dark chocolate buttons surrounded by sugar strands representing the large starspot features that we assume TRAPPIST-1 may have (separated into umbra and penumbra of course). As the star is a red M-dwarf it was only fitting that it should be made out of red velvet cake. The orbiting planets were represented by smaller cupcakes (I used two different sizes to reflect the actual radii of the planets) and I used lots of different coloured sprinkles to reflect their probable chemical diversity and also just because it looked better! The event itself was amazing with so many excellent entries, although probably detrimental to the productivity of the department for the rest of the day as so many of us ended up in a sugar-related stupor before even getting to properly taste all of the bakes. I was really happy and also surprised to win 1st place for aesthetics as, even though I put a lot of thought into my entry, it was so clear that everyone else had too and was obviously a really tough competition! I hope that we do something similar again soon (although not too soon as I still don't think I'm emotionally ready to face eating that amount of cake again in the near future)."

PhD student, Alex Thompson (baker)

"The Astro Bake Off was a great opportunity to get together as a group and enjoy some creative and tasty baked goods. There were a wide range of flavours, styles and astro themes to try and plenty of coffee to enjoy along with the entries!"

PhD student, Sam Wright (baker)

"The Bake off event was quite the surprise. I not only found that more people than I expected participated, but also the extra effort of making the cakes so astro-topical!

My favourite art-category one (the one resembling the Galactic Dynamics by Binney - text book cover), was so alike that I immediately recognized it without reading the tag. Superb works of art from all the Astro group participants... and very tasty!"

Prof. Giorgio Savini (judge)

"I very much enjoyed the Astro Bake-Off – it was a great chance to catch up with members of the Astro Group, to learn new skills, and to see the creativity of the group. As a novice baker, I was both delighted and very surprised to win third place for the taste of my cake – I suspect that the sheer amount of chocolate used may have played a key role in my success! I went for the easy option of baking a rectangular cake, and so turning it into an astrophysics textbook that I hoped would be recognisable even when recreated with icing pens: Galactic Dynamics (2nd Edition) by Binney and Tremaine. The Bake-Off was a wonderful event, bringing the group together, and supplying us all with cake for days!"

Dr Kate Pattle (baker)

"The Astro bake-off was a fantastic initiative to get people together to enjoy some delicious treats baked by members of our group, with the unique twist that the entries needed a connection to Astrophysics. It was wonderful to see the thought and creativity that accompanied the entries – ranging from TRAPPIST-1 cupcakes to the dark (chocolate) side of the Moon – and even nicer to sample them! Thank you to all in our Group who brought something in, and I hope this can become an Astro group tradition in the future."

PhD student, Akshay Roberts (judge)

Immense thanks to all those that took the time to partake, and many congratulations to the all the winners.
Photos: credit and thanks to our in-house photographers Jo Fabbri and Mark Cunningham.
Event organised by Kay Nakum, Astrophysics Group Manager

#Tell Me Challenge

To brighten up our corridors, we asked members of our group to send in an entry or two of static photos/images/ cartoons/comic strip on our shared passion of Astronomy and Astrophysics in a way similar to the #TellMeChallenge, in which social media users ask others to share personal opinions and beliefs without outright saying what they are talking about. We wished for it to be quirky, fun, colourful and imaginative. It certainly was nothing less! The final eye-catching product can be seen below

PhD student Laura Aguilar: The Eagle Nebula, also known as the Pillars of Creation and M16 star forming region, became a very popular region in our skies since 2009 when Hubble Space Telescope took a beautiful picture of it. This Nebula also means so much to me on a personal level. My surname comes from the root word “Eagle”, that I got from my late father who inspired me in being curious about the Universe, also telling me about this Nebula since I was born. When I got my first Astrophysics research internship at the CFHT Telescope in Mauna Kea, Hawaii, back in 2016, supervised by Dr. Nicolas Flagey, I discovered I was going to assess the new Fourier Transform SITELLE camera, investigating this specific Nebula. Out of all the other nebulae known to mankind I confess I liked the coincidence, and poured my heart into this project, leading to my first co-authorship as an undergraduate student in a work published in the A&A journal a couple of years later. I was given many tasks during this internship, including creating my own analysis method, obtaining 2D velocity and density maps to analyse the emission lines of M16, comparing the performance of the camera with other telescope cameras, investigating a large Herbig-Haro flow bow shock region, etc. The image I shared here shows the 11′ × 11′ field of view covered by SITELLE with a commonly used color code: red is the [SII]λ6717 emission line, green is Hα, and blue is the [O III]λ5007 line. The iconic Pillars of Creation are at the center of the image, with the exciting star cluster NGC 6611 towards the top right corner.

PhD student Bryn Parry: The image of the Wolf-Rayet 140 binary star system captivates with its unexpected beauty and complexity. The intricate dust shells formed by the interaction of the binary star system are a testament to the dynamic and unpredictable nature of our universe, showcasing the awe-inspiring phenomena that continue to surprise and inspire astrophysicists.

PS staff Dr Joanna Fabbri: The images I submitted were taken while I was on my first observing trip during my PhD, using the James Clerk Maxwell Telescope (JCMT) on Mauna Kea in Hawai’i. The opportunity to use a telescope on the ‘Big Island’ was literally the pinnacle experience of my choice to study Astrophysics as an undergraduate and then continue with the PhD at UCL. It was also my first far-flung solo travel venture and my first attempt at astro-photography. I purchased a second-hand film SLR camera on the advice of experienced photographer and friend/colleague, Roger Wesson, and set up my first star trail shots not knowing what to expect, nor seeing the results until I got back to London to develop the photos a month later! Thankfully, I managed to take some decent ones and my favourites are included here. One is centred on Polaris, the North Star, showing the concentric star trails with a lovely pale green hue to the longer-exposed night sky and a slightly blurry Suburu telescope (due to motion of the dome during the exposure). Another much shorter exposure, shows a deeper blue sky with the Suburu telescope in the foreground and what looks like a red laser beam being emitted from the Gemini North telescope. I couldn’t see the beam when I set up the shot, but I recall it was one of the first nights that the new adaptive optics laser guide star was being tested and I managed to pick it up in the photo by mistake, which was a wonderful bonus! The final image was the beautiful shadow of Mauna Kea on the clouds taken from the summit at over 4,000m. It was such a magical moment to capture. I have huge nostalgia and wonderful memories of the whole trip. It was such a formative experience. Thanks to PPARC and Mike Barlow for making it possible!

Prof. Jay Farihi: As a grad student at UCLA, I quickly realized there is no substitute for taking your own data at an observatory, and therefore see the collage as myself celebrating these priceless opportunities I’ve had. At the summit, observers can adapt in real time to the conditions, change their instrument settings, abandon one set of targets for another, or even decide on the spur of the moment to trying something new -- indeed, serendipity has played an enormous role in astrophysics throughout its history. It is also a great privilege to stand on these mountains, many of which have deeply rooted cultural significance to the native peoples of the land. And when you are there, this reverence is easy to understand, because it is impossible to ignore the profound natural beauty... and, when the stars emerge, so does our sense of wonder.

Observatory News

The UCL Observatory: where teaching meets research

Students taking modules in astrophysics and related degrees receive training at UCL Observatory (UCLO) throughout their degree programme in techniques of observation. Student access to hands-on and robotic telescope facilities provides them with opportunities to acquire a wide range of data for training and student projects. As well as robotic facilities on site at UCLO, students are also able to benefit from our collaboration with the Telescope Live facility, giving remote access to a 60-cm telescope under southern-hemispheres skies in Chile. A wide range of student data has been acquired over the last year, from direct imaging at UCLO of Milky Way galactic environments and external galaxies, through transient-monitoring and time-series photometry of variable sources, to deep-sky imaging of extragalactic clusters. A sample of student work is shown below, to highlight the range of observational and group-project work undertaken.

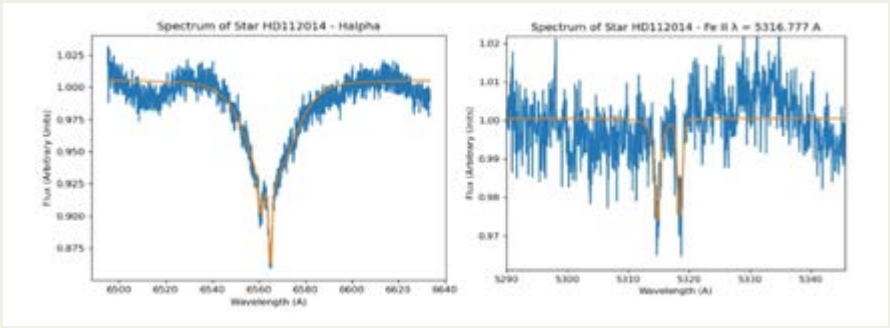
Dr. Steve Fossey, UCLO Director

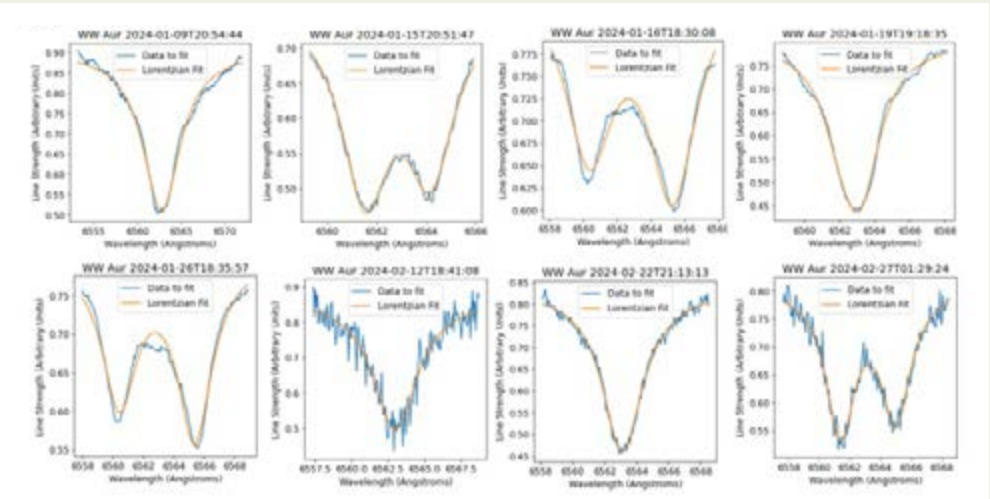
High-resolution spectroscopy for radial-velocity studies of binary stars

The FLECHAS echelle spectrograph on the 0.8-m Perren Telescope was used in Year-3 group project work to measure the radial velocities of selected spectroscopic binary stars. Spectroscopic radial-velocity observations of binary stars are an important step towards determining stellar masses, and hence for checking stellar-evolution theory, especially in well-separated systems where the stellar siblings have evolved as single stars. A number of bright, short-period spectroscopic binary stars were observed by two group-project teams during the spring term to obtain spectra for detailed measurement and analysis of the radial velocities of the binary components.

Right: Spectra of the double-lined system HD112014; as shown here, pairs of spectral-line components are able to be separated in binary systems where the companion stellar masses are similar, seen here in the H-alpha line at 6563 Angstroms, and the Fe II line at 5317 Angstroms, whose line profiles can be modelled to obtain accurate radial velocities.

Students: X. Chang, D. Papp, S. Shrivastava, H. Taylor (Supervisor: Stephen Boyle)



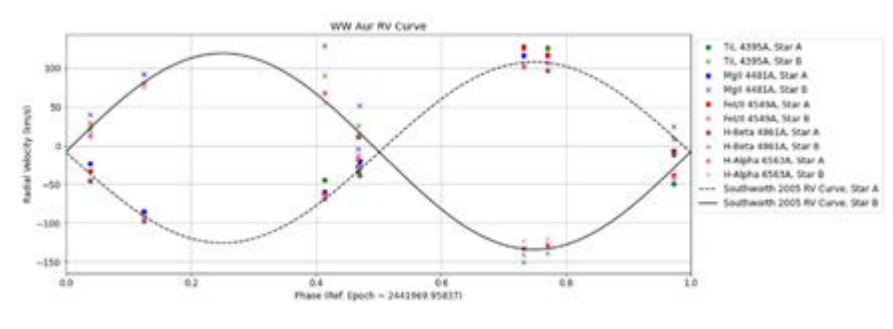


Left: Spectra of the short-period eclipsing-binary system WW Aurigae (period 2.52 days) obtained on multiple dates from 9th January to 27th February. This series shows how the 6563-A H-alpha line components are observed to oscillate in position, reflecting the orbital motion of the stellar pair.

Students: J. Burton-McFaul, G. Craig, R. Howie, E. Parmar (Supervisor: Dr. Steve Fossey)

Data acquisition and spectral calibration were supported by UCLO technical staff Shana Sullivan and Thomas Schlichter.

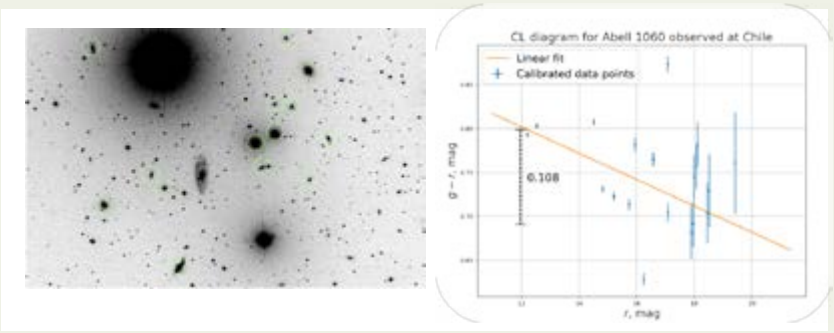
Below: When folded onto a common orbital phase, the measured velocities (from many different spectral lines,as colour coded) are shown to be consistent with predictions from a published model. In the best-observed spectra, a precision in radial velocity of a few km per second is achieved; it is hoped that with careful control of the spectrograph environment, this precision can now be improved further to enable accurate stellar masses to be determined in such systems.



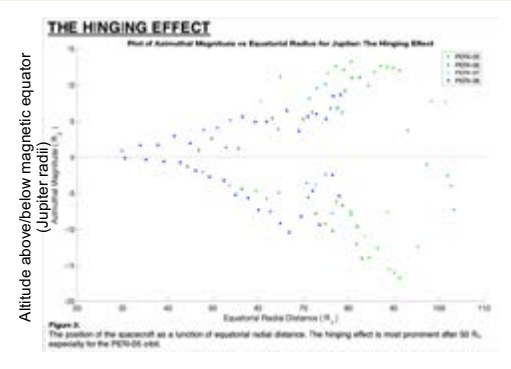
Students: J. Burton-McFaul, G. Craig, R. Howie, E. Parmar (Supervisor: Dr. Steve Fossey)

The colour-luminosity relation of elliptical galaxies

Luminous elliptical galaxies are redder than their feeble counterparts but is this due to their constituent stars being older or more enriched by heavy elements? The student team took deep multi-colour images of rich galaxy clusters such as Abell 1060 (below left: an 1800-second exposure with Telescope Live Chile 60-cm) and analysed the resulting colour-luminosity relation (below right). Using stellar models, the range of colours observed (as indicated on the plot below) is more consistent with variations due to chemical composition than age. This follows if the stronger gravitational field of luminous galaxies retains the enriched material ejected when their stars explode and die.



Students: K. Batrakov, L. Findlay, O. Shirazee, U. Talat (Supervisor: Prof. Richard Ellis)



Students: I. Canell, R. Dias, K. Binti Hadi, Z. Knight (Supervisor: Professor Nick Achilleos)

Investigating the current sheet of Jupiter using Juno magnetometer data

Students' analysis of magnetometer data from the Juno spacecraft orbiting Jupiter was able to show an important result known as the 'hinging' effect, as seen on the right: the spatial positions at which the Juno spacecraft encountered Jupiter's plasma-sheet (the coloured symbols) occur as two 'branches'. In both branches the plasma-sheet lies closer to the magnetic equator (horizontal line at zero) when Juno is closer to the planet. The further Juno travels from the planet, the more these two 'branches' hinge away from the magnetic equator – thus for one branch the plasma-sheet curves upward above the magnetic equator, while for the other the sheet curves downward. This confirms that body forces on the plasma – particularly centrifugal force in this huge, rapidly rotating system – become large enough to overcome the 'tension' in the magnetic field and bend the plasma-sheet.

Astronomical imaging with the UCLO robotic telescopes

Many students' first 'close encounter' with the astronomical sky is using the suite of telescopes at UCLO, including with our robotic telescopes to obtain a rich variety of images on astrophysically interesting targets of their own choosing – some examples above highlight areas of star formation in the Milky Way and beyond, picked out by narrow-band imaging filters which select emission from excited gas. From L-R: The Bubble Nebula (by Alula-Elias Mulugheta), a wind-blown bubble of hot gas around a young, hot O-type star; the Monkey Head Nebula, NGC 2174 (Leo Saiu-Bell), where stellar winds and radiation from young, massive stars sculpt their natal environment of gas and dust; and the barred spiral galaxy NGC 2903 (Charlotte Crick), with luminous knots of bright H-II regions marking the sites of massive-star formation in its spiral arms.

Centre for Space Exochemistry Data (CSED)

2023/24 has been a busy and exciting year for the Centre!

The centre has seen its first successful Hackathon event (Fig. 2), a signing of the contract at National Satellite Test Facility (NSTF) for the testing of the Ariel payload (Fig. 1), sponsorship from Google and Kaggle for the Ariel Data Challenge 2024 (Fig. 3), industrial successes and numerous awards and promotions for the team!

"The centre underwent an office move in early July 2024 from the Atlas Building to Satellite Catapult Applications in the Harwell Campus", said Emma Dunford, CSED manager. "This was a strategic move as we can continue to strengthen our collaborations with Satellite Catapult Applications and be closer to the National Satellite Test Facility where the Ariel payload will start to be tested next year".

The European Space Agency's (ESA) Ariel will be one of the first astronomy missions to use the UK's new National Satellite Test Facility (NSTF), operated by STFC RAL Space. An opening ceremony for the NSTF was held on 21st May 2024, where the UK Space Agency (UKSA) signed a contract to use the NSTF for testing the Ariel payload. Ariel will go through vibration and acoustic testing in the NSTF to ensure it will survive the violent conditions of launch, as well as thermal vacuum testing in RAL Space's smaller scale facilities.

Paul Eccleston, CSED board member and Ariel Mission Consortium Manager at RAL Space, said: "We're delighted to have formalised the agreement for Ariel to use the NSTF dynamics facilities for the payload module's vibration and acoustic testing. Using these fabulous new facilities alongside the other RAL Space cleanrooms and thermal vacuum chambers will allow us to seamlessly integrate, test and calibrate the complex payload for Ariel."

In April 2024, the Centre hosted its inaugural CSED Pilot Hackathon at Satellite Applications Catapult, which was a resounding success. The event brought together 32 participants from diverse backgrounds, including students from prestigious universities such as UCL, Warwick, Oxford, and Cambridge, as well as industry professionals from organizations like ESA, Deimos Space, and RAL Space. Hosting the event at Harwell proved effective in fostering collaboration and bringing together a wide range of expertise. Below are some pictures capturing the highlights of the day (Fig. 2).

Figure 1 – Right to left: Giovanna Tinetti (Ariel Principal investigator, UCL CSED director), Rachel Drummond (Ariel project manager), Sarah Beardsley (Director, RAL Space), and Charly Knight (Principal Test Engineer, RAL Space) stand outside the new National Satellite Test Facility. The Ariel NSTF contract signing represents a major step forward for the Ariel exoplanet mission as the first hardware begins to take shape this year, ahead of launch in 2029. Credit: STFC RAL Space.

AI-generated picture of inaugural CSED Pilot Hackathon at Satellite Applications Catapult

"The data for the hackathon was sourced from the 2021 Ariel Data Challenge, where participants were tasked with extracting planetary spectra from simulated spectroscopic light curves", explained Arun Nambiyath Govindan, who was part of UCL-CSED Hackathon team. "They particularly valued the opportunity to collaborate and deepen their understanding of machine learning and the Ariel Space Mission. Looking ahead, we are excited to announce a major hackathon event in 2025". Feedback highlighted the participants' appreciation for the competition's organization and the support provided by the team: 80% of attendees gained new insights into exoplanet science and machine learning and 93% expressed a keen interest in attending future CSED Hackathons.

Figure 2 – Left: CSED Pilot Hackathon day in Harwell. Right: Winners of the CSED Pilot Hackathon while receiving their award from Ryan King (UKSA) and Giovanna Tinetti (UCL-CSED Director). More photos here. Photo credit: Bex Coates.

Ariel Data Challenge 2024 has launched and it is worth $50,000 USD!

Astrophysics space missions are now producing huge amount of data and AI is becoming essential to process all the information and take giant steps in understanding our universe. The Ariel Data Challenge 2024 is calling all data scientists, astronomers, and AI enthusiasts to help tackle one of astronomy's most complex and important data analysis problems – extracting faint exoplanetary signals from noisy space telescope observations.

The NeurIPS 2024, a world-renowned machine learning conference, will feature an exciting competition based on the Ariel Space Mission. This contest offers participants a unique chance to contribute to cutting-edge research in the field of exoplanet atmospheres. With a substantial prize pool of $50,000 USD at stake, the competition aims to attract top talent and innovative solutions. The final submission deadline is October 31st.

Figure 3 – Ariel Data Challenge 2024 logo, credit Bex Coates.

