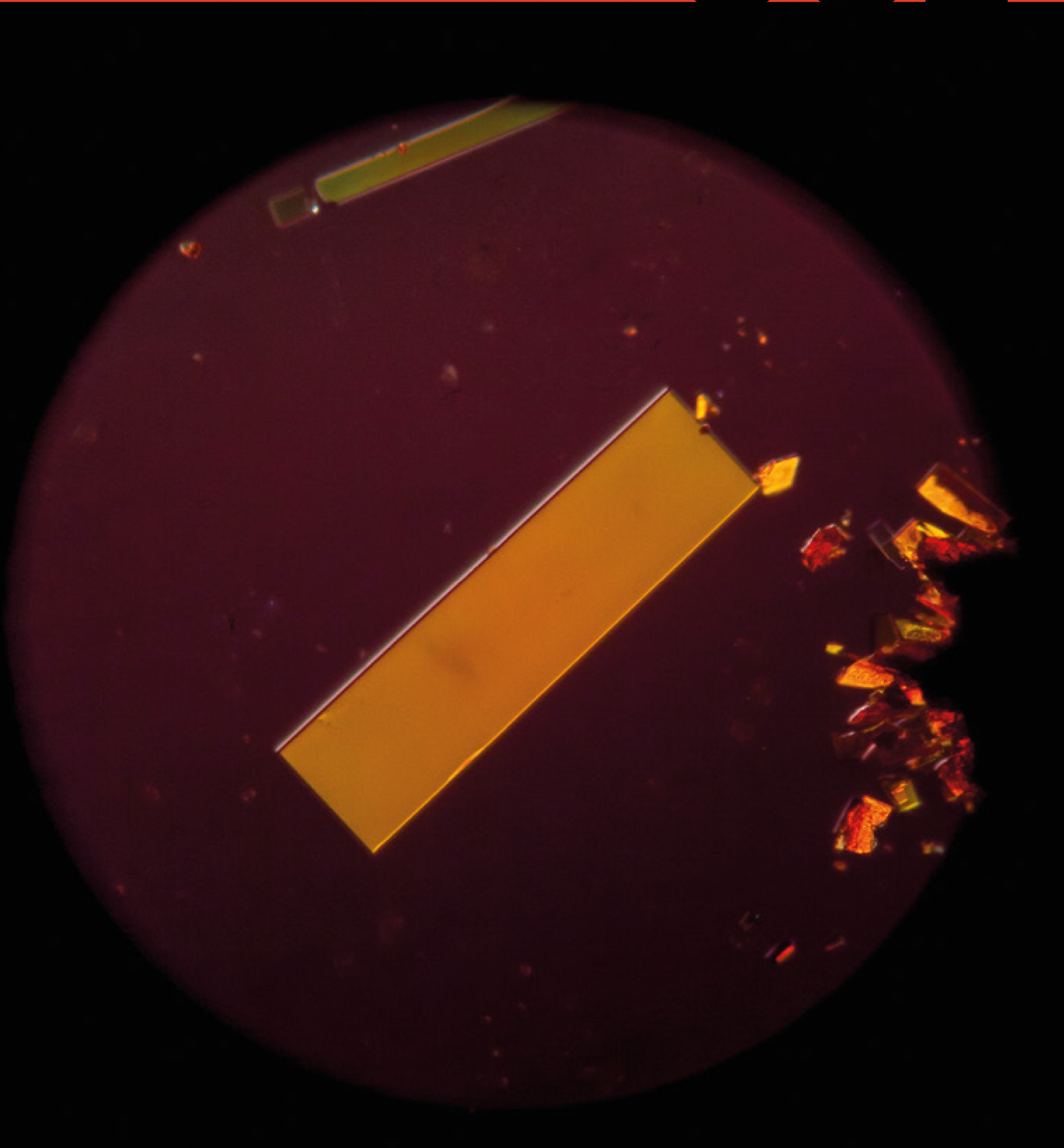
UCL DEPARTMENT OF PHYSICS AND ASTRONOMY

UCL



PHYSICS AND ASTRONOMY
ANNUAL REVIEW 2013–14

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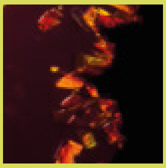
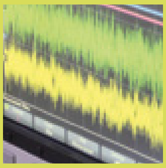
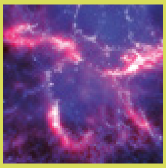



Cover image:
Optical microscope image (50x magnification) of single crystals of the C60 derivative [6,6]-phenyl-C61-butyrric acid methyl ester (PCBM), an electron transporting organic semiconductor widely used in organic solar cells.
Credit: Giuseppe Maria Paternó.

Image page 2:
Credit: UCL Media Services.

Image page 11:
Credit: Arne Wickenbrock.

Image page 17:
Credit: ESA/Herschel/PACS/MESS Key Programme Supernova Remnant Team; NASA, ESA, Allison Loll/Jeff Hester (Arizona State University) and Patrick Owen/Oli Usher (University College London).

Image page 28:
Credit: G Ghiandoni and L Paolasini (ESRF).

Review edited by **Katherine Heyworth**, k.heyworth@ucl.ac.uk

Welcome

Welcome to another edition of our Annual Review. 2013 was a busy and eventful year; the Department has continued to grow and we have made a large number of outstanding academic appointments, some of them jointly with our neighbours, the London Centre for Nanotechnology (LCN). Many of the appointees hold prestigious personal fellowships from UK research councils or the Royal Society; it is exciting to see the great science they are already producing as they settle into the Department. Page 12 of this Review introduces each member of staff and briefly describes their research.

> "This Review serves to highlight some of our most significant successes and challenges during 2013, as well as showing an appreciation towards staff and students."

On the teaching side, the Institute of Physics updated its accreditation of our degree programmes and we also underwent an Internal Quality Review. I am very pleased to report that both were successful and served to validate our approach to teaching. All three undergraduate laboratories have now been refurbished and this year has seen some technological innovations to our teaching programmes. Page 9 describes just a few of these changes. Thanks to **Raman Prinja** in his role as Director of Teaching for spearheading these advances.

2013 has also seen the retirement of two key members of academic staff; **Tony Harker** served as the Deputy Head of Department for nine years. He made a huge contribution to the Department and I am extremely grateful to Tony for the support he has given me, particularly when my tenure as Head of Department began. He not only served as the de facto Head of Department for one year, to enable me to continue my research at CERN working with the Large Hadron Collider, but his essential contribution continued when I returned. Raman Prinja has now taken over as the Deputy Head of Department, and I am grateful to Raman and to **Hilary Wigmore**, Departmental Manager, for ensuring a smooth transition after Tony's departure. **Ian Furniss**, who in his capacity as Programme Tutor has supported many undergraduate students, also retired this year, and I wish him all the very best in his retirement.

There have been many exciting science highlights over the past year, some of which are featured in this Review: the data from the Planck satellite on the cosmic microwave background was cited by Physics World as one of the top ten breakthroughs of the year (page 14); Peter Higgs (an ex-lecturer in UCL Mathematics and now a UCL Honorary Fellow) won the Nobel prize with Françoise Englert for the discovery of the Higgs boson at the Large Hadron Collider – a project several of us worked on here at UCL (page 13). The Jupiter Icy Moons mission (JUICE) was approved by European Space Agency (ESA), with major participation from the Department and the Mullard Space Science Laboratory (MSSL) (page 26), and funding was recently approved for the UCLH proton therapy unit, an exciting development in which we have a strong research interest.

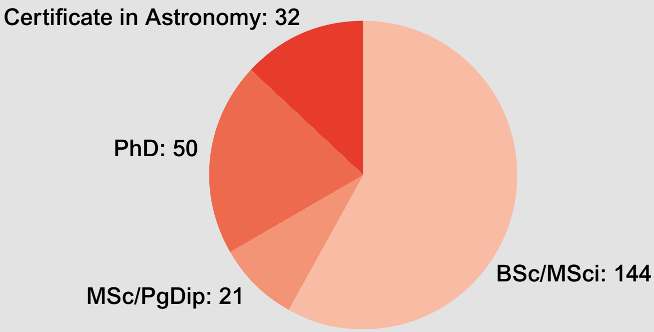
This Review serves to highlight some of our most significant successes and challenges during 2013, as well as showing an appreciation towards staff and students; many of whom have made a notable contribution not only to science, but also to the life of the Department.