Kai Hou (Gordon) Yip, Ariel Data Challenge Lead, UCL-CSED said: "This groundbreaking challenge has been made possible through a collaborative effort led by UCL-CSED, bringing together an impressive international team of academic partners including Centre National D'études Spatiales (CNES), Cardiff University, Sapienza Università di Roma, and Institut Astrophysique de Paris. The competition is sponsored by the Kaggle Competitions Research Program. It also benefits from the support of a consortium of leading space agencies and institutions, including the UKSA, ESA, STFC RAL Space, and STFC DiRAC HPC Facility".

Industrial successes – Two start-ups (Blue Skies Space Ltd, SpaceFlux) have been created for the commercial exploitation of some of the activities supported by the Centre. These can no longer described as start-ups.

Spaceflux Ltd, founded by Ingo Waldmann (CSED deputy director) and Marco Rocchetto in 2018, is today the lead provider of optical space situational awareness and space domain awareness (SSA/SDA) data to UKSA and the UK Ministry of Defence (MoD). It furthermore builds and maintains SSA monitoring infrastructure for the UK MoD at its Cyprus base.

Blue Skies Space Ltd, founded by Marcell Tessenyi, Giovanna Tinetti and Jonathan Tennyson (chair of CSED board), explores innovative approaches to the delivery of space science data from small satellites. BSSL has announced the scheduled launch of its *Mauve* science satellite for October 2025. The satellite will be launched on SpaceX's Falcon 9 rocket as part of the Transporter-15 rideshare programme and is being built by a consortium of European companies. A new branch was opened in Italy, Blue Skies Space Italia Srl. BSSL investors include Japan's SPARX Group Co. Ltd. - Space Frontier Fund, following investment from Toyota Motor Corporation, Mitsubishi UFJ Bank, Sumitomo Mitsui Banking Corporation, and UK SFC Capital.

Congratulations to UCL-CSED board members Ingo Waldmann, on being promoted to Professor, and Ahmed Al-Refaie, on being promoted to Principal Research Fellow!

ACADEMIC SHOWCASE

A Sample of Staff Accolades

Department Teaching Prize

This year's Departmental Teaching Prize is awarded to **Professor David Bowler**. Dave arrived in the Department of Physics and Astronomy as a postdoc in October 1998. In the intervening quarter century, he has consistently contributed to the department's education profile, at all levels and across many modules. He has introduced many innovations, as well as supported the department via enabling roles and mentoring new staff, all while simultaneously demonstrating considerable success in computation condensed matter physics research.

Dave was instrumental in the creation of our third year undergraduate Electromagnetic Theory module in 2005, when our delivery of electricity and magnetism moved from years 1/2 to years 2/3. He taught this module for a number of years, returning full-circle to delivering this module this year. He also taught waves for many years as part of our first year programme, innovating with lecture demonstrations involving organ pipes and coupled pendulums. When Dave taught our third year Quantum Mechanics module, he was among the first in the department to create videos to support key areas of the syllabus - these remain on YouTube, with some accumulating more than 5000 views. Dave has also innovated by being an early adopter of Jupyter Notebooks, thus taking Python coding beyond our computational laboratories to support lecture modules, providing additional insights into physics beyond that afforded by traditional pen-and-paper approaches. More recently, Dave has created a core Computational Physics module for our theoretical physics students, introducing them to techniques that open up whole new areas of physics to mathematically-minded undergraduate students.

Dave's contributions extend far beyond the lecture theatre and computer lab however - he has recently taken over leadership of our academic strands system, co-ordinating subcommittees of all our module leads to ensure that our taught material is coherent and topical across all our taught programmes.

The breadth of Dave's success and contribution, across all dimensions of teaching and learning in the department, make him a most worthy winner of this year's departmental Teaching Prize.

Technician of the Year Award

The Physics and Astronomy Departmental Technician of the Year Award has been awarded to **Thomas Schlichter**.

Thomas Schlichter has played an outstanding role in supporting research, teaching, and learning activities at UCL Observatory (UCLO).

The development of robotic telescope facilities at UCLO has hugely expanded the capabilities of our students to acquire original data for their investigations, and supported many Masters-level research projects. This has been realised through Thomas's innovation in establishing robust systems for robotic-telescope operations and equipment safety, including the design and build of novel hardware electronics (e.g., automated dome closure in bad weather) and software development (e.g., for camera control, and automated data archiving).

Thomas's expert contribution has culminated in the last few years with the acquisition and installation of the Perren 80-cm telescope, concluding a major facility development at UCLO, and now equipped with a high-speed imaging camera and a high-resolution spectrograph. Thomas has played a critical role in leading several aspects of this installation, and working in collaboration with all UCLO staff in specifying engineering requirements and resolving many technical issues. Thomas has been dedicated (and indispensable) in leading commissioning runs on the Perren, observing with and configuring the new high-speed camera and echelle spectrograph, to bring the facility into readiness for student use.

We have come to appreciate Thomas's work even more as he has supported cutting-edge research on detectors, and his expertise has been comparable in certain respects to that of a competent PDRA.

Thomas's work underpins all student activity at UCLO, and can also be recognized in his direct contribution to teaching and supporting students in the operation of the telescopes, and especially the Perren – where he has shown huge dedication to his post and to our students, often staying well after hours to help with student observations. Thomas's contribution therefore goes way beyond his technical role, through his enthusiastic engagement in training and guiding small groups of undergraduates, and helping to inspire our students through their access to and operation of UCLO's advanced telescope facilities.

Professional Services Staff Prize

This year our Professional Services Staff Prize is celebrating **Rebecca Martin**.

Rebecca has been in post as Senior Research Officer since 2021, and in only two years has become an exemplar of professional excellence within the department. Rebecca received multiple nominations which demonstrates the esteem that Rebecca is held in by the P and A community.

Overseeing all aspects of research administration within P&A, she advises on the costing and submission of grant applications, and handles department processes for the STFC and Royal Society Fellowships. Rebecca supports our academics in managing over £50 million worth of grant funds. She also provides expert assistance on complex European grants, with a combined worth of over £10 million.

A busy role, the grants team has supported over 100 grant applications in the last year, and, ably assisted by Josh Grimond, our Research Administrator, the feedback across the department is of a helpful, friendly and knowledgeable service.

Research Degrees

January 2023 – December 2023

Heloise F. Chomet
Phase-space analysis of quantum effects in strong field ionisation
(Prof C. Figueira De Morisson Faria)

Yaqi Lee
Strain and electrostatic engineering in ferroelectric-dielectric superlattices
(Prof P. Zubko)

Augustin L. L. Marignier
From Dark Matter to the Earth's Deep Interior: There and Back Again
(Prof S. Viti)

Mario Morvan
Deep Learning, Shallow Dips: Transit Light Curves have never been so Trendy
(Prof S. Viti)

Simeon Bash
The CHIPS Prototype Water Cherenkov Detector
(Prof J. Thomas)

Alexander J. Broad
Tuning the growth and mechanical properties of calcite using impurities: insight from molecular simulation
(Prof D. Duffy)

Michael B. Davies
Solving mysteries of ice formation with simulation and data-driven methods
(Prof A. Michaelides/ Prof J. Blumberger)

Benjamin Stölzner
Redshift distributions of extragalactic galaxy surveys
(Prof A. Korn)

Krishna M. Jadeja
Development and testing of a facility for the trapping and cooling of isomers
(Prof F. Renzoni)

Ava C. A. Lee
Flavour tagging and measurements of WH and ZH production in the H-»bb decay channel with the ATLAS detector
(Prof G. Hesketh)

Stephen H. Mann
Investigation of rare-earth pyrochlore thin films
(Prof S. Bramwell)

Kevin Mulder
Adversarial training to improve robustness of deep neutrino classifiers in the NOvA experiment
(Prof R. Nichol)

Bin Yi
Quantum Entanglement and Quantum Causal Analysis
(Prof S. Bose)

Tarek A. Allam
Efficient Deep Learning for Real-time Classification of Astronomical Transients
(Prof J. McEwen)

Jamie W. McGowen
Approximate N3LO Parton Distribution Functions: In the pursuit of theoretical uncertainties
(Prof R. Thorne)

Catarina Sampaio Alves
Enabling supernova cosmology with large time-domain surveys
(Prof J. McEwen)

Mikolaj D. Uryszek
Criticality of Nodal Point Semimetals
(Dr F. Kruger)

Eric A. S Lundgren
Toward atomic-scale doping of bismuth in silicon: the study of bismuth precursor molecules on silicon (100)
(Dr R. Perry)

Donovan M. Newson
Formation and scattering of positronium from atoms and molecules
(Prof G. Laricchia)

William S. Quinn
The sensitivity of the NEMO technique to neutrinoless double beta decay and the commissioning of the SuperNEMO demonstrator module
(Prof D. Waters)

Lauren E. C. Dawson
Commissioning and Sensitivity Studies for the SuperNEMO Demonstrator Module
(Prof R. Saakyan)

Thomas M. Mellor
Method Development in Rovibrational Caculations of Polyatomic Molecules
(Prof S. Yurchenko)

Andrew Patterson
Algorithms for Near-Term and Noisy Quantum Computers
(Prof D. Browne)

Alexander L. Sopio
A Study of the Substructure of Jets Initiated by Top Quarks and W Boson
(Prof G. Hesketh)

Aidan S. Kelly
Measurement of Detector-Corrected Cross-Sections in Events with Large Missing Transverse Momentum in Association with Jets
(Prof E. Nurse)

Jeremy V. Ocampo
Designing Convolutional Neural Networks for Scintillation Photography and General Applications
(Prof S. Viti)

Samuel J. Van Stroud
Graph Neural Network Flavour Tagging and Boosted Higgs Measurements at the LHC
(Prof S. Viti)

Ioannis Ierides
New materials and architectures for organic photovoltaic diodes
(Prof F. Cacialli)

Sophia M. Patomaki
Qubit couplers for silicon spin qubit architectures
(Dr J. Morton)

Lewis J. Whitehouse
The origin of dwarf carbon stars
(Prof J. Farihi)

Johannes N. F. Heyl
A statistical and machine learning approach to the study of astrochemistry
(Prof S. Viti)

Cathal E. Sweeney
Measurement of the muon neutrino charged-current single charged pion production cross-section in the NOvA Near Detector
(Prof G. Hesketh)

Mohammed H. Hussain
Studying the effects of alternative magnetic field configurations on the sensitivity of the SuperNEMO demonstrator to the 0νββ decay of ^{82}Se
(Prof G. Hesketh)

Eva Kilian
Exploring Quantum Superpositions of Macroscopic Systems as Detectors for Particles
(Prof S. Bose)

Alexander A. Nico-Katz
Informational Aspects of Quantum Many-Body Systems
(Prof S. Bose)

Saad Shaikh
A Quality Assurance Range Calorimeter for Proton Beam Therapy
(Prof S. Jolly)

Dominika Vasilkova
Searching for a muon electric dipole moment with the straw trackers at the Fermilab muon g-2 experiment
(Dr R. Chislett)

Pedro J. Buigues Jorro
Developments on Enhanced Sampling and Machine Learning Analysis Techniques for Understanding Biomolecular Events
(Prof E. Rosta)

Camilia Di Mino
Weak Inter-molecular Interactions in Bulk Liquid and at Liquid/Nanomaterial Interfaces
(Prof N. Skipper)

John A. Hallford
Magnetic Spectroscopy with Scintillation Detectors at the LUXE Experiment
(Prof M. Wing)

Matthew B. Peters
Correlated three-electron ionization in strongly-driven atoms and molecules
(Prof A. Emmanouilidou)

Matthew H. Rayment
Experiments with electrostatically trapped NO and N2 molecules in high Rydberg states
(Prof S. Hogan)

Thithawat Trakoolwilaiwan
Development of Thermochromic Lateral Flow Assay for Sensitive Detection
(Prof T. Nguyen)

James M. Dborin
Implementing Tensor Network Algorithms on Quantum Computers
(Prof A. Green)

Jared A. Jeyaretnam
Ergodicity breaking and stabilisation of quantum order
(Prof A. Pal)

Constantina Nicolaou
Machine Learning for Multi-messenger Astronomy
(Prof S. Viti)

Nikolay Walters
A multi-wavelength observational study of white dwarfs with anomalous atmospheric signatures
(Prof J. Farihi)

Staff News

Promotions 2023-24

We are very pleased to announce the latest round of senior promotions; congratulations to the staff listed below on their well deserved achievements:

Dr Jonathan Breeze, Associate Professor
Dr Gabriel Facini, Associate Professor
Dr Mihkel Kama, Associate Professor
Dr Maxim Molodtsov, Associate Professor
Dr Jason Sanders, Associate Professor
Dr. Ahmed Al-Refaie, to Principle Research Fellow

Portrait of...

Andrew Pontzen

What is your role and what does it involve?

I've just finished being a Professor of Cosmology at UCL and am moving to Durham. During my time at UCL, I was lucky enough to be co-founder and co-director of the department's Cosmoparticle Initiative, which built bridges between cosmologists, high energy physicists, quantum physicists and space scientists – we often speak surprisingly different languages!

Most of my time was and will continue to be spent overseeing students and postdocs on various research projects: understanding the way that galaxies form and evolve, understanding what dark matter is, and using laboratory experiments to better understand quantum aspects of the early universe. I taught postgraduate-level cosmology, though am now moving onto first year undergraduate electromagnetism in Durham: quite a contrast, but a welcome challenge. And, finally, I enjoy engaging with the public, in person and through the media, and sit on the Royal Society's Public Engagement Committee.

How long were you at UCL and what was your previous role?

I arrived at UCL in 2013, so was astonished to find that I've been here for 11 years. Before that I held junior research fellowships in at the universities of Oxford and Cambridge.

What working achievement or initiative are you most proud of?

The Cosmoparticle Initiative that I built with Hiranya Peiris starting in 2016. As I said before, it's all about building links between academics, postdocs and students in different disciplines, and it's now been acknowledged in 145 publications and contributed to securing a diverse range of grants totalling £16M. But these numbers don't convey what I am most proud of, which is an environment emphasising the essentially collaborative and joyous nature of research. We've organised a number of academic workshops. Then, a few years ago, we travelled to a remote part of the Grizedale Forest to try innovative outreach ideas in a setting where nobody would expect to encounter physicists. And we set up various support systems for students, like peer learning – regular sessions where everyone gets together and talks about important but often-overlooked skills, ranging from data processing through to time management and building supportive professional networks.

Tell us about a project you are working on now which is top of your to-do list

As well as writing a new first-year course for undergraduates, I'm starting work on a successor to my non-specialist book, *The Universe in a Box*, which was published to really positive press reviews last year. That is a book all about cooperation - how everything from quantum particles to black holes work together to produce the incredible, complex, evolving universe. But it's also about cooperation between people, and how 21st century technology is changing humanity's conception of our origins, of science and of reality itself. And of course, it features a lot of the work we did at UCL over the last few years.

What is your favourite album, film and novel?

I'm not sure I really have favourites like that, so I just have to pick some examples. My parents were both professional musicians and I acquired some pretty eclectic tastes. In recent years one of

the real stand-out British recording artists has been Jacob Collier, who seems to have a command of every aspect of music theory, and uses it to weave genre-defying original and cover tracks; try *Djesse Volume 1*. I don't get to see much film these days, with a young family, but on the TV I was recently bowled over by *A Small Light*. My grandparents were Jewish immigrants to the UK in the second world war, and I'm only now beginning to get to grips with what they went through. Novel-wise, recently I enjoyed *Tomorrow, and Tomorrow, and Tomorrow* by Gabrielle Zevin.

What is your favourite joke (pre-watershed)?

Did you hear about the magic tractor? It went down the road and turned into a field.

Who would be your dream dinner guests?

If I am allowed to bring people back from the dead, I think I'd invite Beatrice Tinsley. She kick-started the entire field of computational galaxy formation during her PhD in the late 1960s, but struggled for recognition from her own institution, even as she became internationally renowned. She died tragically young in 1981, and so today many researchers haven't even heard of her. Senior academics in the field still remember her, of course – and they have puzzlingly differing accounts of what she was like. As I was researching my book, I became absolutely absorbed in her story; she is a truly fascinating figure who I'd like to meet for myself.

What advice would you give your younger self?

Be patient with life. Listen carefully to criticism.

What would it surprise people to know about you?

When I was an undergraduate, I was part of an improvised comedy troupe. We went to the Edinburgh Festival Fringe with a show called *Out Of Your Mind*, where we pretended to psychoanalyse the audience. In many ways it was the epitome of a cliched student show, but to our astonishment we ended up being reviewed by *The Guardian*. After a preamble about enjoying the overwhelming volume of rubbishy student shows at the Fringe, the reviewer said we were "actually, properly, non-ironically great". It was very heartening, although in truth he probably caught us on a lucky night.

What is your favourite place?

Any ruined castle, preferably overlooking the sea, on a warm summer's evening with swallows darting.

RESEARCH SPOTLIGHT

Condensed Matter And Material Physics (CMMP)

The Condensed Matter & Materials Physics Group (CMMP) has 24 permanent academic staff who cover a very wide range of research in condensed matter and materials physics using experimental, theoretical and computational approaches. Research in CMMP can be broadly divided in Scattering and Microscopy, Energy and Electronic Materials, Magnetic and Ferroic Materials, Quantum Materials, Statistical Mechanics and Soft Matter and Theory and Modelling of Materials. Techniques developed and applied include neutron and X-ray scattering, atomic-scale fabrication, scanning tunnelling microscopy, thermodynamic measurements, theory and computational modelling. The CMMP maintains strong connections with the UK central facilities at Harwell, with the Thomas Young Centre for the Theory and Simulation of Materials and Molecules and with the London Centre for Nanotechnology (LCN).

After a distinguished career in experimental condensed matter physics our valued colleague Prof Des McMorrow retired at the end of last year. Des has held the Chair for experimental Physics in the LCN and has received prestigious awards including the Royal Society Wolfson Merit Award and a EPSRC established career fellowship. His best-selling book ``Elements of Modern X-Ray Physics" has been described as ``a defining moment in the field of synchrotron radiation". Des has been (acting) Director of the LCN (2014-15) and Vice Dean of Research in the MAPS faculty (2015-18). He is now an Emeritus Professor of Physics - we wish him well in his retirement.

Following the departure of Prof Franco Cacialli, we have welcomed two new academic staff this year. Dr Venkat Kapil has joined us from Cambridge to take up a lectureship in Computational Materials Science and Dr Jack Gartside has been appointed Associate Professor in (experimental) Alternative Computing, a joint-post between LCN/CMMP and the National Physics Laboratory (NPL).

Since the last edition of this Departmental Review we have had a number of promotions of our academic staff, congratulations to Prof Arijeet Pal and Prof Robin Perry for promotion to Professor (from October 2023) and to Dr Steven Schofield for promotion to Professor (from October 2024). Congratulations also to Dr Jon Breeze for his promotion from Lecturer to Associate Professor and for being awarded (jointly) the Faraday Medal and Prize by the Institute of Physics. Well done everyone – keep up the good work!

We would also like to congratulate this year's winners of the Marshall Stoneham Prize for the best PhD thesis in CMMP: Dr Camila Di Mino, supervised by Prof Neal Skipper, for her experimental thesis on ``Weak Intermolecular Interactions in Bulk Liquids and at Liquid/Nanomaterial Interfaces", and Dr James Dborin, supervised by Prof Andrew Green, for his theoretical thesis on ``Implementing Tensor Network Algorithms om Quantum Computers".

CMMP members have also stepped into new roles in the Faculty and within the Department. Prof Stan Zochowski has taken over as the MAPS Faculty Graduate Tutor succeeding Prof Tania Monteiro and Prof Ian Ford has taken on the role of P&A Tutor for Postgraduate Teaching. Dr Steven Schofield has taken over from Dr Mark Buitelaar as CMMP PhD admission tutor and Mark followed Des McMorrow as LCN PhD admission tutor. A big thank you to Mark for fighting our corner in PTC meetings over the last 5 years! Prof Chris Howard was appointed P&A Climate Research Lead and Prof Edina Rosta was appointed a member of the departmental Research Strategy Committee covering interdisciplinary research.

As to research, our PIs have continued to make important progress in understanding the world of condensed matter and materials. Two highlight contributions, one by Dr Steven Schofield on scaling up dopant-based quantum technology and another by Prof Alexander Shluger on the development of a universal model to understand dielectric breakdown can be found on pages X respectively Y of this review. A selection of this year's other research highlights in the CMMP group is given below.

Probing the critical fluctuations of condensed light (by Marzena Szymanska)

The experimental realisation of Bose-Einstein condensates (BECs) enabled investigations of macroscopic quantum systems. One fundamental question relates to the role of fluctuations close to the critical point of a BEC transition. Critical quantum fluctuations arise from the uncertainty principle and play an essential role in a wide range of physical phenomena such as the structure of the universe, the Casimir effect, and transitions between two competing phases of matter. Understanding these fluctuations is important for statistical physics of phase transitions and quantum critical phenomena. Phase fluctuations determine the low-energy properties of quantum condensates. However, at the condensation threshold, both density and phase fluctuations are relevant.

Polaritons (half-light, half-matter particles in semiconductors) provide a versatile system in which to study quantum fluid phenomena. They manifest strong density fluctuations (as shown in figure) close to the critical point. In this joint experimental-theoretical work, we reveal the intricate links between the classical and quantum fluctuations inherent in the system. The manifestation of a critical quantum state competition unlocks possibilities for the study of condensate formation but also paves the way for novel avenues in practical applications, particularly in the field of photonic lasers.

H. Alnatah, P. Comaron, S. Mukherjee, J. Beaumariage, L. N. Pfeiffer, K. West, K. Baldwin, M. Szymanska, and D. W. Snoke, "Critical fluctuations in a confined driven-dissipative quantum condensate." Science Advances 10, no. 12 (2024): eadi6762.