Professor Jonathan Butterworth
Head of Department

Community Focus

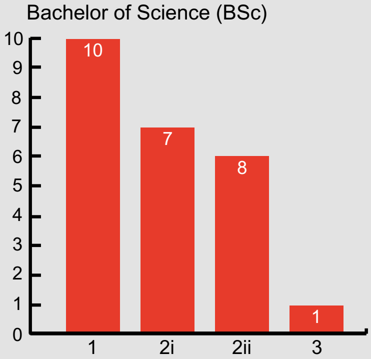
Teaching Lowdown

Intake

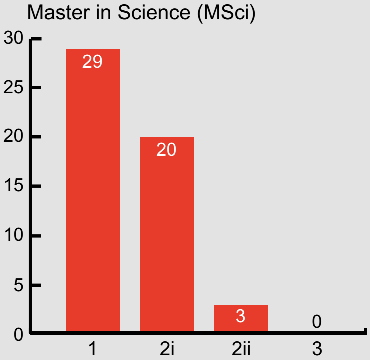


Awards

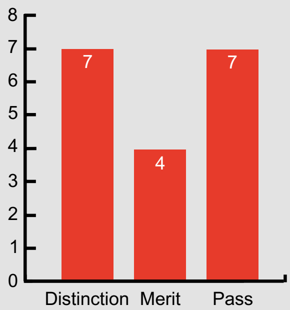
Bachelor of Science (BSc)



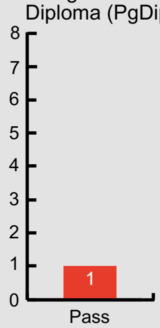
Master in Science (MSci)



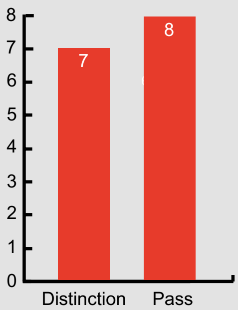
Master of Science (MSc)



Postgraduate Diploma (PgDip)



Certificate in Astronomy



Headline Research

New material for quantum computing discovered out of the blue

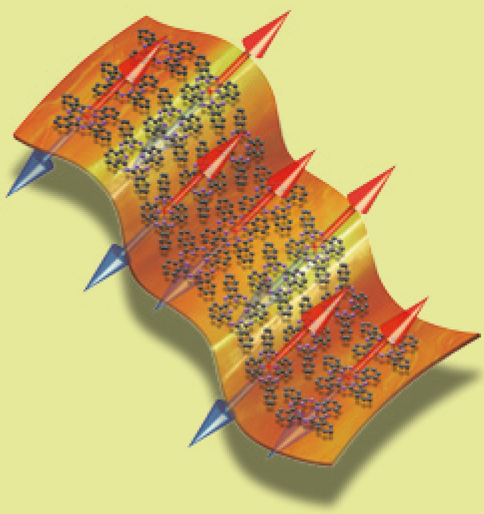
A common blue pigment found in many household products, including the £5 note, could have an important role to play in the development of a quantum computer.

Quantum computers have the potential to efficiently solve certain problems which would be very hard for classical computers. They are distinguished from their classical counterparts by the ability of the underlying quantum bits (qubits) representing the information, to exist in two states at once, in so-called ‘superposition states’.

The blue pigment, copper phthalocyanine (CuPc), is a low-cost organic semiconductor where the electron spins can remain in ‘superposition’ for surprisingly long times. This means that this simple dye molecule may have the potential to be a medium for quantum technologies.

Crucially, CuPc can be processed into a thin film that can be readily used for device fabrication, a significant advantage over similar materials that have been previously studied.

Published by **M. Warner**, **G. W. Morley**, **A. M. Stoneham**, **J. A. Gardener**, **A. J. Fisher**, **G. Aeppli** and co-authors, Potential for spin-based information processing in a thin-film molecular semiconductor, Nature, 503 (2013).



Credit: Phil Bushell, Sandrine Heutz, Gabriel Aeppli, and James Gilchrist.

Student Accolades

Undergraduate Awards

Departmental Awards

Oliver Lodge Prize
Best performance first year physics
Jamie Parkinson

Halley Prize
Best performance first year astronomy
James Fernandes-Pettingill

C.A.R. Tayler Prize
Best second year essay/comms
Anamaria Barburas

Wood Prize
Best performance second year physics
Harapan Ong

Huggins Prize
Best performance second year astronomy
Felix Priestley

David Pointer Prize
Most improved performance first and second year
Mark Longhurst

Sydney Corrigan Prize
Best performance in second year experimental work
Sebastian Bending

Sessional Prize
Best performance third year physics
Yago del Valle-Inclan

Sessional Prize
Best performance third year astronomy
Sandor Kruk

Additional Sessional Prize for Merit
Best fourth year physics project achieving a balance between theoretical and practical physics
Abigail Van Cleef & Liam Cooper

Burhop Prize
Best performance fourth year physics
James Auger

Herschel Prize
Best performance fourth year astronomy
Marco Rocchetto

Brian Duff Memorial Prize
Best fourth year project in the department
Emma Barton (Nat Sci)

William Bragg Prize
Best overall undergraduate
Zhi Wong

Tessella Prize for Software
Best use of software in final year physics/astronomy projects
James Cockburn

Faculty Awards

(only physics and astronomy winners are listed here)

Faculty Medal
Zhi Hao Wong

Dean's List
Yago De Valle-Inclan
James Auger
Leon Gatys
Sami Al-Izzi
Marios Zacharias
Marco Rocchetto

Postgraduate Awards

Harrie Massey Prize
Best overall MSc student
Yik Chan

Carey Foster Prize
Outstanding postgraduate research physics, AMOPP
Susan Skelton

HEP Prize
Outstanding postgraduate research physics, HEP
Stephen Bieniek

Marshall Stoneham Prize
Outstanding postgraduate research physics, CMMP
Bo Chen

Jon Darius Memorial Prize
Outstanding postgraduate research astrophysics
Stephen Feeney

External Awards

Royal Astronomical Society Michael Penston Thesis Prize (runner up)
Stephen Feeney

Physics and Astronomy prize winners 2013

University of London Observatory

Robotic Observing at the University of London Observatory (ULO)

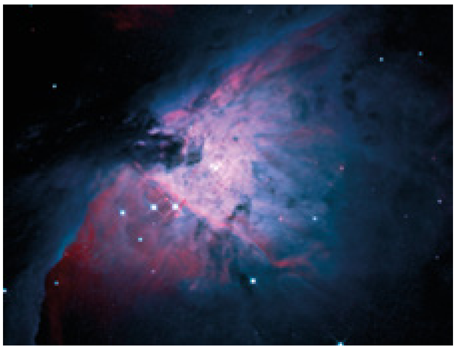
The traditional picture of the astronomer conducting observations is of someone standing at the ‘little end’ of a telescope, wrapped up in warm clothing, manually adjusting mechanisms in near-total darkness. However, modern telescopes invariably use computer control for pointing, tracking targets and data acquisition. This means that the contemporary astronomer can operate instruments from the keyboard, in the well-lit warmth and comfort of a control room. A dedicated control room is typically located adjacent to the telescope but the reliability of networking means that there is no longer any compelling need for an observer to be physically close to the equipment, thus resulting in the eminent possibility of remote observing. Moreover, intelligent software (to the extent that there is such a thing) means that it is not even necessary to operate in real time; observations can be scheduled and performed automatically, robotic observing.

> “This robotic system means that every student can reliably acquire their own data, even if the weather is poor during scheduled classes.”

While robotic observing is conceptually simple, many tasks that are trivial for an on-site observer, such as assessing the current and imminent weather conditions or recognising a target and centring it in the telescope field of view, are significant challenges for a fully automated system; especially when that system has to be secure, reliable, and fail-safe. After several years of systems development and testing, the 2012/13 academic year saw the deployment of robotic observing as an integral part of the routine undergraduate courses at the Department’s University of London Observatory (ULO).

This robotic system means that every student can reliably acquire their own data, even if the weather is poor during scheduled classes. As well as requiring students to draw up observing plans that require a knowledge of basic celestial co-ordinates (“is this object observable from ULO at this time of year?”), activities include projects grounded in current research, such as monitoring exoplanetary transits and photometry of variable stars. These imaging tasks are of value in developing image-processing skills and the results can be highly motivating. The accompanying images illustrate results from student programmes conducted over the last academic year. The specialist CCD cameras used in astronomy record monochrome images and separate observations are made through different filters (typically red, green, and blue), they are then combined to form the colour images shown here.