Research Headline

Scaling-up Dopant-based Semiconductor Quantum Technology

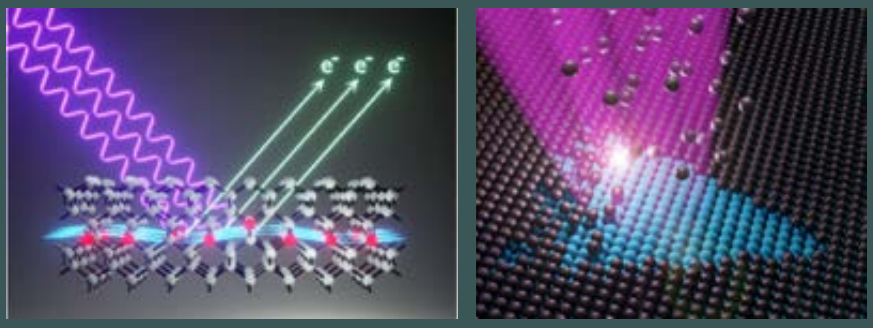


Figure 1: (Left) Measuring thickness and electronic properties of 2D donor-based electron liquids in silicon. (Right) Hydrogen desorption lithography with EUV light for scaling up dopant-based quantum devices.

Spin states in semiconductors offer stable, noise-resistant environments ideal for reliable quantum technologies. Advances in the deterministic placement of impurity dopant atoms in semiconductors have enabled demonstrations of one- and two-qubit gates and analogue quantum simulations of the Hubbard model. The grand challenge now lies in developing large-scale arrays of these dopant atoms and their associated circuitry for quantum computing and fundamental explorations in condensed matter physics.

Two publications, from the PhD thesis work of CMMP graduate Dr Procopios Constantinou (now at the Paul Scherrer Institute) and the research group led by Dr Steven Schofield, aim to tackle key obstacles in scaling up semiconductor quantum technology.

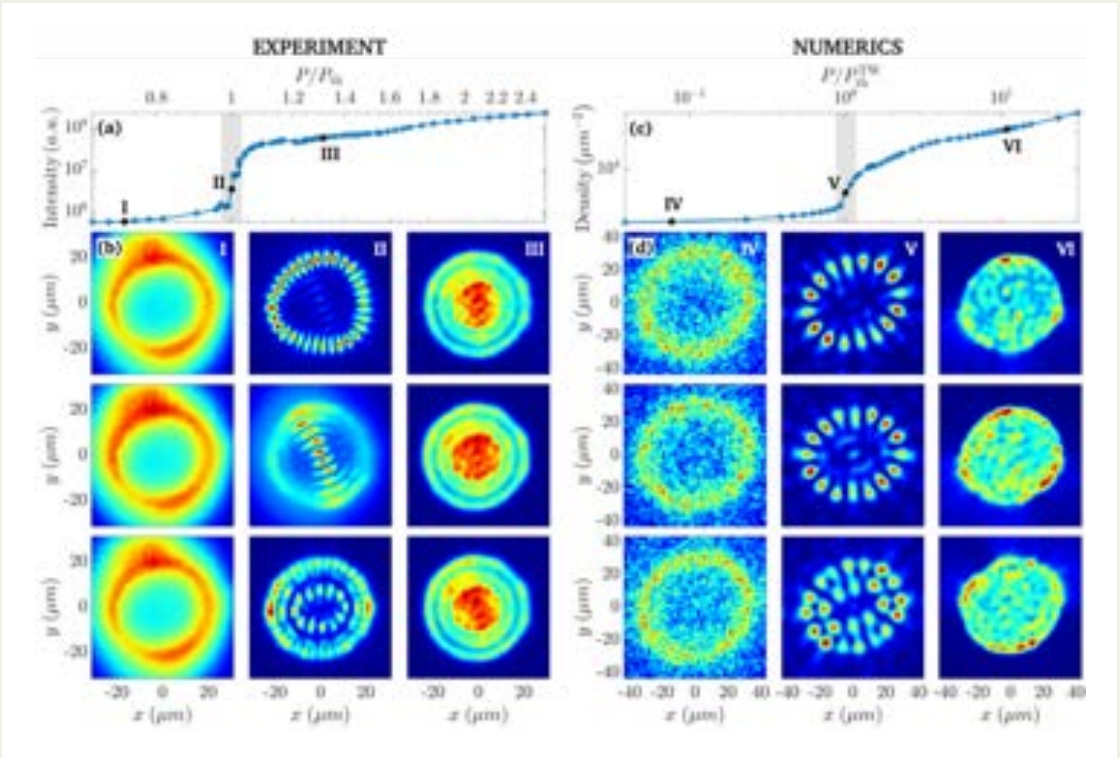
In one study, the team used soft x-ray angle-resolved photoelectron spectroscopy (SX-ARPES) to probe two-dimensional (2D) layers of arsenic in silicon. These atomically thin dopant planes create high-mobility 2D electron liquids (2DELs), essential for future quantum computers and next-generation transistors. This research demonstrated the utility of SX-ARPES to non-destructively probe electronic information on the 2DELs and showed that our samples host the thinnest technological 2DELs ever fabricated in silicon, with an electronic thickness of 0.45 ± 0.04 nm, comparable to the silicon lattice parameter (0.54 nm).

In a separate study, the researchers focused on addressing the challenges of speed, throughput, and reliability of dopant atom positioning. Published in Nature Communications, this work demonstrates the use of extreme ultraviolet light (EUV) to pattern hydrogen resist layers, marking a breakthrough in enabling large-area nanometre positioning of dopant atoms in semiconductors. This advancement is crucial for scaling up quantum devices to the millions of qubits required for practical quantum computing.

[1] Constantinou, et al., “Momentum space imaging of ultra-thin electron liquids in δ-doped silicon,” Advanced Science, 10, 2302101, 2023.

[2] Constantinou, et al., “EUV-induced hydrogen desorption as a step towards large-scale silicon quantum device patterning,” Nature Communications, 15, 694, 2024.

Fig. 1: Critical mode competition and density patterns in experiment (left) and theoretical modelling (right). Selected snapshots of the polariton density distributions, where each column corresponds to a fixed pump power below (I column), near (II column) and well above (III column) threshold, are shown in the rows below.



Emergence of liquid following laser melting of gold thin films (by Ian Robinson)

Femtosecond laser-induced melting of 300 nm-thick evaporated gold films (significantly thicker than the optical penetration depth [1]) were melted using a 400 nm pump laser of variable intensity during X-ray diffraction (XRD) measurement with 100 fs probe X-ray pulses generated by the Pohang Accelerator Laboratory X-ray Free-Electron Laser (PAL-XFEL). There was sufficient X-ray flux that the diffraction pattern could be measured in a single shot on a wide-angle area detector placed 50 mm behind the sample [1]. The gold samples were evaporated onto thin silicon nitride membrane windows in arrays that allowed automated positioning. Single-shot measurements were required, because the laser melting of the film was found to shatter the windows at high-fluence levels, so the diffraction pattern was safely recorded on the detector before any significant damage could take place. Pump–probe delay scans, with each delay point using a fresh window in an array, tracked the conversion of the crystalline material of the thin films through the shape of its Bragg peaks. These peaks, especially the strong 111 first Bragg peak of polycrystalline gold, were found to split into two separate components, one remaining close to the starting position and one at a smaller momentum transfer ($Q=|\mathbf{k}_f-\mathbf{k}_i|$) for which the intensity built up over time. This lower-Q diffraction peak was identified as gold heated to its melting point, which underwent melting and release of latent heat [1]. We conclude that melting starts at the internal grain boundaries of the film, where electron scattering is enhanced [2]. The heat then propagates as classical melt fronts into the grains themselves, clearly confirming an inhomogeneous melting process [1].

In the recent extension of this work, we extracted the X-ray diffuse scattering signal, representing the liquid phase of the sample [3]. The rise-time of the liquid was 13 ps, roughly independent of the incident pump fluence and consequent final liquid fraction, and in the range previously observed in electron scattering experiments [2, 4]. We then compared this transient diffuse scattering structure factor S(Q) with the previously measured S(Q) of liquid gold [5] and detected some small differences, shown in Fig. 1. Following its characteristic rise-time of 13 ps, the liquid was then seen to relax over 200 ps, becoming slightly more ordered, as indicated by a narrowing and shift of the first liquid peak in S(Q). While the single-shot results are too noisy for more detailed interpretation, it looks promising for future investigations to evaluate transient structural changes within liquids shortly after their formation.

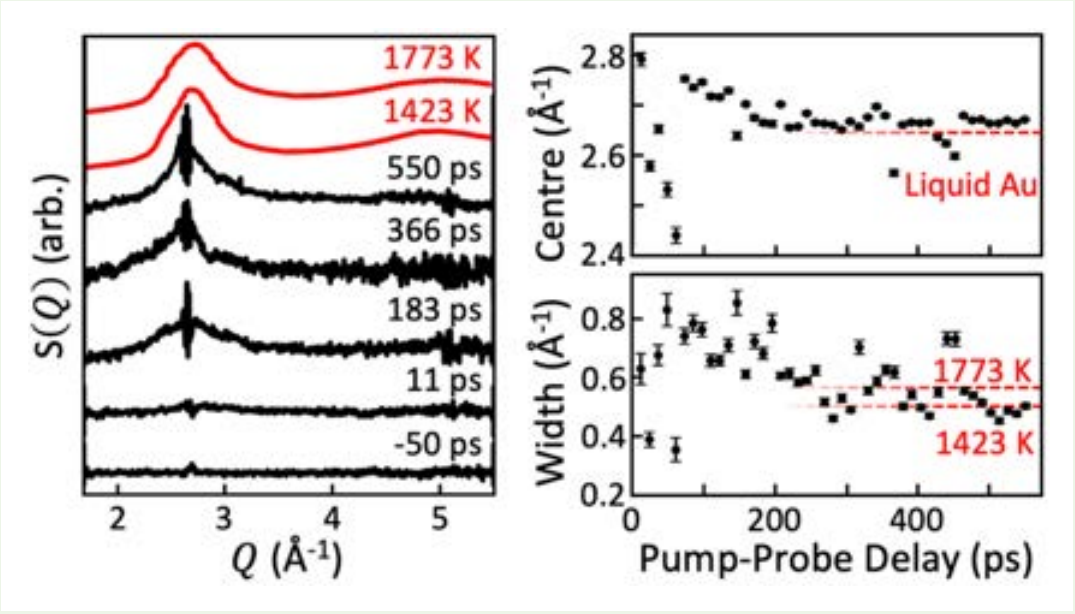


Fig. 2 (left) Excess diffuse scattering profile of transient liquid Au as a function of pump-probe delay. Data were extracted by removal of the Bragg peak contributions and subtraction of the profile measured at negative time delay. The structure factor of liquid gold is shown at two temperatures in color at the top of the panel. (right) Results of Gaussian fitting of the first maximum of the structure factor as a function of pump–probe delay time.

1. Assefa, T. A., Y. Cao, S. Banerjee, S. Kim, D. Kim, S. Kim, J. H. Lee, S-Y. Park, I. Eom, J. Park, D. Nam, S. Kim, S. H. Chun, H. Hyun, K-S. Kim, P. Juhas, E. S. Bozin, M. Lu, C. Song, H. Kim, S. J. L. Billinge and I. K. Robinson, Melt-front Dynamics in Polycrystalline Gold Thin Films, Science Advances 6 eaax2445 (2020), doi: 10.1126/sciadv.aax2445

2. Giret, Y. N., Naruse, N., Daraszewicz, Y., Murooka, J., Yang, J., Duffy, A. L., Shluger, K. and Tanimura, K. Appl. Phys. Lett. 103 253107 (2013)

3. Robinson, I. K., Robert Koch, Tadesse A. Assefa, Ana F. Suzana, Jack P. Griffiths, Yue Cao, Sungwon Kim, Dongjin Kim, Heemin Lee, Sunam Kim, Jae Hyuk Lee, Sang-Youn Park, Intae Eom, Jaeku Park, Daewoog Nam, Sangsoo Kim, Sae Hwan Chun, Hyojung Hyun, Kyung sook Kim, Ming Lu, Changyong Song, Hyunjung Kim, Simon J. L. Billinge and Emil S. Bozin, Emergence of liquid following laser melting of gold thin films, IUCrJ 10 656–661 (2023)

4. Mo, M. Z. Z., Chen, Z., Li, M., Dunning, M., Witte, J. K., Baldwin, L. B., Fletcher, J. B., Kim, A., Ng, R., Redmer, R., Reid, P., Shekhar, P., Shen, M., Shen, K., Sokolowski-Tinten, K., Tsui, Y. Q., Wang, Q., Zheng, Q., Wang, S. H. and Glenzer, S. H., Science, 360, 1451–1455 (2018)

5. Waseda, Y. and Ohtani, M., Phys. Status Solidi B, 62 535–546 (1974)

Disorder-induced transition from transient quantum delocalization to charge carrier hopping conduction in a non-fullerene acceptor material (by Jochen Blumberger)

Charge carrier transport in organic semiconductors is at the heart of many revolutionary technologies including organic electronics, organic light emitting diodes and organic photovoltaics. In contrast to inorganic semiconductors, the nature of the charge carriers in organic materials and their transport mechanism remain elusive and are the subject of intense debates in the scientific community.

In collaboration with researchers at Imperial College, University of Mons and others, Dr Ljiljana Stojanovic in Prof Jochen Blumberger's group (now at STFC) computationally characterizes charge transport in a novel electron-accepting organic optoelectronic material. By solving the time-dependent electronic Schrödinger equation coupled to nuclear motion, it is shown that excess electrons in single crystals are delocalized on average over three molecules and move within the crystal via dynamical wavefunction expansion and contraction events termed ``transient quantum delocalization". In disordered thin films of the same material the carrier wavefunction collapses on a single molecule due to structural and electrostatic disorder concomitant with a change in transport mechanism from transient quantum delocalization to charge carrier hopping and a dramatic decrease of the electron mobility by 6 orders of magnitude, in good agreement with experimental measurements.

The work shows the value of computational methods to distinguish among different regimes of transport for different types of molecular packing. Future research will focus on the question of how molecular packing and quantum delocalization affects the dissociation efficiency of electronic excitations into charge carriers at the interfaces of organic optoelectronic devices.

Ljiljana Stojanović, Jack Coker, Samuele Giannini, Giacomo Londi, Anders S. Gertsen, Jens Wenzel Andreasen, Jun Yan, Gabriele D'Avino, David Beljonne, Jenny Nelson, and Jochen Blumberger, Phys. Rev. X 14, 021021 (2024).

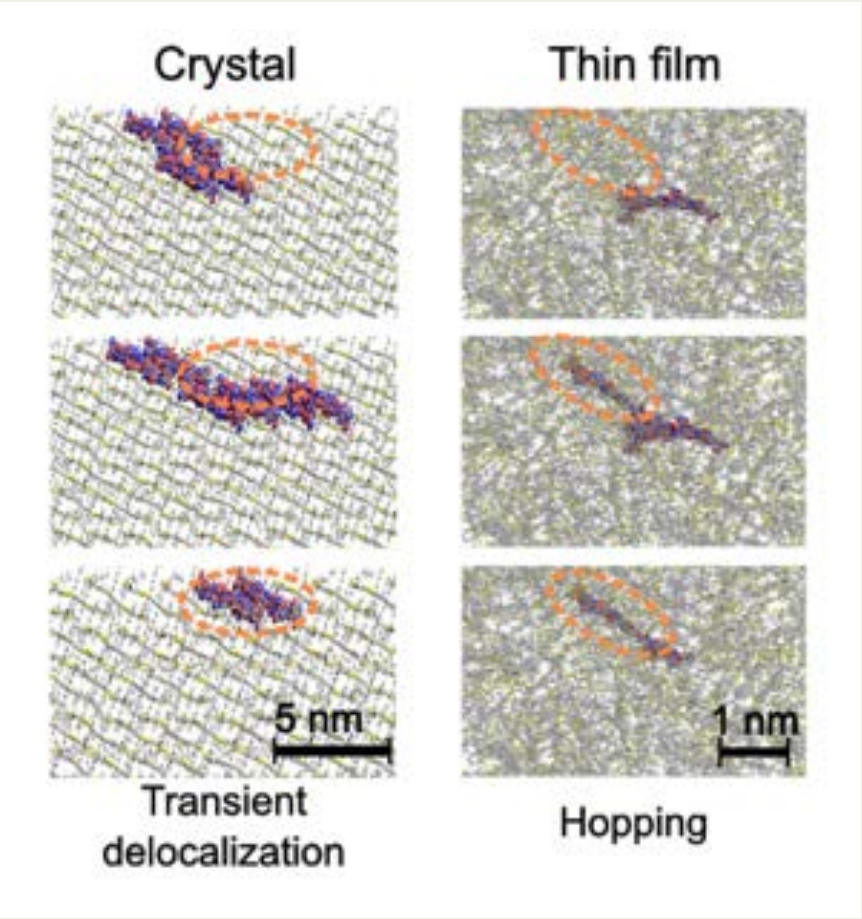


Fig. 3: Charge transport in the non-fullerene acceptor O-IDTBR. Non-adiabatic molecular dynamics simulations is used to propagate the wavefunction of an excess electron in time revealing a transient delocalization mechanism in the crystal (left column) and a charge carrier hopping mechanism in a disordered thin film (right column). For each material, the wavefunction (depicted in blue/red isosurfaces) is shown at three different times: before, during and after a spatial displacement that contributes to diffusion and charge mobility. Notice the different scale bars in the two materials.

Research Headline

Towards a Universal Model of Dielectric Breakdown

Dielectric breakdown (DB) occurs in all insulating materials – gases, liquids or solids, when the electric field caused by an applied voltage exceeds the material's dielectric strength. This complicated phenomenon is manifested by a sudden and catastrophic increase in the conductivity of an insulator and its mechanisms have been studied for more than 100 years [1]. When this phenomenon occurs in the gate oxide(s) of a transistor, it causes a short that compromises device/circuit functionality. Due to the critical importance of DB for the reliability of microelectronic devices, the behaviour of oxides traditionally used in these devices (SiO2, HfO2, Al2O3) still remains one of the most challenging areas in the field of semiconductor device reliability. Despite massive research efforts conducted for over 50 years by industry and academia, a consensus has not yet been reached on the microscopic nature of the degradation process leading to DB, and none of the models proposed over the years provides a comprehensive and consistent description of all the experimental observations [1].

In a recent work investigating the DB mechanism in amorphous alumina (a-Al2O3) metal/insulator/metal (MIM) stacks [2], density functional theory (DFT) calculations by Dr Jack Strand and Prof Alexander Shluger revealed that oxygen vacancy (VO) generation in a-Al2O3 occurs via thermochemical (TC) bond-breaking and, even more efficiently, via newly discovered pathways enabled by electron trapping by under-coordinated Al ions and in existing oxygen vacancies. An example of a vacant oxygen site in amorphous alumina structure which traps two electrons is shown in Figure 1. However, to what extent the structure and properties of point defects in amorphous solids are similar to those in the crystalline phase is still debated. The validity of this analogy and the experimental and theoretical evidence of the effects of oxygen deficiency in amorphous oxide films are critically discussed in [3]. Calculations demonstrate that, apart from atomistic structures analogous to crystal vacancies, more stable defect states can be characterized by the bond formation between under-coordinated Al ions.

Further simulations including electron injection from electrodes, defect creation and current propagation through oxide films support the importance of these processes, and allow explaining the experimental DB dynamics in a-Al2O3. They provide insights into the role of carriers' injection in the degradation and reliability of high-k materials. A more general microscopic breakdown BD model in which chemical bonds are weakened by carrier injection and trapping into pre-existing structural defects (precursors) and by the electric field in a-Al2O3 and other amorphous oxides, such as SiO2 and HfO2, is shown schematically in Figure 2 and described in detail in [1,4]. This model goes beyond the existing ones by consistently explaining the role of both current and temperature, along with the role of the electric field. It also explains the non-Arrhenius temperature dependence of DB. It suggests a new comprehensive physics-based framework (with tight connections to material properties) which allows one to reconcile the many breakdown theories proposed so far within a more universal breakdown model.

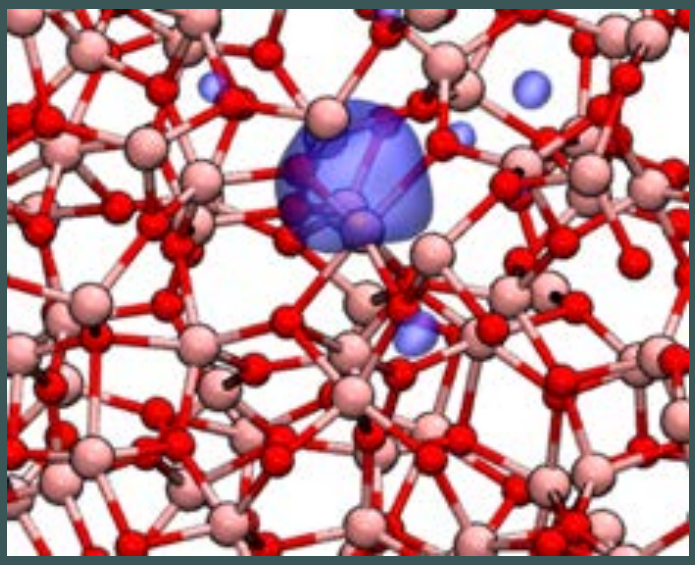


Figure 1: (Left) Measuring thickness and electronic properties of 2D donor-Figure 1. An amorphous Al2O3 structure with one missing O atom and two electrons trapped in a vacant O site. The blue colour shows the degree of localization of the square modulus of the wavefunction describing these two electrons near the vacancy. Oxygen ions are read and Al ions are pink.

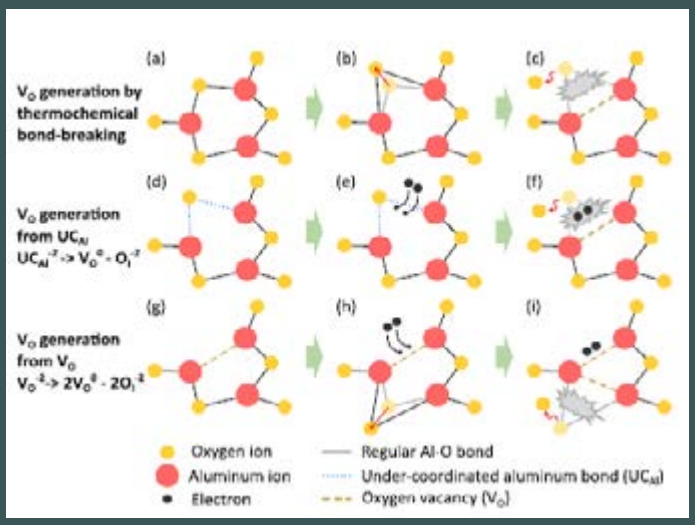


Figure. 2. Schematic representation of different pathways for generation of oxygen vacancies (VOs): a typical O-Al-O bond (a) stretched by an electric field (b) breaks generating a VO (c); a structural precursor site (undercoordinated Al ion, UCAl) (d) traps two electrons (e) facilitating the creation of VO - Oi2− pair (f); a VO (g) traps two electrons (h), facilitating the creation of the second VO and interstitial Oi2− ion (i).

[1] A. Padovani, P. La Torraca, J. Strand, L. Larcher, A. L. Shluger, Dielectric breakdown of oxide films in electronic devices, Nature Review Materials 2024 (accepted)

[2] P. La Torraca, A. Padovani, J. Strand, A. Shluger, and L. Larcher, The Role of Carrier Injection in the Breakdown Mechanism of Amorphous Al2O3 Layers, IEEE Electron Device Letters 45, 236 (2023) DOI: 10.1109/LED.2023.3337882

[3] J. Strand and A. L. Shluger, On the Structure of Oxygen Deficient Amorphous Oxide Films, Advanced Science 11, 2306243 (2023)

[4] A. Padovani, P. La Torraca, J. Strand, A. L. Shluger, V. Milo, and L. Larcher, Towards a Universal Model of Dielectric Breakdown, 2023 IEEE International Reliability Physics Symposium (IRPS) 2A-2-1 (the best paper); DOI: 10.1109/IRPS48203.2023.10117846

Astrophysics (Astro)

A very intense year for the UCL Astro group, marked by many achievements and scientific discoveries.

The Dark Energy Spectroscopic Instrument (DESI) collaboration, led by the Lawrence Berkeley National Laboratory in the US and involving Profs Ofer Lahav and Peter Doel, has made the most precise measurements to date of how fast the universe has expanded throughout its history. DESI is an international collaboration of more than 900 researchers from over 70 institutions around the world.

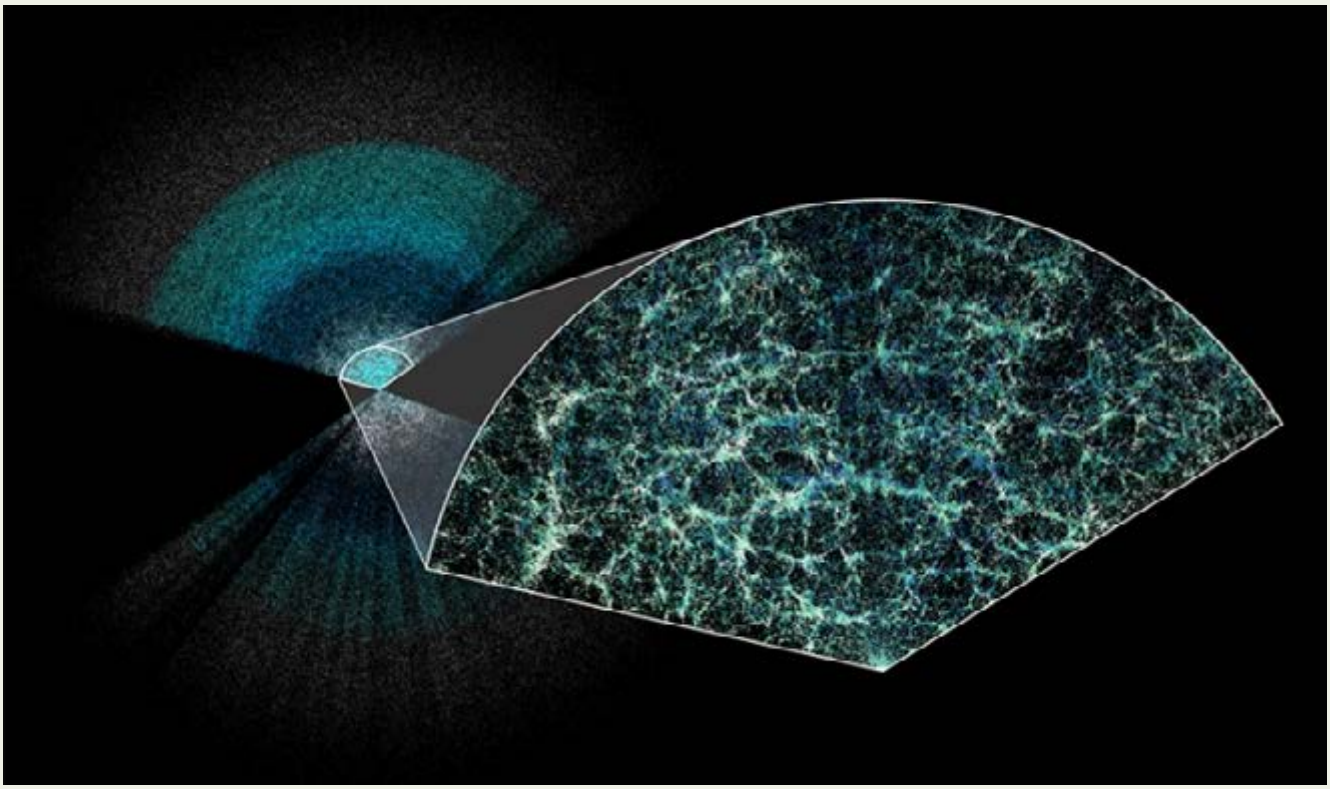


Fig. 1 – DESI has mapped galaxies and quasars with unprecedented detail, enabling researchers to look 11 billion years into the past and study how fast the universe has expanded over time. This is the first time that scientists have measured the expansion history of that distant period with a preci-sion of better than 1%, giving us our best view yet of how the universe evolved.

The analysis, based on the largest 3D map of the cosmos ever created with just the first year of data from DESI, confirms the basics of our current best model of the universe – with some tantalis-ing areas to explore with more data (Fig. 1). The instrument, which sits on a mountaintop telescope in Arizona, in the US, contains 5,000 fibre-optic "eyes", each of which can image a galaxy in just 20 minutes.

Prof. Ofer Lahav, who has coordinated UCL's involvement in DESI and in other cosmology surveys and is a member of the DESI Executive Committee, said: "Congratulations to the DESI team on this remarkable measurement of dark energy and dark matter properties. The results validate spec-tacularly that the universe's expansion is accelerating, probably due a cosmological constant Lambda proposed by Einstein in 1917, or a variant of it. UCL has contributed, with STFC's support, to the construction of the DESI optical corrector and to the science analysis infrastructure. "More data from DESI and other surveys are needed to pin down the mysterious nature of dark energy and dark matter that make 95% of the present universe."

Dr. Dirk Scholte, who helped create the DESI catalogue of millions of galaxies used in this study, said: "Beyond cosmology, the DESI spectra provide a very rich data set to study the physical prop-erties of an unprecedented number of galaxies and their evolution with cosmic time."

Prof. Peter Doel, who worked on the optical corrector alongside Prof. David Brooks, said: "I'm ex-cited to see the publication of the key findings from the first year of the DESI survey. And I'm pleased that the high-quality survey data used was due in part due to the success of the wide field corrector optics that was assembled and tested at UCL."

In May, CNES has officially confirmed the balloon-borne project BISOU for Phase A (Fig. 2). BISOU is a concerted effort by several laboratories in France, Italy, Ireland, the UK, the USA and Japan

"Thirty years after the CMB (Cosmic Microwave Background) spectrum was first precisely measured by the COBE/FIRAS instrument, we are now in the unique position to perform measurements of the CMB energy spectrum by several orders of magnitude, allowing transformational steps towards the detection of signals expected within the Lambda-Cold Dark Matter (LCDM) model", explained Prof. Giorgio Savini contributing to the design and modelling of the BISOU' spectrometer and calibration source.

He added: “although COBE demonstrated that the average CMB energy spectrum follows that of a near-perfect black body at a temperature of T = 2.7255 +/- 0.0006 K, theory predicts small deviations from Planck’s law, known as spectral distortions. Measuring these distortions will provide a unique way of tracing the thermal history of our Universe, to gain deeper insight in the theory of inflation, structure formation and particle physics”.

This prospect makes high precision CMB spectrum measurement one of the priorities in experimental cosmology and astrophysics, as clearly recognized by several space agencies.

An international team of astronomers, including Prof. Mike Barlow, have discovered the first conclusive evidence that a neutron star exists at the centre of Supernova 1987A, a star explosion observed 37 years ago.

Supernovae are the spectacular end result of the collapse of stars more massive than 8-10 times the mass of the sun. They are the main sources of chemical elements (such as carbon, oxygen, silicon, and iron) that make life possible. The collapsed core of these exploding stars can result in much smaller neutron stars, composed of the densest matter in the known universe, or black holes.

The Sir Robert Wilson Lecture 2023 was given by Prof. Sheila Rowan, Chair of Natural Philisophy, Director of the Institute for Gravitational Research at the University of Glasgow and Physical Secretary and Vice-President of the Royal Society of London. In her lecture, she gave a personal perspective on the work leading up to the discovery of gravitational waves in 2015 and its announcement in 2016. She

“Our detection with James Webb’s MIRI and NIRSpec spectrometers of strong ionised argon and sulphur emission lines from the very centre of the nebula that surrounds Supernova 1987A is direct evidence of the presence of a central source of ionising radiation. Our data can only be fitted with a neutron star as the power source of that ionising radiation. This radia-tion can be emitted from the million degree surface of the hot neutron star, as well as by a pulsar wind nebula that could have been created if the neutron star is rapidly spinning and dragging charged particles around it. The mystery over whether a neutron star is hiding in the dust has last-ed for more than 30 years and it is exciting that we have solved it.”

Prof. Mike Barlow

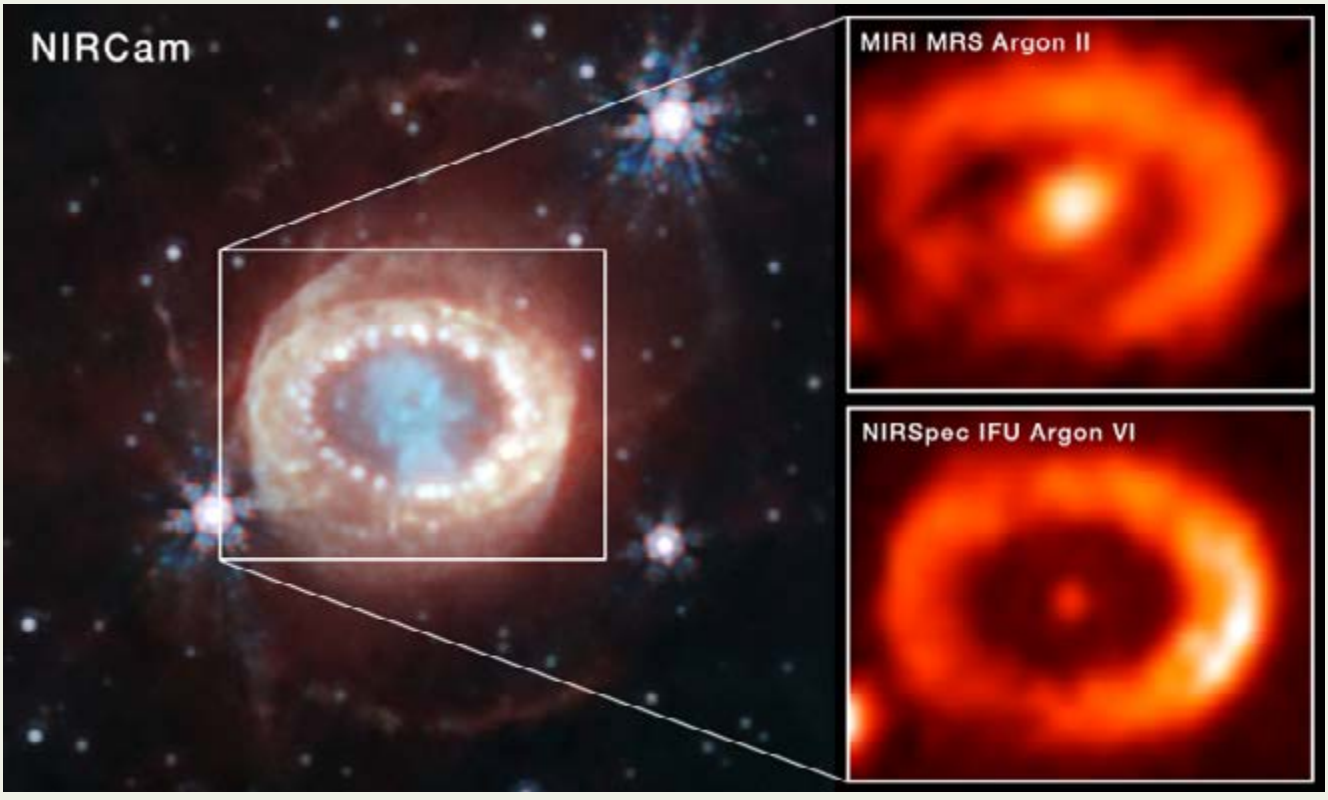


Fig. 3 – Supernova 1987A, located in the Large Magellanic Cloud, a neighbouring dwarf galaxy, was the nearest, brightest supernova seen in the night sky in 400 years.

Research Headline

The first direct observation of gravitational waves on 14th September 2015 signalled the opening of a new observational window onto the Universe. Astrophysics has traditionally charted and explored the Universe using optical telescopes (in other words: with light), with neutrinos a second messenger that has recently been added to the arsenal of physicists. Gravitational waves now add a novel third way of doing so, allowing us to probe previously unexplored parts of the Universe. More specifically, the LIGO-Virgo-KAGRA (LVK) collaboration cartographs the Universe by detecting and mapping the cataclysmic collisions of black holes and neutron stars. To give a sense of the enormous scales associated with these collisions, the above-mentioned first detected event released an energy equivalent to around three solar masses in gravitational waves, in the process reaching energy emission levels larger than the power of the light radiated by all stars in the observable Universe combined. Since that first detection in 2015 we have gone from detecting a few individual events to detecting such mergers at scale (see figure 1), unravelling clues e.g. about galaxy evolution, the nature and formation history of black holes themselves, and about the nature of neutron stars in the process.

As our understanding of the gravitational waves emitted by black hole and neutron star mergers improves, a complementary aspect of gravitational wave science has very recently come to the fore: Using gravitational wave science to probe fundamental physics, in particular understanding the nature of what we believe are the two dominant components of the Universe today - dark matter and dark energy, the cornerstones of the so-called ΛCDM model (the current “standard model of cosmology”). The new Gravitational Wave group at UCL, established in October 2023, is at the heart of ongoing efforts in this enterprise. Both within the LVK, where Dr Johannes Noller co-chairs the “Testing LCDM” working group focused on better understanding dark matter and dark energy and deriving related observational constraints, and locally at UCL, where the group has been developing the theoretical machinery required to model the impact of these universal components on the gravitational waves we detect.

An example neatly illustrates the ongoing work of the UCL gravitational wave group: In recent work led by PhD student Sergi Sirera, black hole ringdown was studied as a tool to detect new particles and degrees of freedom that may be related to dark matter or dark energy. Here black hole ringdown denotes the final phase of a black hole merger, when the remaining merged black hole is in an excited state as a result of the merger and radiates away excess energy. This process is analogous to a bell being struck and emitting a superposition of musical notes. Which notes are excited depends on how the bell is struck, but the spectrum of notes that can be emitted is determined by the structure and makeup of the bell. In the same fashion, the gravitational waves emitted during black hole ringdown have a characteristic frequency spectrum that is affected by the degrees of freedom surrounding the black hole, ultimately encoding information about the particle content of the Universe. Sergi showed how this spectrum is altered in the presence of candidate dark energy theories and this will be used in upcoming analyses to place constraints on such theories using upcoming events detected by LVK.

At present LVK is collecting further data throughout its ongoing fourth observing run. As part of the LIGO Science Collaboration (LSC), the UCL Gravitational Wave group is therefore currently preparing the analysis of this incoming data. With upgraded detectors capable of sensing fainter gravitational wave events than before, new discoveries are just around the corner!

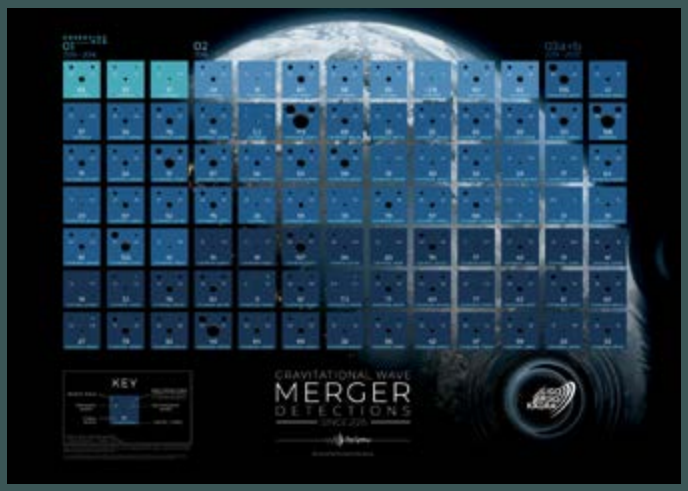


Figure 1: Figure showing gravitational-wave merger detections from the first three observing runs of LVK. Credit: Carl Knox (OzGrav, Swinburne University of Technology).

Figure 2: The collision of two black holes holes in a still from a computer simulation, showing how it would appear to our eyes if seen from nearby. The stars appear warped due to the incredibly strong gravity of the black holes. Image Credit: SXS, the Simulating eXtreme Spacetimes (SXS) project (http://www.black-holes.org)

explained the science being enabled by the study of gravitational waves and what the future for the field might hold (read the Astro research highlight by Dr. Johannes Noller about this topic). The existence of these 'ripples in space-time' was a longstanding prediction of Einstein's General Theory of Relativity dating back to 1916. Achieving their detection required new measurement techniques to be invented and pushed to the limits of their performance, needed international collaboration across continents and perhaps most of all, perseverance.

Public engagement

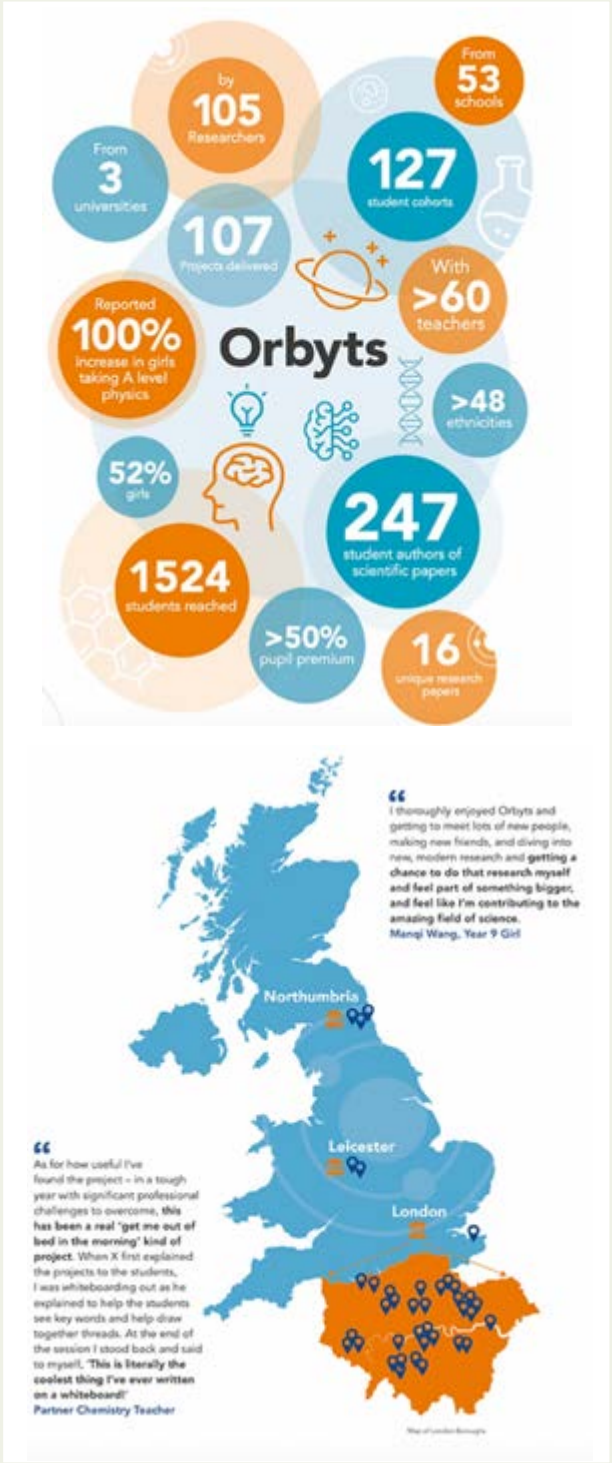
Orbyts is a multi-award-winning program, coordinated by Dr. Will Dunn and supported by many PhD students and colleagues in Astro (amongst many others!), that partners scientists with schools to empower school students to undertake world-leading research, while providing them with relatable science role models who dispel harmful stereotypes about who can be a scientist. To ensure that these opportunities go to those who need them most, schools that join Orbyts must ensure that at least 50% of students on an Orbyts project are girls and minority genders and at least 50% are pupil premium and SEND students.

Over the past six years the Orbyts programme has enabled a transformational impact on young people, researchers and teachers alike, an impact which the Orbyts team have recently shared via their first impact report.

To date, Orbyts has created over 100 research partnerships between researchers and schools, empowering 1500+ school students by helping them to see that there is a place for them in science and that they are beyond capable of working on world-class research. The project has increased inclusivity in post-16 STEM uptake, with student groups that Orbyts have engaged being 50+% girls, 50+% pupil premium, and with students identified from 48+ ethnicities. They have grown with new Hubs in North East England and Leicester, alongside expansion of their London Hub.

Read the report for all the statistics on Orbyts, spotlights on the ground-breaking research being led by students, and all the exciting plans for Orbyts in 2024!

- Orbyts Impact Report (2017-2023): orbyts.org/impact
- Orbyts website **https://www.orbyts.org/**



Promotions and prizes:

Drs Jason Sanders and Mihkel Kama, have been promoted Associate Professors, Dr. Ahmed Al-Refaie, has been promoted Principal Research Fellow.

Prof. Nick Achilleos was awarded the Royal Astronomical Society Chapman Medal, which recognizes "... a single investigation, or a series of closely linked investigations, of outstanding merit".

Prof. Richard Ellis has been elected as an international member of the US National Academy of Sciences (NAS) in recognition of his "distinguished and continuing achievements in original research".

Dr Johannes Heyl was awarded the 2024 MERAC Prize for the Best Doctoral Thesis in New Technologies (Computational).

Dr. Lucy Hogarth was awarded the Christopher Skinner Prize and Dr. Catarina Alves was awarded the Jon Darius Memorial Prize for outstanding postgraduate physics research in Astrophysics.

Dr. Vinooja Thurairethinam won the Departmental Equality, Diversity and Inclusion Prize.

Thomas Schlichter was awarded the Departmental technical staff prize

Alexandra Thompson, PhD student, won the CPS Outreach and Engagement Award for her founding and implementing the Orbyts STAR (STudents Advancing Research) programme in partnership with Great Ormond Street Hospital.

High Energy Physics (HEP)

High Energy Physics (HEP) looks at extremely small sizes, or equivalently, at extremely high energies. Its aim is to explore the underlying nature and foundations of the entire physical universe, as well as the forces and laws that govern its development.

As one of the largest particle physics groups in the country our research at UCL HEP covers a wide range of areas, from theoretical physics and exploring the world's highest energy proton-proton collisions at the Large Hadron Collider (LHC), to unlocking the mysteries of neutrinos, searching for elusive dark matter, exploring new physics with precision muon studies and much more. In addition to fundamental physics research, we are involved in several interdisciplinary and knowledge exchange projects and are active in promoting particle physics in schools and among the general public.

While the main strands of our research in fundamental particle physics are outlined below, a vital area of the group's activity is in applications of the technology that we develop. Most notably, we continue to play an important role in developments around proton beam therapy, in particular delivering instruments for verifying the range of therapeutic proton beams, in close collaboration with UCLH and others. We are also increasingly active in seeking applications of our technology and expertise to help tackle some of the challenges resulting from global heating and climate change.

Research Headline

High Energy Physics Mechanical Engineering Team (Harry Barnett)

Hardware is one of the foundations of High Energy Physics research. The group's ongoing demand for new technologies requires adaptable engineering and technical proficiency. I arrived at the start of 2024 and, together with Connor Godden, make up the HEP mechanical engineering team. We offer design consultation, technical drawings, documentation, manufacturing (both in the HEP workshop, the central UCL workshop and with external companies), and installation. We support many experiments and projects, and here are some those that we've worked on recently:

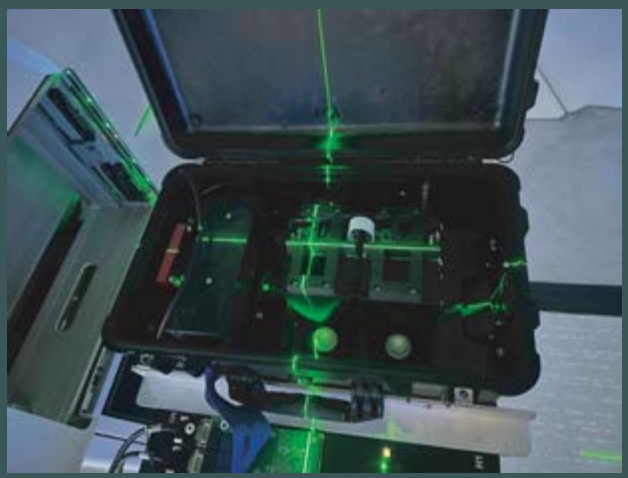
SuperNEMO: In early 2021, the engineering team was tasked with developing neutron shielding for the SuperNEMO detector, which aims to detect rare nuclear decays to determine the nature of the neutrino. The shielding, made of hydrogen-rich water and polyethylene, slows down neutrons, allowing them to be captured before they enter the detector. Designing this system around a complex structure posed civil engineering challenges, especially given the unique requirements of a deep underground laboratory. The project involved detailed technical documentation and technical drawings, and collaboration with French manufacturers. The shielding is on track to be completed by the end of September 2024.

PEUO: In early 2022, the engineering team joined PUEO to assist with the "PALS Enclosure" system. This enclosure, designed for an array of Hard Disk Drives, will be fastened to a balloon platform and ascend to around 30,000 ft, remaining operational until descent. It must function in freezing conditions, protect the HDDs from sudden accelerations, and act as a heat sink due to the thin atmosphere at that altitude. After many design iterations, the enclosure's footprint was significantly reduced, and systems design practices ensured internal components were compact and light. Due to the bespoke and intricate nature of the PALS design, parts are being manufactured across UCL and in collaboration with specialist external companies. This work will be completed for PUEO's flight in 2025, which will measure ultra-high energy cosmic ray interactions in the Antarctic ice sheet.

DUNE: The neutrino oscillation experiment DUNE will determine the matter-antimatter asymmetry and mass ordering of neutrinos. It uses gigantic liquid-argon time-projection chambers to record the neutrino interactions, and UCL has led the development of purity monitors that will continuously check the liquid-argon quality. The HEP engineering team has designed and manufactured a new mounting system for the purity monitors at specific locations, requiring detailed knowledge of the apparatus and providing sufficient strength to suspend the monitor mass on a cantilever beam. Made entirely in-house from aluminum, the mounts are machined, folded, and TIG welded and will be installed in the ProtoDUNE cryostat at CERN in September.

PBT: For the past few years, the HEP engineering team has aided the research into improving Proton Beam Therapy (PBT) efficiency, focusing on beam calibration. PBT therapy centres face long calibration times, which in turn reduces patient throughput. The engineering team has assisted the PBT group in the development of novel proton-range-verification detectors that can speed up this calibration process, and in particular we are designing and fabricating bespoke enclosures that will provide easy to use instruments in a clinical setting.

It has been a very busy but also very interesting first 8 months at UCL. I'm very much looking forward to working on a variety of exciting projects across HEP and the wider department in the future.



New arrivals over the last year include Sonia Escribano (proton therapy), Andrew Stevens and Joe McLaughlin (Dark Matter and LZ), Jayesh Bhatt (DUNE and LUXE), Flavia Cicala (SBND and DUNE), Mohammad Hassanshahi (Quantum Computing for HEP), Chayan Majdumar (Theory) and Melissa Yexley (ATLAS). Welcome to all of them!

More information on the UCL HEP group activities can be found at: **http://www.hep.ucl.ac.uk/research.shtml**

ATLAS and the Energy Frontier

ATLAS and the Large Hadron Collider (LHC) are now well into their new run, aiming to double the existing dataset and significantly extend the discovery reach for new physics beyond the Standard Model. UCL have leadership in several areas, and a pioneering analysis of di-Higgs production featured in the last annual review was published earlier this year. A lot of technical work continues to take place preparing for the high-luminosity phase of the LHC, scheduled to start towards the end of this decade, and its associated detector upgrades.

The future of the energy frontier after the LHC is a subject of much debate in the field at the current time. At UCL we are making key scientific contributions to this question, in particular through R&D into new and innovative plasma-acceleration techniques via our participation and leadership in the AWAKE project.

Neutrinos and Dark Matter

The group has a long-standing tradition of initiating and leading international experiments exploring new physics with neutrinos and searching for dark matter. In the past year we have made significant contributions to neutrino oscillation experiments (NOvA, DUNE and SBND) and neutrinoless double beta decay experiments (SuperNEMO & LEGEND). LEGEND has recently presented its first search for neutrinoless double-beta decay with unprecedented sensitivity (see Research Highlight). UCL has also played a leading role in the analysis of the latest NOvA data and, in combination with T2K, placing constraints on CP-violation in the neutrino sector.

Research Headline

Missing Energy (Jon Butterworth)

Here's a question you might not have asked yourself before. When protons collide in the Large Hadron Collider, how often are undetectable particles produced?

Maybe a quick follow up question would be, why does it matter?

A paper the UCL ATLAS group have been working on for several years (arXiv:2403.02793) was recently accepted by the journal for publication and answers the first question, at least under certain conditions.

One reason it matters is because from various astrophysical observations, it seems likely that around 80% of the mass of the universe is undetectable, in the sense that, while we see the gravitational influence of enormous clumps of it, if it is made of particles they interact so weakly with normal matter that all our detectors are blind to them. Astronomers and Physicists refer to this as "Dark Matter", although as has been pointed out before, "Transparent Matter" would have been a more accurate, if less evocative, name.

It might be that whatever this Dark Matter is, it can be produced in collisions at the Large Hadron Collider (LHC) at CERN. For what it is worth, many theories predict this. If you care what 80% of the universe is made of (and why wouldn't you?) then this matters.

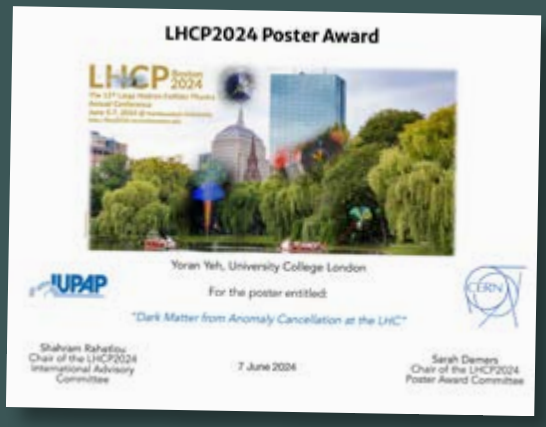
If Dark Matter were to be produced in a collision, it would escape our detectors without registering directly. Since our detectors surround the collision point, however, we have a chance of inferring its presence from the fact that we would see an imbalance when we add up the momentum of all the other particles produced in the collision. Searches for Dark Matter have been done before at the LHC using this effect, and have found no sign of it. Spoiler alert, we also find no sign. This analysis is different from the previous searches though, in what I strongly believe is a crucial respect. It is more than just a null result.

Null results are important, and we are privileged to have a culture in particle physics where we can readily publish them. They add to the sum of knowledge by ruling out possibilities, and they avoid future wasted effort. I say that our paper is not a null result though because undetectable particles are produced at the LHC, and we have measured how often that happens. The particles in question are called neutrinos, tiny particles which are too fast moving to explain the observed effects of Dark Matter, but which are an essential component of the "Standard Model" of particle physics.

The measured production rate agrees quite well with the best predictions of the Standard Model, although in detail there are some discrepancies, which we have quantified. The discrepancies don't look as though they are due to Dark Matter though, and may well be to do with deficiencies in the predictions. Time will tell.

Anyway, measuring a physical process at higher energies and more precisely than ever before, and using that to test our theory in a new regime, is not a null result by any stretch. There is an added bonus in that now this measurement has been made, it can be used in lieu of dedicated searches for Dark Matter, to rule out possible new theories – something we demonstrate in the paper with a couple of examples. Null results are important, but when theories proliferate it is important to be efficient when confronting them. A dedicated search for each of them might be optimal for each theory, but is not efficient. A single measurement of what really does happen, made in a theory-neutral way, can do a good enough job for many possibilities, now and far into the future.

As well as demonstrating the is the ATLAS paper, we submitted an independent paper showing new reach for a class of Dark Matter models (arXiv:2405.03749). PhD student Yoran Yeh presented both results as posters at the LHCP2024 conference in Boston. This is the main annual conference for LHC results, and Yoran won the poster prize (see figure).



UCL now provides the spokesperson and one of the key analysis leads for the LZ experiment, searching directly for the feeble interactions of dark matter particles. At the time this article goes to press LZ will have just announced their latest results - either a discovery, or the most stringent constraints on dark matter over a wide range of parameter space. In parallel, exciting new quantum techniques for searching for other forms of dark matter are being pioneered here at UCL in close collaboration with the AMOPP group.

Flavour Physics

One of the most promising avenues in the search for answers to the outstanding questions in particle physics is to pursue the precision frontier rather than the energy frontier. Having initiated UK participation in a new ultra-precise measurement of the muon's magnetic dipole moment, UCL is now playing a leading role in the search for exotic decay modes of the muon including conversion to 1 or 3 electrons/positrons. Over the next few years these projects will offer real discovery power, complementary to the direct particle-production searches at the LHC.

Astroparticle Physics

UCL has a long-standing participation in the ANITA balloon experiment, searching for ultra-high energy cosmic-ray neutrino interactions in the Antarctic icesheet. We are now actively involved in the successor instrument, named PUEO, scheduled for launch in late 2025. In parallel, UCL have initiated UK participation in the planning and design of a new underwater neutrino telescope, P-ONE, to be deployed in the Pacific Ocean.

Quantum Technologies

UCL (HEP and AMOPP) lead the Quantum Technologies for Neutrino Mass (QTNM) project. Over the last year this project has progressed through initial studies to a design for an atom trap and cyclotron radiation detection system that is currently under construction. A number of important milestones have been achieved along the way, including a demonstration by Hogan's group at UCL that Rydberg atom magnetometry can be used to map magnetic fields with the precision required for a future neutrino mass experiment. The investigation of how quantum computing can be used to speed up and solve previously inaccessible problems in particle physics, as well as other areas of physics, is another topic that is being led by the HEP group at UCL.

Theory

UCL is leading in several efforts exploring the properties of neutrinos, and using them as a portal to look for new physics beyond the Standard Model. This includes theoretical and phenomenological studies interpreting experimental results and proposing novel processes and mechanisms as signatures of new physics in the neutrino sector. A crucial process in this regard is nuclear double beta decay, and the HEP theory group work closely with experimentalists on LEGEND and SuperNEMO on this topic.

The world-leading work by members of the UCL HEP group on the structure of the proton continues to be recognised. The HEP theory group is also engaged in collider physics research through the development of high precision Monte Carlo simulations of LHC collision events. Recently, the group has been focused on the decades-old problem of quantifying and improving the precision of parton-shower simulations, the most widely used theoretical tools in particle physics. The group has enjoyed recent success in this area developing and demonstrating, for the first time, full-fledged parton shower simulations accurate at so-called next-to-leading logarithmic order.

Research Headline

The Search for Neutrinoless Double-Beta Decay with LEGEND (Will Quinn)

The quest to uncover the mysterious nature of the elusive neutrino has captivated physicists for decades. Unlike other fermions in the Standard Model of particle physics—such as the electron, muon, tau, and quarks—the neutrino is neutral for both the strong and electromagnetic forces, interacting only via the weak force. Its uniqueness also manifests in its apparent mass, which is less than one-millionth that of the next lightest fermion, the electron. The precise mass of the neutrino and the mechanism that generates it remain unknown, making these questions excellent avenues for expanding our understanding of the cosmos.

Neutrinoless Double-Beta Decay ($0\nu\beta\beta$) is a hypothesised radioactive decay in which, unlike standard double-beta decay, the nucleus of an atom emits two electrons without the corresponding emission of two antineutrinos. In this scenario, the pair of electrons carry away all the energy of the decay, leaving none as "missing energy" typically associated with neutrinos. This decay is forbidden in the Standard Model due to its violation of particle-antiparticle symmetry. However, if the neutrino is its own antiparticle—a Majorana particle—this process could occur. Observing $0\nu\beta\beta$ would confirm the Majorana nature of the neutrino and provide critical insights into the origin of the matter-antimatter asymmetry in the observable universe. The challenge lies in the fact that standard double-beta decay has a half-life far longer than the age of the universe, with $0\nu\beta\beta$ being even more rare. Thus, any detectors for it must contain large amounts of $\beta\beta$ radioisotope, possess exceptional background suppression and signal discrimination capabilities, and offer a high energy resolution.

The LEGEND experiment (Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay) is at the forefront of the search for $0\nu\beta\beta$, involving a large, global collaboration of researchers, including several PhD students, postdocs, and professors from UCL. LEGEND uses an array of High-Purity Germanium (HPGe) detectors enriched with the isotope 76Ge, submerged in a liquid argon (LAr) cryostat. To reduce backgrounds, the array is placed deep underground to shield it

UCL hosted the LEGEND Collaboration Meeting in May 2024, focused on the final preparations for the new world-leading result. UCL Physics & Astronomy colleague Prof. Oher Lahav gave a keynote science talk on determining the neutrino mass from cosmology

from cosmic rays. Each component in LEGEND is screened to ensure background impurities are minimised, and the detectors are actively shielded by the LAr, which scintillates when ionising radiation passes through, allowing for an efficient background veto. The HPGe detectors also have excellent energy resolution and are designed to distinguish signal-like events from background-like events using pulse-shape discrimination. These combined shielding and discrimination techniques allow LEGEND to achieve a flat, and nearly zero, background environment, making it a discovery-driven experiment capable of detecting 0νββ with just a few events recorded at the Q-value of 76Ge double-beta decay.

LEGEND-200 (L200), the first phase of the experiment, involves approximately 200 kg of HPGe detectors and is currently operational at the Gran Sasso National Laboratory in Italy. L200 recently released its first results at the prestigious Neutrino 2024 biennial conference after 270 days of operation, combining data from its predecessor experiments, GERDA and MAJORANA. No significant excess of events was observed, setting a lower limit on the 0νββ half-life of 1.9 x 1026 years. The UCL group played a pivotal role in achieving this result, leading efforts in data acquisition, processing, quality monitoring, and analysis under the guidance of Dr Matteo Agostini, L200's analysis co-lead. UCL also recently hosted the LEGEND collaboration meeting, where key plans for the release of this result and the subsequent paper were finalised. Furthermore, the UCL team has been heavily involved in modelling L200's background and developing improved simulation techniques for HPGe detectors.

The next phase, LEGEND-1000 (L1000), will scale up the experiment to one tonne of HPGe detectors, with a 0νββ half-life discovery sensitivity better than 1028 years, completely covering the phase space for the so-called "inverted hierarchy" neutrino mass ordering. This project has been prioritised by both US and European funding agencies as the future experiment with the best discovery power.

This is an exciting time for 0νββ research as L200 progresses into advanced data-taking stages, allowing it to set world-leading limits on the 0νββ half-life and, in the coming years, L1000 begins construction. The future holds significant promise for unravelling the deep mysteries of the neutrino and its role in the universe, with UCL ideally placed to be part of the expedition.

Atomic, Molecular, Optical and Positron Physics (AMOPP)

The impact and international visibility of the **Atomic Molecular Optical and Positron Physics** (AMOPP) group's major research activities in Precision Tests of Fundamental Physics, Quantum Optics & Quantum Information Theory, Quantum Optomechanics, Quantum Interfaces & Sensing, Attosecond Physics, Molecular Physics & Spectroscopy and Optical Biophysics has continued to go from strength to strength over the last year.

Theoretical work on reconciling **gravity and quantum mechanics** has been central to the research output of the group this year. This has been pursued from a quantum information theory perspective. It has included work led by Prof Jonathan Oppenheim on the construction of a **postquantum theory of classical gravity**, in which classical gravity is coupled to quantum field theory in a consistent way; studies of the conditions under which a quantum system can be taken to its classical limit, by reducing ħ toward zero, to allow the investigation of consistent classical-quantum dynamics; and an investigation of the trade-off between gravitationally induced decoherence of a quantum system, and diffusion in classical phase space as are required to occur when distinct classical and quantum systems are coupled. Further work in this area has been carried out by Prof Sougato Bose. This has, for example, included studies of effects of gravitational entanglement in Stern-Gerlach interferometers for massive objects with large spin; approaches to the generation of macroscopic spatial superposition states of objects with large mass for tests of non-classicality, and the development of mass-independent schemes to test the quantumness of massive objects; an analysis of the optimal spatial extent of superpositions of separated momentum states for particle detection; and investigations of photon-matter entanglement for light propagating in a gravitational field in the quantum regime, when both the light and the matter exhibit nonclassical features.

Further work in the broader area of **Precision Tests of Fundamental Physics** has included experiments led by Prof David Cassidy to generate energy-tunable beams of positronium atoms in the excited 2 $^2S_1$ metastable level; measure excited state lifetimes; and precisely measure the $n = 2$ fine-structure intervals by high-resolution microwave spectroscopy. There is also significant ongoing work in collaboration with researchers in the HEP group in this general area. This has included the generation and manipulation of cold dense beams of atomic hydrogen isotopes for a measurement of the absolute neutrino mass (Hogan), and the development of approaches to Dark Matter detection using levitated nanoparticles (Barker). Dr Luke Caldwell continues to develop activities in his laboratory to exploit ultracold molecules for tests of fundamental symmetries.

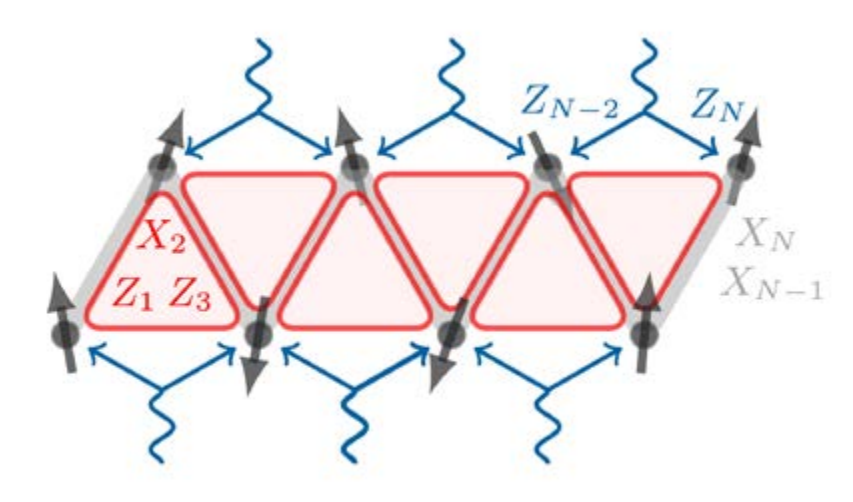


Fig.1: Model of a many-body spin system with three-spin interactions (red triangles), two-spin perturbations (grey lines) and coupling to an environment (wavy blue arrows). From Paszko, Rose, Szymańska and Pal, PRX Quantum 5, 030304 (2024).

Research in the area of Quantum Optics & Quantum Information Theory has included activities led by Prof Marzena Szymańska on phase transitions in driven dissipative spinor quantum fluids; tuning coherently driven systems of micro-cavity polaritons to access regimes of superfluid behaviour; and the identification of symmetry protected topological states suitable for quantum information processing in open quantum systems (see Fig. 1). In addition to this, Prof Dan Browne has led work on the parallelization of approaches to quantum error correction that would enable a route toward scalable fault tolerant quantum computing (see Fig. 2); a variational quantum eigensolver that exploits a set of fault-tolerant gates and could be implemented on an error-corrected quantum computer; and a fast new quantum approach to tackling combinatorial optimisation problems. Prof Alessio Serafini has led work on the quantum information associated in random quantum scattering processes, and the entropy of entanglement in scalar quantum electrodynamics. This area has also included work led by Prof Sougato Bose on coherent quantum dynamics for low-dissipation data transfer, and digital quantum simulation of gravitational optomechanics using IBM quantum computers.

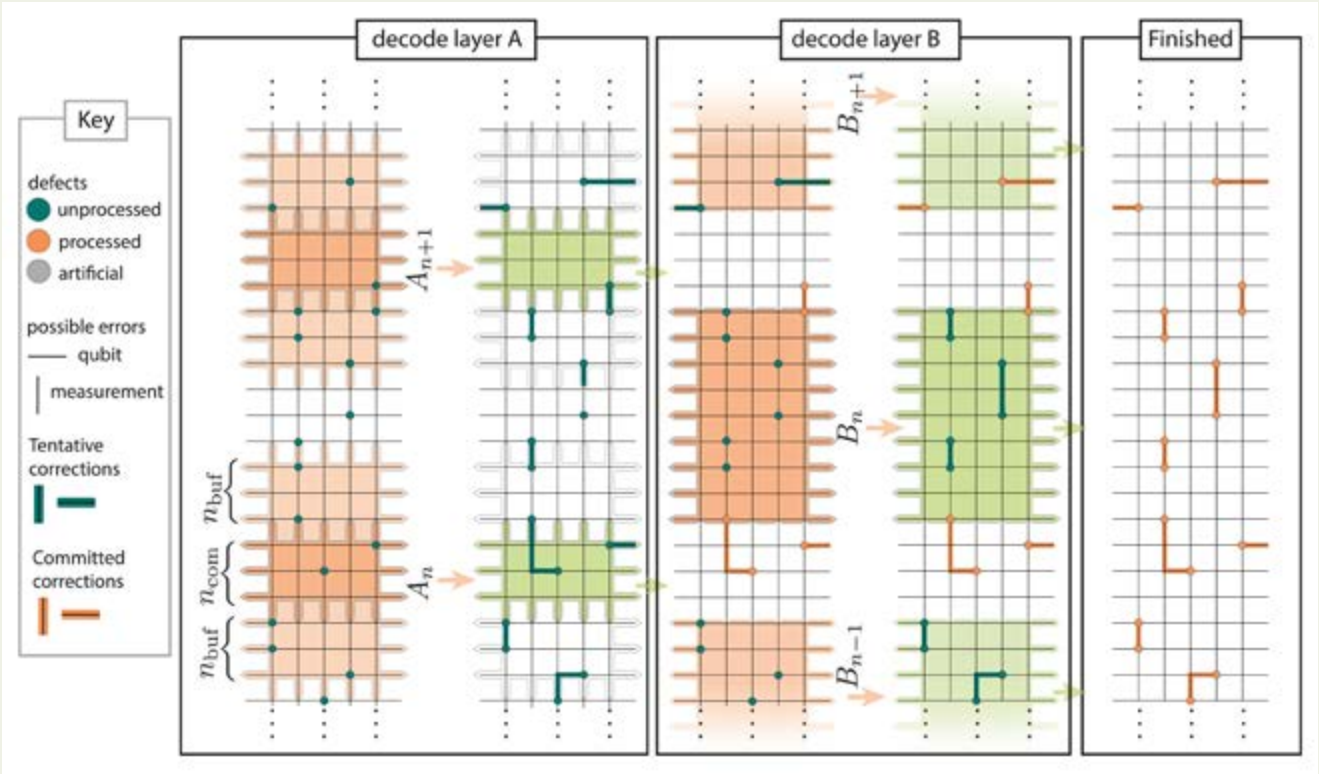


Fig. 2: Diagram representing a parallel window decoding scheme that could enable scalable fault tolerant quantum computation. From Skoric, Browne, Barnes, Gillespie and Campbell, Nature Comms. 14, 7040 (2023).

The work of Prof Peter Barker and Prof Tania Monteiro on **Quantum Optomechanics** has led in the last year to the award of a patent covering an inertial sensor based on whispering gallery mode optical resonators; theoretical work on sympathetic cooling levitated nanoparticle using laser cooled atoms; the use of levitated optomechanical systems for sensing directional broad-band noise signals of the kind of interest in searches for Dark Matter (see Fig. 3); and studies of polarization blockade effects in the hyperpolarization of nuclear spins using optically active defects, such as NV centres in diamond. This is of interest in NMR based approaches to quantum information processing and nanoscale MRI.

In the broader area of **Quantum Interfaces & Sensing** Prof Ferruccio Renzoni has led work on using neural networks to aid in the optimisation of radio-frequency magnetometers. Prof Stephen Hogan's group have realised tunable interfaces between Rydberg atoms and superconducting microwave circuits with significantly reduced sensitivity to stray electric fields by dressing the atoms with additional microwave fields.

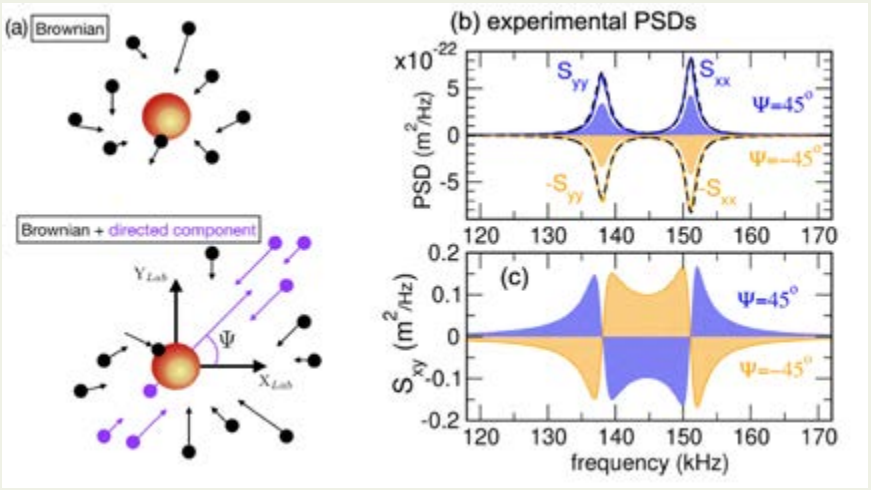


Fig. 3: Interaction of a levitated nanoparticle with directional broad-band noise (a) which imparts a calibration-free signature on the cross-correlation spectrum (c). From Gosling, Pontin, Iacoponi, Barker and Monteiro, Phys. Rev. Research 6, 013129 (2024).

In the area of theoretical **Attosecond Physics** Prof Agapi Emmanouilidou has led the development of a three-dimensional semiclassical approach to treating the ionisation of three or more electrons during dissociation of small molecules in high-intensity infrared laser fields; work on correlated three-electron ionisation of atoms in infrared fields of this kind; and strong-field photoelectron spectroscopy to detect molecular chirality using laser pulses that are arranged to synthesise a locally chiral electric field. Prof Carla Faria has led activities centred around the implementation of strong-field path integral methods, and studies of catastrophes and hidden dynamical symmetries in ultrafast photoelectron holography and spectroscopy, respectively; investigations of the impact of the continuum Coulomb interaction in quantum-orbit based calculations of high-order above threshold ionisation; and interference effects in below threshold non-sequential double ionisation in few-cycle laser pulses.

In the area of **Molecular Physics & Spectroscopy** Prof Jonathan Tennyson led the 2024 release of the ExoMol data base. This contains spectral line lists for 91 molecules, and 224 isotopologues with a total of almost 10^{12} individual transitions. This database is widely used in modelling exoplanet atmospheres, cool stars, and for terrestrial applications. He has also led work on an empirical determination of the rovibronic energy levels of C_3 which plays an important role in astrophysics and carbon plasmas; studies of Rydberg states in He_2 using R-matrix methods; the numerical equivalence of adiabatic and diabatic representations of diatomic molecules; the absorption spectrum of the radioactive water isotopologue $H_2{}^{14}O$; and studies of the UV spectra of Ar, N_2, O and CO in the atmosphere of Mars. Prof Sergey Yurcheko has led work on the implementation of machine learning approaches to predict rotational state dependences of spectral line broadening; the analysis of the out-of-equilibrium chemistry that occurs in hot Jupiter-like exoplanets; and contributions of photochemical processes to the observation of SO_2 in exoplanet atmospheres. In this area Prof Stephen Hogan led experiments to prepare cold trapped N_2 molecules for the first time (see Fig. 4). This was achieved by laser photoexcitation of the molecules to high Rydberg states and subsequent deceleration and trapping using inhomogeneous electric fields; and first studies of effects of rotational and vibrational excitation on the decay of electrostatically trapped Rydberg NO molecules.

In the area of **Optical Biophysics** Prof Alexandra Olaya-Castro has led theoretical work on contributions from the vibrational degrees of freedom in biological molecules relevant to photosynthesis, to excited state decay processes in cavities. In this area Prof Angus Bain leads studies of time- and polarization-resolved fluorescence in biological molecules to study energy transfer processes and binding configurations.

Over the last year members of the AMOPP group have contributed to important large-grant successes. Prof Ferruccio Renzoni will contribute through his work on atomic magnetometry to the '*The UK Quantum Biomedical Sensing Research Hub (Q-BIOMED)*' which is led at UCL by Prof. Rachel McKendry in the LCN. Prof Sougato Bose, Prof Dan Browne and Prof Marzena Szymańska have contributed as co-directors to the new *'EPSRC Centre for Doctoral Training in Quantum Computation and Quantum Communications (QC2)'*.

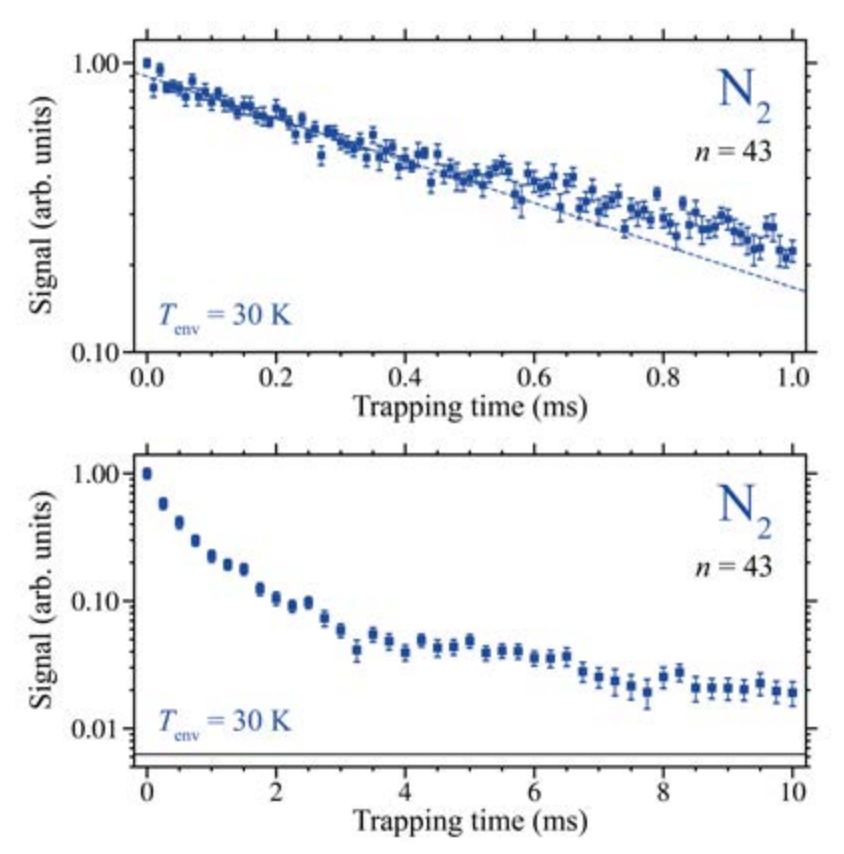


Fig. 2: Diagram representing a parallel window decoding scheme that could enable scalable fault tolerant quantum computation. From Skoric, Browne, Barnes, Gillespie and Campbell, Nature Comms. 14, 7040 (2023).

We have also seen particular successes this year in the award of prestigious fellowships for early career researchers. Dr Luke Caldwell was awarded a UKRI Future Leaders Fellowship to support his experimental work on using 'Ultracold triatomic molecules as *Quantum Sensors for New Physics*'. This was the first of these fellowships to be awarded to a researcher in our department. Dr Valentina Zhelyazkova was awarded a Royal Society University Research Fellowship to join us in early 2025 to open a new line of experimental research on low-temperature (< 1K) ion-molecule scattering enabled by excitation of neutral species to high Rydberg states.

The 2024 AMOPP H**arrie Massey Lecture** was given by Prof Dmitry Budker (Johannes Gutenberg University, Mainz; Helmholtz Institute Mainz;

University of California, Berkeley). The title of this year's lecture was *'How big is your tabletop? Many ways to explore fundamental questions'* and connected to a growing range of research activities that link the AMOPP, HEP and Astro groups in the department.

This year's **Carey Foster Prize** 'for outstanding postgraduate physics research in AMOPP' was awarded to Dr Thomas Mellor (supervisor Prof Sergey Yurchenko) for his theses on *'Method Development in Rovibrational Calculations of Polyatomic Molecules'*.

Biological Physics (BioP)

The Biological Physics (BioP) group has welcomed the arrival of Dr Jaime Agudo-Canalejo and Dr Kabir Hussain as our new lecturers in Theoretical and Computational Biophysics. The teams within BioP continue to develop exciting interdisciplinary research, applying physics to explore biosystems from the molecular to the multicellular scale.

Jaime Agudo-Canalejo develops theory and computational modelling of nonequilibrium processes in biology at the smallest scales (subcellular down to molecular) as well as in synthetic active matter. Research in his lab include the nonequilibrium transport and collective behaviour induced by the catalytic activity of enzymes, the mechanisms, and effects of compartmentalization in lipid membranes and biomolecular condensates, and the stochastic (thermo)dynamics of biomolecular machines such as enzymes, molecular motors, and nanoswimmers. Some of his recent research has shown how catalytically active particles like enzymes can sense each other through the chemical gradients that they produce [1].

Kabir Hussain develops theory and experimental approaches to understand how the parameters of biological evolution emerge from physical interactions at the molecular scale. A particular focus is the study of mutations, namely, changes in the DNA sequence of an organism which have a variety of implications. The research aims to understand the rate at which mutations arise and the effect they have, using a combination of statistical physics theory and molecular biology experiment. An example of Kabir's research is the recent attempt to understand how non-equilibrium error correction evolves to lower mutation rates in biology [2].

We also welcomed Prof. Edina Rosta's joint affiliation with both CMMP and BioP. Rosta's team uses atomistic molecular modelling tools for understanding the function of enzymes with application to key chemical reactions in living organisms, particularly focusing on phosphate transfer and cleavage.

Away from UCL and surrounded by wonderful green fields, the BioP team gathered for an academic retreat at West Dean College near Chichester (Fig. 1). It was a valuable opportunity for us to share our research plans for the next five years. The fruitful discussions during the retreat have already sparked new collaborative efforts, leading to promising funding bids that will drive our research forward.

Fig 1. BioP Academic retreat. From left to right Jaime Agudo-Canalejo, Zena Hadjivasiliou, Kabir Hussain, Nick Bell, Thanh Nguyen, Angus Bain. Maxim Molodtsov was hiding behind the tree. Picture below includes Alexandra Olaya-Castro and Edina Rosta.

The research teams within BioP are actively advancing interdisciplinary research that brings a wide range of physics to investigate biosystems at different scales.

On the theory front and intramolecular level, Olaya-Castro's research team has put forward quantum optical proposals to test the quantum behaviour and vibronic mechanisms driving picosecond energy transfer in single supramolecular complexes. The team has demonstrated that frequency-resolved and polarization-filtered second-order correlations of the light emitted by these biomolecular complexes can reveal clear signatures of the quantum dynamics behind their function. Experimental realisation of this proposal is currently underway in collaboration with the University of Cambridge.

Bridging across biological scales, Hadjivasiliou's theory lab at The Crick investigates how physical phenomena drives embryo development and evolution across species. This year, the team published a review highlighting the use of math and physics to understand the diversification of biological forms. They also developed a framework that treats tissues as active porous materials, uncovering scaling properties for molecule diffusivity and tissue robustness. Currently, they are preparing this work for publication and collaborating with EMBL Heidelberg to apply their framework to zebrafish embryo development. Their research promises to provide new insights into mechano-chemical feedback in biology.

Molodtsov's lab at The Crick institute continues to explore how mechanical forces rearrange DNA, impacting gene expression and cell division, with implications for developmental diseases and cancer. In 2023-24, two PhD students made significant contributions: one uncovered how the cohesin protein maintains DNA cohesion during cell division, published in *Nature Structural and Molecular Biology*, while the other developed new tools for probing cellular forces, securing BBSRC and Crick Institute funding for advanced instrumentation.

Nguyen's lab at the Royal Institution has developed a thermochromic-based lateral flow assay (LFA) for detecting the dengue virus, the cause of a serious disease prevalent in tropical regions that often leads to hospitalizations and deaths, particularly in areas with limited healthcare. The assay offers both quantitative results via smartphone and semi-quantitative estimates of virus concentration. It boasts enhanced sensitivity with a detection limit of 1.56 ng/mL, four times better than traditional LFAs, making it a valuable tool for disease control, surveillance, and monitoring dengue infections.

Bell's lab has developed a bespoke "magnetic tweezers" microscope which allows manipulation of individual molecules of DNA and proteins to understand the biophysics of molecular assembly. The microscope utilises neodymium-based permanent magnets to create high magnetic field gradients, applying forces on DNA through small superparamagnetic beads. This instrument has been used to study DNA repair proteins, which play a crucial role in cancer, as well as to investigate how DNA structure influences the progression of Huntington's disease in collaboration with the UCL institute of Neurology.

Phil Jones's optical tweezers team uses laser light to manipulate microscopic materials, including cells and synthetic micro-objects. Their recent work focuses on "active" microparticles –objects that can extract energy from the environment to perform work. They have studied the complex dynamics of such particles in an optical speckle pattern landscape, revealing intricate motion paths driven by transverse optical momentum and enhanced by thermophoretic effects, if coated with light-absorbing material (Fig. 2). This research is expected to provide insights into broader phenomena, such as bacterial motion and animal migration. The experimental work was carried out by David Bronte Ciriza, a visiting PhD student, as part of the MSCA-ITN "Active Matter".

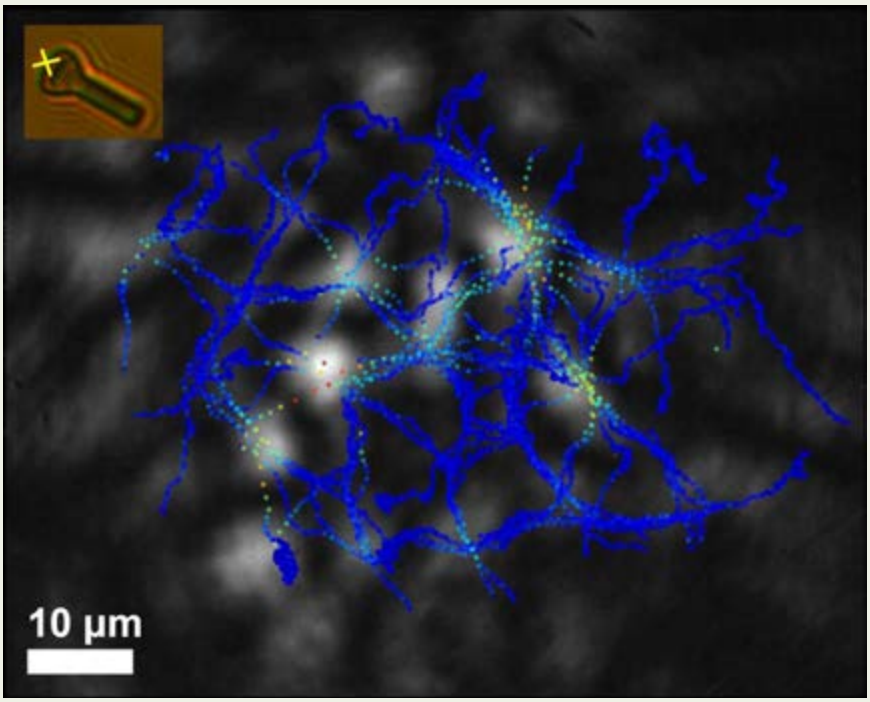
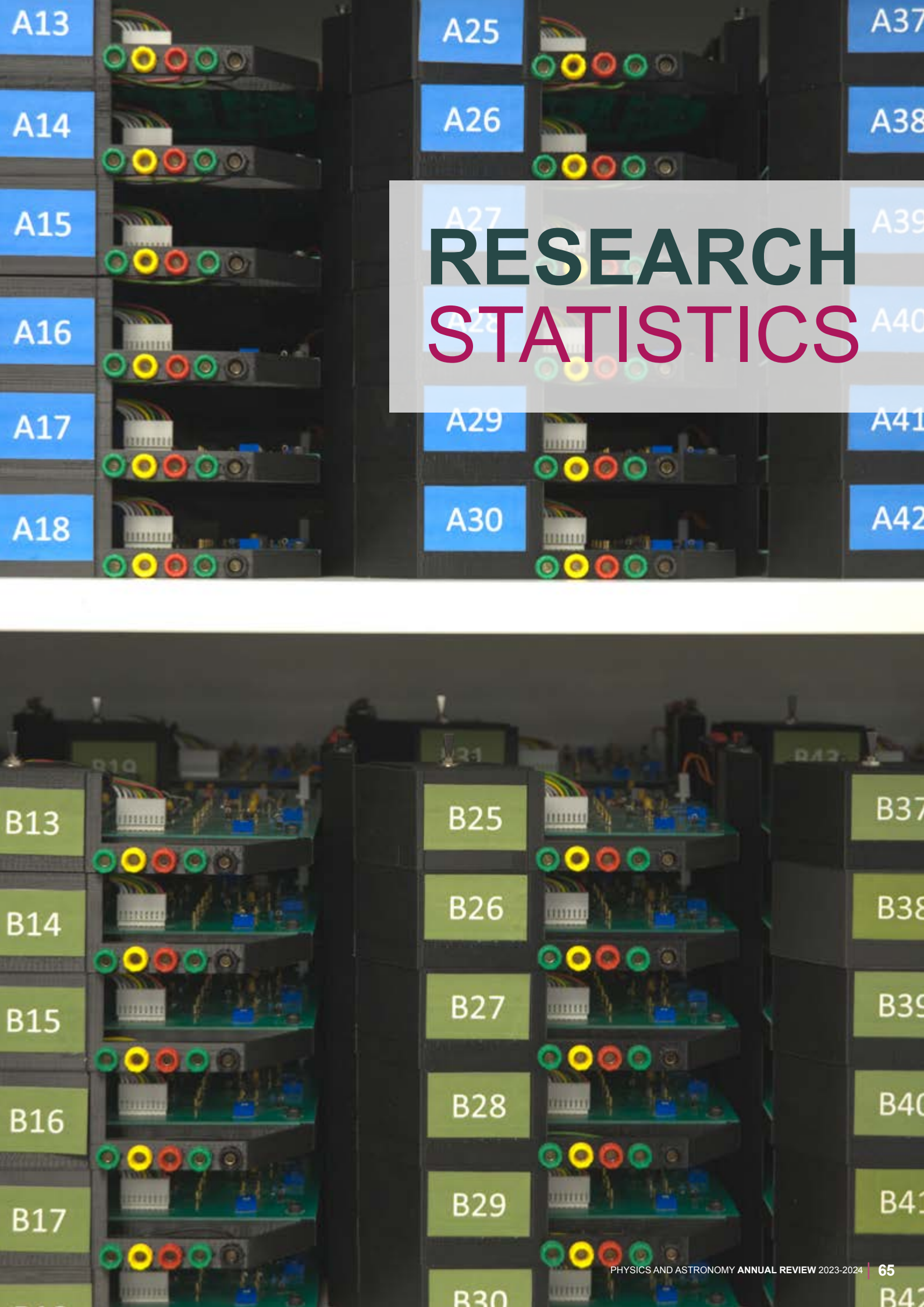


Fig. 2. intricate and dynamic network of pathways of microparticles in an optical speckle pattern landscape.

Hoogenboom's research team at the London Centre for Nanotechnology, currently focusses on investigating the additional, "outer" membrane that helps many bacteria resist antibiotics and harsh environments. Using atomic force microscopy (AFM), they have a unique, molecular-resolution perspective on bacteria as they live and die. Recent research, currently under reviews, shows how proteins in blood first perforate and next kill bacteria. The research has earned recognition through two recent BBSRC grants and a Welcome Trust Discovery Award in collaboration with the University of Oxford. Alongside these projects, Bart directs most of his time to translating his AFM expertise into commercial products via an executive role at AFM manufacturer Nanosurf.

[1] M. W. Cotton, R. Golestanian, and J. Agudo-Canalejo, "Catalysis-induced phase separation and autoregulation of enzymatic activity" , Phys. Rev. Lett. 129, 158101 (2022).

[2] R. Ravasio*, K. Husain*, et al. "A minimal scenario for the origin of non-equilibrium order." arXiv preprint arXiv:2405.10911 (2024).



RESEARCH STATISTICS

Research statistics

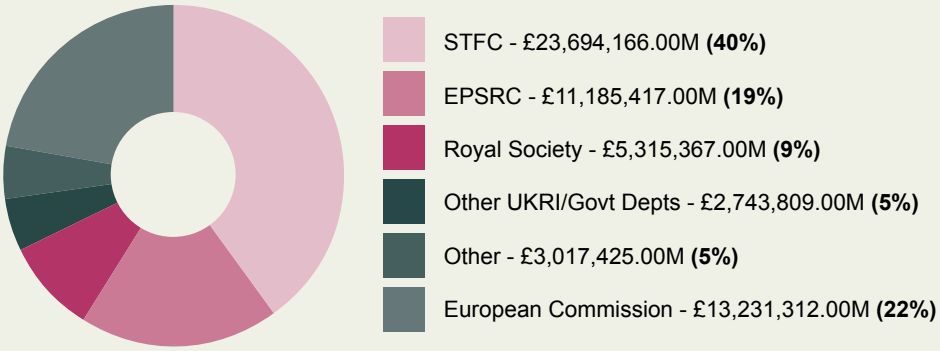
Active Grants and Contracts

In the last financial year (Aug 2023 – Jul 2024) the Department of Physics and Astronomy held an overall amount of £59 million in research grants, divided between 146 projects, awarded by 27 different funders, and held by 58 Principal Investigators.

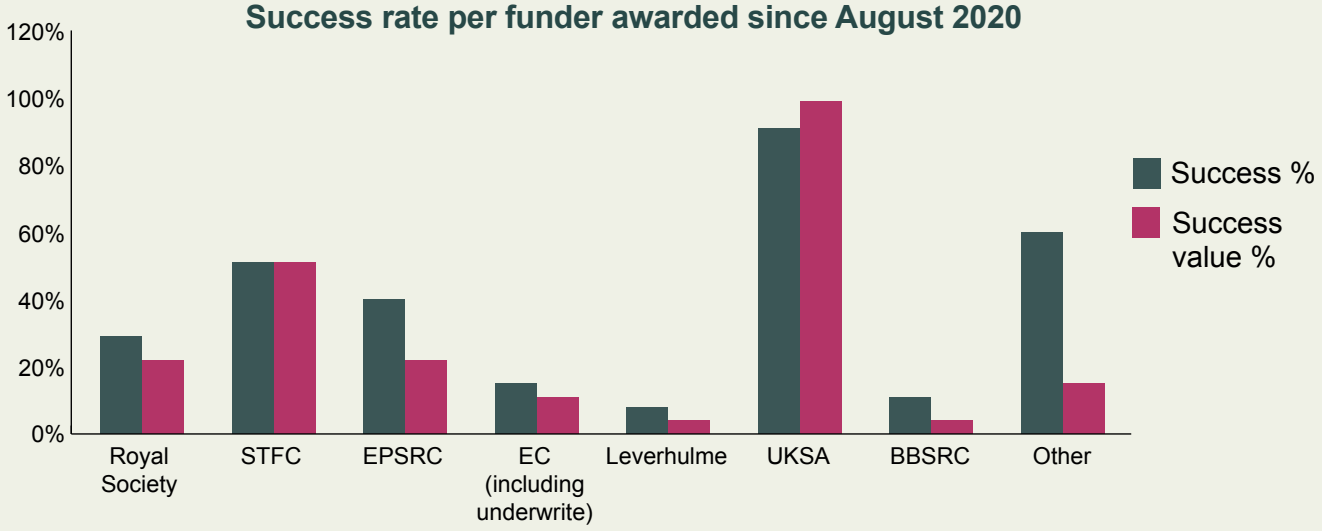
Applications

In FY 2023-24, 123 applications were submitted, of which 16 were awarded and 13 were unsuccessful. The remaining 94 are still pending a decision from the funder.

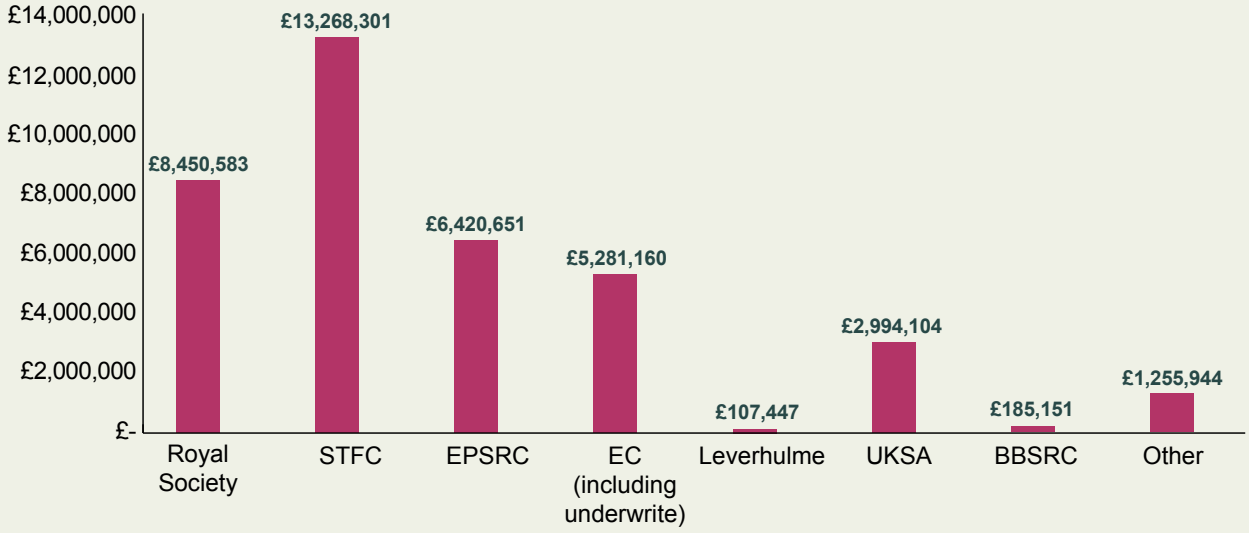
As a comparison, in FY 2022-23, 110 applications were submitted of which 33 were awarded and 77 were unsuccesful – giving a success rate of 30%.



Success rate per funder awarded since August 2020



Success rate per funder awarded since August 2020



Astrophysics (Astro)

Implementation of Coupled-Thermosphere-Ionosphere-Plasmasphere Model in ESA's Virtual Space Weather Modelling Centre (VSWMC); ESA European Space Agency; Achilleos, N, £39,370.08

Europlanet - Research Infrastructure 2020-2024; Achilleos, N, £51,091.73

Predicting the upper atmospheric response to extremes of space weather forcing; NERC Natural Environment Research Council; Aruliah, A; £49,225.00

DRivers and Impacts of Ionospheric Variability with EISCAT-3D; NERC Natural Environment Research Council; Aruliah, A; £95,222.20

CIRCE: CubeSat study of thermosphere-ionosphere dynamics; NERC Natural Environment Research Council; Aruliah, A; £51,022.50

Growing The Transformative Orbyts Research-with-Schools Programme To A National Scale; UKSA UK Space Agency; Dunn, W; £99,215.22

X-raying the Gas and Ice Giants; STFC Science and Technology Facilities Council; Dunn, W; £573,248.52

First Light; European Commission H2020; Ellis, R; £2,068,100.29

UCL Astrophysics PATT Travel Grant 2023-2024; STFC Science and Technology Facilities Council; Farihi, J; £27,430.16

DiRAC-3 Operations 2023-26 – UCL –Additional Grant; STFC Science and Technology Facilities Council; Jenner, C; £318,609.20

DiRAC Operations 2023-2026 - UCL; STFC Science and Technology Facilities Council; Jenner, C; £660,470.03

Photometric redshift estimation and DESC-related software development; STFC Science and Technology Facilities Council; Joachimi, B; £313,767.64

Euclid UK Science Ground Segment Bridging Grant Phase III; UKSA UK Space Agency; Joachimi, B; £676,068.00

Unveiling the growth of structure in the Dark Universe; UKRI Horizon Europe Underwrite; Joachimi, B; £1,926,103.38

Spectral Characterisation of Exoplanet Hosts and Other Stars; EC Horizon Europe Innovate Underwrite; Kama, M; £240,154.00

Constraining Gravity With Cosmology; STFC Science and Technology Facilities Council; Noller, J; £187,548.00

UCL/IAR Submillimetre Polarimetry Exchange Visits ; Royal Society; Pattle, K; £12,000.00

The Role of Magnetic Fields in ISM Evolution and Star Formation; Royal Society; Pattle, K; £662,130.75

Understanding the Hubble sequence; Royal Society; Pontzen, A; £356,433.96

Quantum Simulators for Fundamental Physics Version A; STFC Science and Technology Facilities Council ; Pontzen, A; £622,975.64

GMGalaxies - Understanding the diversity of galaxy morphology in the era of large spectroscopic surveys; European Commission H2020; Pontzen, A; £1,451,241.59

Cold gas as a probe of galaxy evolution: multi-phase outflows at high resolution; Royal Society; Saintonge, A; £106,838.00

Cold gas as a probe of galaxy evolution; Royal Society; Saintonge, A; £352,852.69

Cold gas as a probe of galaxy evolution: the dust connection; Royal Society; Saintonge, A; £220,670.08

UCL Astrophysics Consolidated Grant 2021-2024; STFC Science and Technology Facilities Council; Saintonge, A;£780,046.90

Studying the baryon-to-halo mass relation in galaxies with DESI and 4MOST; STFC Science and Technology Facilities Council; Saintonge, A; £462,714.69

Dynamics of the Milky Way with Gaia; Royal Society; Sanders, J; £540,863.92

6 Month Bridging - Litebird Bid For Bilateral Consortium; UKSA UK Space Agency; Savini, G; £26,303.68

LiteBIRD UK: A major UK contribution to the LiteBIRD mission - Phase1 (March 25); UKSA UK Space Agency; Savini, G; £492,795.11

LiteBIRD UK: A major UK contribution to the LiteBIRD mission - 4-month bridge funding; UKSA UK Space Agency; Savini, G; £9,070.26

Ariel Space Mission 2022 - 2025; UKSA UK Space Agency; Tinetti, G; £455,806.54

AstroChemical Origins; European Commission H2020; Viti, S; £450,516.10

Co-Sponsored PhD: "Enabling data-driven searches in ESA Astronomical images for the first time with deep learning"; ESA European Space Agency; Waldmann, I; £40,769.23

Co-Sponsored PhD: "Enabling fast modeling of large interdependent data sets using graphical neural networks"; ESA European Space Agency; Waldmann, I; £71,428.57

Liquid density-functional modelling of rovibrational molecular spectroscopy and dynamics in quantum solvents; Royal Society; Yurchenko, S; £6,000.00

Modelling of non-LTE spectroscopy of exoplanets and cool stars; STFC Science and Technology Facilities Council; Yurchenko, S; £471,544.67

Atomic, Molecular, Optical and Positron Physics (AMOPP)

3D NanoView: Unleashing A New Dimension In Electron Microscopy; Innovate UK; Barker, P; £31,624.26

Development of Levitated Quantum Optomechanical Sensors for Dark Matter Detection; STFC Science and Technology Facilities Council; Barker, P; £404,758.50

Fundamental science and technology with levitated cavity optomechanics; EPSRC Engineering and Physical Sciences Research Council; Barker, P; £745,510.00

Demonstrating The Exploration Of Dark Matter Detection Using Levitated Quantum Sensors; STFC Science and Technology Facilities Council; Barker, P; £89,452.96

Uncovering the Nonclassicality of Macroscopic Systems; Royal Society; Bose, S; £131,250.00

Levitated Quantum Diamonds; STFC Science and Technology Facilities Council; Bose, S; £121,505.00

MACON-QC: Many-Body Phases In Continuous-Time Quantum Computation; EPSRC Engineering and Physical Sciences Research Council; Bose, S; £326,701.09

Non-Ergodic Quantum Manipulation; EPSRC Engineering and Physical Sciences Research Council; Bose, S; £570,712.68

Measurement-based entanglement of single-dopant As spin qubits; EPSRC Engineering and Physical Sciences Research Council; Bose, S; £70,981.09

Nonclassicality of the Harmonic Oscillator Persisting Up to the Macroscopic Domain; EPSRC Engineering and Physical Sciences Research Council; Bose, S; £451,886.88

EPSRC-SFI: Developing A Quantum Bus For Germanium Hole-based Spin Qubits On Silicon; EPSRC Engineering and Physical Sciences Research Council; Bose, S; £280,201.00

Macroscopic superpositions towards witnessing the quantum nature of gravity; Henry Moore Foundation; Bose, S; £109,154.94

Unlocking The Potential Of Quantum LDPC Codes For Low-overhead Fault-tolerance; EPSRC Engineering and Physical Sciences Research Council; Browne, D; £451,886.88

Compilation And Verification Of Quantum Software In The Noisy And Approximate Regime; EPSRC Engineering and Physical Sciences Research Council; Browne, D; £276,946.37

Software Enabling Early Quantum Advantage; EPSRC Engineering and Physical Sciences Research Council; Browne, D; £217,076.65

Prosperity Partnership in Quantum Software for Modeling and Simulation; EPSRC Engineering and Physical Sciences Research Council; Browne, D; £328,200.00

Making quantum processors robust: from theory to practice; Innovate UK; Browne, D; £25,732.86

Quantum Computing and Simulation Hub; EPSRC Engineering and Physical Sciences Research Council; Browne, D; £252,643.08

Quantum error correction in materials simulations using machine learning based optimization; National Physical Laboratory; Browne, D; £40,000.00

Reliable and Robust Quantum Computing; EPSRC Engineering and Physical Sciences Research Council; Browne, D; £57,062.92

Unlocking The Potential Of Quantum LDPC Codes For Low-overhead Fault-tolerance; EPSRC Engineering and Physical Sciences Research Council; Browne, D; £478,506.77

Robust And Reliable Circuit Cutting; EPSRC Engineering and Physical Sciences Research Council; Browne, D; £57,062.92

Production of positronium atoms, ions, and molecules; EPSRC Engineering and Physical Sciences Research Council; Cassidy, D; £853,721.00

Precision Microwave Spectroscopy of Positronium; EPSRC Engineering and Physical Sciences Research Council; Cassidy, D; £949,020.84

Quantum Sensing for Antimatter Gravity; STFC Science and Technology Facilities Council; Cassidy, D; £368,762.00

AQuA DIP: Advanced Quantum Approaches to Double Ionisation Processes; EPSRC Engineering and Physical Sciences Research Council; Figueira De Morisson Faria, C; £388,202.00

Exploring Pump-probe Schemes For Attosecond Quantum Technologies; Institute of Physics; Figueira De Morisson Faria, C; £37,106.00

A Prototype Interface Between Neutral-atom And Superconducting Quantum Processors; EPSRC Engineering and Physical Sciences Research Council; Hogan, S; £1,012,857.28

IT from Qubit; Simons Foundation; Oppenheim, J; £473,650.81

Solving the puzzle of the nuclear magnetic octupole moment; Leverhulme Trust; Renzoni, F; £107,447.00

Gamma-ray coherent emission in a Bose-Einstein condensate of 135mCs isomers; Air Force Office of Scientific Research; Renzoni, F; £75,015.00

Pushing the Boundaries of Stochastic Resonance: Noise-assisted Image Processing; Royal Society; Renzoni, F; £12,000.00

DELTA; Innovate UK; Renzoni, F; £429,897.08

Far From Equilibrium Quantum Simulators; EPSRC Engineering and Physical Sciences Research Council; Szymanska, M; £850,350.00

Protection Of Quantum Information In Small Clusters Of Qubits; EPSRC Engineering and Physical Sciences Research Council; Szymanska, M; £211,200.00

Quantum and many body physics enabled by advanced semiconductor nanotechnology; EPSRC Engineering and Physical Sciences Research Council; Szymanska, M; £361,968.00

Radiative transport modeling in technological plasmas and combustion; STFC Science and Technology Facilities Council; Tennyson, J; £360,511.22

Exploring complexity and scalability of Near-term Quantum Computing algorithms for Quantum Chemistry; Rahko Ltd; Tennyson, J; £33,000.00

ExoMolHD: Precision spectroscopic data for studies of exoplanets and other hot atmospheres; European Commission H2020; Tennyson, J; £2,017,327.64

Primary spectrometric thermometry for gases; UKRI Horizon Europe Underwrite; Tennyson, J; £59,285.00

Biophysics (BioP)

Additional BioP grants are held through the London Centre for Nanotechnology (LCN).

Molecular mechanisms of condensate-membrane interaction and mutual reshaping; DFG; Agudo-Castro, J; £81,643.29

Micron scale electromagnetic tweezers with light controlled magnetic nanoparticles for force manipulation inside live cells; BBSRC Biotechnology and Biological Sciences Research Council; Molodstov, M; £179,778.84

Chemical synthesis and characterisation of doped iron oxide nanoflower for magnetic hyperthermia cancer treatment; Royal Society of Chemistry; Nguyen, T; £9,999.99

Comprehensive market research of magnetic nanoflowers for cancer treatments; EPSRC Engineering and Physical Sciences Research Council; Nguyen, T; £20,000.00

Real-time tracking stem cells in vivo using dual mode NIR-II fluorescence and magnetic resonance imaging ; Royal Society; Nguyen, T; £12,000.00

Bio-optomechanics: controlling molecular vibrations on a chip; EPSRC Engineering and Physical Sciences Research Council; Olaya-Castro, A; £99,698.36

Revealing unambiguous signatures of quantum coherence in photosynthetic complexes on a photonic chip; Gordon and Betty Moore Foundation; Olaya-Castro, A; £1,480,212.59

Condensed Matter & Materials Physics (CMMP)

Additional CMMP grants are held through the London Centre for Nanotechnology (LCN).

Understanding solvation and redox transformations at oxide/liquid water interfaces from machine learning-accelerated ab-initio molecular dynamics; Pacific Northwest National Laboratory; Blumberger, J; £48,221.01

Diamond masers – a new quantum technology platform; Royal Society; Breeze, J; £681,965.49

Room Temperature Continuous-Wave Inorganic Maser; EPSRC Engineering and Physical Sciences Research Council; Breeze, J; £257,411.20

Spin physics in Two-Dimensional Layered Ferromagnets; EPSRC Engineering and Physical Sciences Research Council; Howard, C; £20,391.94

Graphene Flagship Core Project 3; European Commission H2020; Howard, C; £30,539.84

Strain-tuning of Magnetic Frustration in Quantum Materials; Diamond Light Source; Johnson, R; £27,280.00

Correlated Non-Equilibrium Quantum Matter: Fundamentals and Applications to Nanoscale Systems; European Commission H2020; Pal, A; £1,237,716.24

Bionet - Dynamical Redesign of Biomolecular Networks; European Commission H2020; Rosta, E; £797,394.63

Novel Enhanced Sampling Methods in Multiscale Modeling; EPSRC Engineering and Physical Sciences Research Council; Rosta, E; £541,660.34

Establishing the Accessible Computational Regimes for Biomolecular Simulations at Exascale; EPSRC Engineering and Physical Sciences Research Council; Rosta, E; £11,094.29

Defect Functionalized Sustainable Energy Materials: From Design to Devices Application; EPSRC Engineering and Physical Sciences Research Council; Shluger, A; £470,810.80

From MEMImpedance To Complex-valued Neural Networks; EPSRC Engineering and Physical Sciences Research Council; Shluger, A; £14,513.28

Degradation and dielectric breakdown in modern HfON based devices; Synopsys Inc; Shluger, A; £36,000.00

Molecular dynamics simulation of interface structure of interface structure and interface diffusion phenomena for the Cu/TiW system; Infineon Technologies Austria AG; Shluger, A; £40,000.00

Atomistic calculations of relevant point defects near the SiC/SiO2 interface; Infineon Technologies Austria AG; Shluger, A; £45,000.00

Physical Chemistry of Reactive Interfaces in Devices; Nanolayers Research Computing Ltd; Shluger, A; £50,000.00

Understanding the Nature of the Interface Between Silicon Oxide and Slightly Oxidised Metals under Different Conditions; Intrinsic Semiconductor Technologies; Shluger, A; £65,511.13

New paradigms of quantum many-body dynamics; EPSRC Engineering and Physical Sciences Research Council; Turner, C; £463,724.32

FNR - Fundamentals of Negative Capacitance: Towards New Low Power Electronics; EPSRC Engineering and Physical Sciences Research Council; Zubko, P; £464,861.00

Materials for Neuromorphic Circuits; European Commission H2020; Zubko, P; £219,210.05

High Energy Physics (HEP)

Uncovering the Origin of Neutrino Masses through Direct Searches and Global Fits; STFC Science and Technology Facilities Council; Agostini, M; £529,519.28

SoftWare InFrastructure and Technology for High Energy Physics experiments; STFC Science and Technology Facilities Council; Butterworth, J; £106,373.63

SoftWare InFrastructure And Technology For High Energy Physics Experiments - 18 Month Extension; STFC Science and Technology Facilities Council; Butterworth, J; £89,250.51

Commissioning Studies For The Time Projection Chambers In The SBND Experiment; Universities Research Association Inc; Cicala, F; £8,904.22

XLZD Pre-Construction; STFC Science and Technology Facilities Council; Cottle, A; £414,721.57

STFC New Applicant Award; STFC Science and Technology Facilities Council; Cottle, A; £1,340.36

South-Eastern Particle Theory Alliance Sussex - RHUL - UCL 2020-2023 - UCL Node; STFC Science and Technology Facilities Council; Deppisch, F; £124,598.00

Neutrino Masses And New Physics; Royal Society; Deppisch, F; £87,500.00

Exploring The Majorana Nature Of Neutrinos; Royal Society; Deppisch, F; £12,000.00

Ultra-fast three and four-electron dynamics in intense electro-magnetic laser fields; EPSRC Engineering and Physical Sciences Research Council; Emmanouilidou, A; £430,851.06

XENON FUTURES: R&D for a Global Rare Event Observatory - Phase 1; STFC Science and Technology Facilities Council; Ghag, C; £117,773.00

XENON FUTURES: R&D FOR A GLOBAL RARE EVENT OBSERVATORY; STFC Science and Technology Facilities Council; Ghag, C; £61,887.16

LZ Spokesperson Support; STFC Science and Technology Facilities Council; Ghag, C; £200,000.00

UCL Experimental Particle Physics Consolidated Grant (2019-2022); STFC Science and Technology Facilities Council; Ghag, C ; £3,785,064.00

Spanning multi-TeV to GeV scales for collider discoveries and measurements; European Commission H2020; Hamilton, K; £291,630.34

Developing Quality Assurance Tools for Proton Beam Therapy; STFC Science and Technology Facilities Council; Jolly, S; £304,452.99

Quality Assurance Range Calorimeter for Proton Beam Therapy; STFC Science and Technology Facilities Council; Jolly, S; £364,766.58

Quality Assurance Detector for Proton Beam Therapy; STFC Science and Technology Facilities Council ; Jolly, S; £384,435.04

ATLAS Phase-2 Upgrades – Construction project; STFC Science and Technology Facilities Council; Konstantinidis, N; £970,302.00

Upgrade Of The ATLAS Detector At The LHC (2023-26); STFC Science and Technology Facilities Council; Konstantinidis, N; £643,658.14

CDT in Data Intensive Science 2017; STFC Science and Technology Facilities Council; Konstantinidis, N; £2,666,566.88

CDT in Data Intensive Science 2022; STFC Science and Technology Facilities Council; Konstantinidis, N; £1,370,168.00

Upgrade Of The ATLAS Detector At The LHC (2023-26); STFC Science and Technology Facilities Council; Konstantinidis, N; £643,658.14

UCL Experimental Particle Physics Consolidated Grant (2022-2025); STFC Science and Technology Facilities Council; Korn, A; £4,674,426.15

UCL Experimental Particle Physics Responsive PDRA Call (2022-2025); STFC Science and Technology Facilities Council; Korn, A; £259,720.04

Search for dark matter with quantum sensors; Royal Society; Malik, S; £615,507.09

DUNE Construction Grant; STFC Science and Technology Facilities Council; Nichol, R; £350,947.00

QTNM Research Visits; STFC Science and Technology Facilities Council; Saakyan, R; £50,000.00

Determination of Absolute Neutrino Mass Using Quantum Technologies ; STFC Science and Technology Facilities Council; Saakyan, R; £2,027,333.34

Quantum Extension PDRA Funds; STFC Science and Technology Facilities Council; Saakyan, R; £87,622.00

Quantifying Soil Carbon Sequestration with Gamma Spectroscopy; UNDO Carbon Ltd; Saakyan, R; £50,265.75

Deep Learning in the CHIPS water Cherenkov detector; Czech Technical University in Prague (CTU); Scanlon, T; £48,000.00

Exploring the Higgs Sector and Probing for New Physics using H->bb; Royal Society; Scanlon, T; £370,348.57

Enhancing H-bb: Exploring the Higgs Sector and Discoving New Physics; Royal Society; Scanlon, T; £199,796.22

CHROMIUM; European Commission H2020; Thomas, J; £2,287,002.17

Peering at Neutrino Oscillations with a Magnifier; Royal Society; Thomas, J; £1,289,464.41

Standard Model Phenomenology; STFC Science and Technology Facilities Council ; Thorne, R; £366,312.00

Standard Model Phenomenology 2023-26; STFC Science and Technology Facilities Council; Thorne, R; £368,377.65

LEGEND: Neutrinoless Double-Beta Decay and Germanium Detector Technology; STFC Science and Technology Facilities Council; Waters, D; £23,840.00

Production of high quality electron bunches in AWAKE Run 2; STFC Science and Technology Facilities Council ; Wing, M; £286,284.04

Advancement and Innovation for Detectors at Accelerators; European Commission H2020; Wing, M; £104,000.00

Production of high quality electron bunches in AWAKE Run 2 (2022 Award); STFC Science and Technology Facilities Council; Wing, M; £416,424.64

Production of high quality electron bunches in AWAKE Run 2 (2020 Award); STFC Science and Technology Facilities Council; Wing, M; £268,284.04

STAFF SNAPSHOT

Staff snapshot

Head of Department
Professor R. K. Prinja

Deputy Head of Department
Professor F. Renzoni

Astrophysics
Head of Group: Professor G. Tinetti

Professors:
N. Achilleos, A. L. Aruliah, A. P. Doel, R. Ellis, J. Farihi, B. Joachimi, O. Lahav, A. Pontzen, R. K. Prinja, J. M. C. Rawlings, G. Tinetti, A. Saintonge, G. Savini

Associate Professors
S. Fossey, M. Kama, J. Noller, J. Sanders, I. Waldmann

Lecturers:
F. Diego, K. Pattle,

Professorial Research Fellow:

Senior Research Fellows:
A. Al-Refaie, M. Tessenyi,

Research Fellows:
B. Augstein, W. Dunn, E. Hang, N. Jeffrey, A. Jenkins, G. Joshi, J. Karoly, G. Lawrence, K. Naidoo, N. Nikolaos, J. Ruiz-Zapatero, A. Shitvov, N. Tessore

Professional Services:
E. Dunford, J. Fabbri, C. Jenner, K. Nakum, M. Rangrej, R. Raupp, A. Williams

Computing, Engineering and Technical Staff: S. Boyle, D. Chapman, J. Deacon, E. Edmondson, T. Schlichter, S. Sullivan

Atomic, Molecular, Optical and Positron Physics
Head of Group: Professor S. Hogan

Professors:
A. Bain, P. Barker, S. Bose, D. Browne, D. Cassidy, A. Emmanouilidou, C. Figueira de Morisson Faria, S. Hogan, T. Monteiro, J. Oppenheim, F. Renzoni, A. Serafini, M. Szymanska, J. Tennyson, S. Yurchenko

Lecturer: L. Caldwell

Research Fellows:
C. Bowesman, L. Brown, L. Cruz Rodriguez, D. Das, A. Deger, A. Ferrier, R. Ghosh, J. Gosling, G. Katsoulis, E. Kilian, S. Koutsioumpas, M. Lane, D. Lewis, C. McLauchlan, C. Nation, O. Polyansky, M. Rademacher, S. Reeder, J. Romans, D. Rose, A. Sokolov, A. Strikis, B. Symons D. Toniolo, M. TorosJ. Zou, M. Webster, H. Yao

Professional Services:
A. Bountoureli

Computing, Engineering and Technical Staff:
J. Dumper, C. Godden, F. R. Jawad, F. Noyes

Biological Physics
Head of Group: Professor A. Olaya-Castro

Professors:
A. Bain (also AMOPP), J. Blumberger (also CMMP), G. Charras (Cell & Developmental Biology), B. Hoogenboom, P. Jones, T. Nguyen, A. Olaya-Castro (also AMOPP), I. Robinson (also CMMP)

Associate Professor: M. Molodtsov (Crick)

Lecturer:
J. Agudo-Canalejo, N. Bell, K. Husain

Senior Research Fellows: Zena Hadjivasiliou (Crick)

Senior Research Associates: T. Le

Research Fellows:
S. Ghosh, C. Nation, G. Pobegalov (Crick),

Professional Services: J. Gill-Thind

Condensed Matter and Materials Physics
Head of Group: Professor J. Blumberger

Professors:
J. Blumberger, D. Bowler, S. Bramwell (joint with LCN), A. Fisher, I. Ford, A. Green, C. Howard, A. Pal, I. Robinson, E. Rosta, A. Shluger, N. Skipper, M. Szymanska, S. Zochowski, P. Zubko

Associate Professors: J. Breeze, M. Buitelaar, F. Kruger, R. Johnson, R. Perry, S. Schofield

Lecturers: V. Kapil, C Perez Martinez (LCN)

Research Fellows:
D. Berta, M. Buraschi, P. Comaron, B. Dudas, B. Mukherjee, D. Rose, M. Szyniszewski, T. Wei

Most Research staff are employed through the LCN

Professional Services: J. Levin

Computing, Engineering and Technical Staff: F. Ducluzeau, F. Sidoli

High Energy Physics
Head of Group: Professor D. Waters

Professors:
J. M. Butterworth, M. Campanelli, F. Deppisch, C. Ghag, K. Hamilton, G. Hesketh, S. Jolly, N. Konstantinidis, A. Korn, R. Nichol, , R. Saakyan, T.Scanlon, J. A. Thomas, R. S. Thorne, D. Waters, M. Wing

Associate Professor: G. Facini

Lecturer:
R. Chislett, N. Nikolaou, A. Cottle

Principal and Senior Research Associates: A. Basharina-Freshville, R. Flack, P. Sherwood, B. Waugh

Ernst Rutherford Fellows:
M. Agostini, , N. McConkey (until 31/12/23)

Royal Society University Research Fellows: S. Malik

Research Fellows:
A. Al-Musalhi, S. Bash, J. Bateman, F. Cicala, D. Cooke, S. Escribano Rodriguez, L. Harland-Lang, M. Hassanshahi, S. Jones, N. Kimura, P. Manek, G. Marshall, A. Martynwood, V. Monachello, D. Newson W. Quinn, S. Rettie, M. Sakurai, R. Sheldon, L. Shi, A. Sztuc, S. Van Stroud, S. Vergani, M. Yexley

Professional Services: A. Bountoureli

Computing, Engineering and Technical Staff: H. Barnett, G. Crone, E. Edmondson, C. Godden, T. Hoare, E. Motuk, M. Warren

Teaching
Director of Education and Student Experience:
L. Dash

Director of Postgraduate Studies:
S. Zochowski

Undergraduate Careers Officer:
J. Farihi

Professor (Teaching): P. Barlett

Associate Professors (Teaching):
D. Armoogum, E. Ashgrove, J. Bhamrah, S. Boyle, S. Fossey, L. Dash, N. Nicolaou

Lecturer (Teaching):
F. Diego Quintana, J. Frost-Schenk, G. Giannopoulos, M. Szumilo

Laboratories

Director of Laboratories:
P. Bartlett

Superintendent of U/G Physics Laboratories:
D. Thomas

Senior Teaching Laboratory Technician:
B. T. Bristoll

Laboratory Technician:
E. Milner, M. A. Sterling

Experimental Development Officer:
K. Vine

The Workshop: High Precision Design and Fabrication Facility (HPDFF)

Physics, Chemical and Biochemical Engineering Facility
R. Saakyan

Admissions Tutors:
A. Aruliah (MSc), F. Diego (Astronomy Certificate), P. Jones (Undergraduate), M. Szymanska (Postgraduate Research),

Schools Liaison Officer:
C. Howard

Programme Tutors:
D. Armoogum (Undergraduate), S. Fossey (MSc), N. Nicolaou (Undergraduate), J. C. Rawlings (Astronomy Certificate), S. Zochowski (PhD)

UCL Observatory

Director: S. Fossey

Senior Observatory Technicians:
T. Schlichter (Computing and Instrumentation Officer)

Observatory Technician:
S. Sullivan

Professional Services

Departmental Manager:
L. Coletti Campbell

Deputy Departmental Manager:
L. Keepking

Senior Staffing Officer:
O. Aluoch

Senior Research Officer: R. Martin

Senior Finance Officer: A. Balcuinas

Research Administrator: J. Grimond

Education Support Team

Senior Postgraduate and Student Finance Administrator: N. Waller

Teaching and Learning Manager: S. Lovell

Senior Teaching Administrator:
H. Copeland

Postgraduate Taught Teaching and Learning Administrators: L. Dell (maternity cover), S. Begum, S. McGrath

UG Teaching and Learning Administrators: D. Balogh (secondment cover) T. Crorie, L. Medici, S. Patel

Postgraduate Research Teaching Administrator: J. Bristow

Student Advisor: A. Afriyie

Research Groups

Astrophysics Group Manager:
K. Nakum

AMOPP/HEP Research Group and Operations Administrator: A. Bountoureli

Biological Physics (BioP) Research Administration Officer: J. Gill-Thind

Finance Officer and CMMP Research Group Administrator: J. Levin

Centre Manager (Centre for Space Exoplanet Data): E. Dunford

Thomas Young Centre (TYC) & Materials & Molecular Modelling (MMM) Hub Coordinator: K. Stoneham

Project Manager and Scientific Officer (The Centre for Planetary Sciences):
J. Fabbri

Project Manager (Cosmoparticle Physics (CPP) Initiative) and Executive Assistant: R. Raupp

Project Manager (Euclid): M. Rangrej

Safety Officer and Estates Manager:
L. Bebbington

Outreach and Public Engagement

Outreach Coordinator and Ogden Science Officer: M. Fuller

Science Centre Organiser:
S. Kadifachi

Doctoral Training Centre

CDT Manager, CDT in Data Intensive Science (DIS):
R. Xu CDT

Manager, CDT in Data Intensive Science (DIS) and Industry: E. De Ben Rockson

Computing and IT

Computing Manager and IT Coordinator:
B. Waugh

Computing Administrator (HEP):
T. Hoare

IT Systems Managers: M. Mufuka (AMOPP & BioP), F. Ihsan (Teaching and Learning)

Visiting Professors, Honorary Professors and Emeritus Staff:
A. Aylward, S. Balbus, M. Barlow, D. Brooks, F. Cacialli, A. Charalambous, I. Crawford, D. H. Davis, J. Drew, M. M. Dworetsky, G. Efstathiou, M. Ellerby, M. Esten, I. Ferreras, J. L. Finney, I. Furniss, M. J. Gillan, P. Guio, A. H. Harker, K. Heng, B. Hiley, I.D. Howarth, J. W. Humberston, T. W. Jones, G. Laricchia, S. Mahapatra, B. R. Martin, G. Materlik, K. A. McEwen, A. Michaelides, D. J. Miller, R. Maiolino, W. Newell, G. Peach, K. Peters, O. Polyanksy, R. Radogna, D. Sankey, P. J. Storey, D. N. Tovee, S. Viti, C. Wilkin, D. A. Williams, Z. Yao

UCL Department of Physics and Astronomy
Gower Street • London • WC1E 6BT
www.ucl.ac.uk/physics-astronomy