M1 – The Crab Nebula is the remnant of a supernova that was observed to explode in 1054. The red filaments are the detritus of the progenitor star while the blue light from the inner regions arises from high-energy particles emitted by a central pulsar, visible at the heart of the nebula.



M42–the Orion Nebula is the nearest easily observed site of massive-star formation, and can be seen with the naked eye. The nebula is lit up from within by stars that formed from its gas and dust.

Hardware and electronics integration for the project was carried out by ULO technical staff, **Mick Pearson** and **Thomas Schlichter**. The web-based interface to the underlying software infrastructure, as well as much back-end functionality was created by undergraduate student **Marco Rocchetto**. The initial data-processing pipeline was built by **Dominic Reeve**. Marco and Dominic’s efforts were in part funded by a UCL E-learning Development Grant and by the Royal Astronomical Society.

By Professor Ian Howarth and Dr Steve Fossey

• STOP PRESS • STOP PRESS •

Supernova in Messier 82 discovered at ULO

Students and staff at UCL’s training observatory, the University of London Observatory, were the first to spot one of the brightest supernovae in recent decades. The team discovered the exploding star on 21 January 2014 in the nearby galaxy Messier 82 (the ‘Cigar galaxy’), during a routine telescope-training session led by Senior Teaching Fellow **Dr Steve Fossey**.

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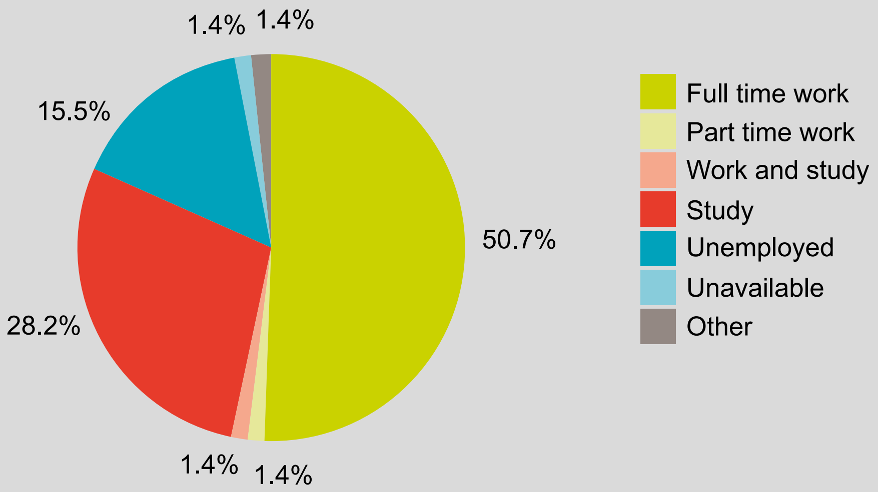
Career Profiles

Graduate Destinations

Total Number of Graduates: 112

Response Rate: 83.32%

Median Salary: £28,000
(full time employment)



Data for 2012 graduating cohort, compiled in June 2013

Adam Davison

Data Scientist, MSci Physics (2006), PhD Physics and Astronomy (2011)

I joined UCL as an undergraduate Physics student in 2002. The combination of interesting people and great research opportunities led me to stay for a PhD and subsequent position as Research Associate. My research at UCL was focussed on the much publicised search for the Higgs boson with the ATLAS experiment at CERN. Being involved in such a high profile international enterprise brought opportunities to travel the world and work with some fantastically smart people. The intense public interest also meant that explaining what you do for a living in the pub, often turned into a fifteen minute Physics lecture!

In 2013 I decided it was time to move on to something new. Luckily, it turns out that some of the problems high energy physicists have spent the last twenty years solving, such as how to analyse data when it arrives at a rate of about one CD per second, are now being faced by many commercial organisations. So, I'm now applying the expertise I gained in seven years of research at UCL, as a Data Scientist in the online retail industry.

> "Luckily, it turns out that some of the problems high energy physicists have spent the last twenty years solving, are now being faced by many commercial organisations."

Overall my time at UCL was fantastic, I met many interesting people and had experiences I don't think I could have had anywhere else. The photo shows just where physics got me.

Lyn Penfold

Lawyer, BSc Chemistry and Physics (1983)

After completing my joint honours degree in Physics and Chemistry, I spent several years as a PhD research student, first in the High Energy Physics (HEP) team and later the thermodynamics group in the Chemistry Department. I never wrote up my PhD – after meeting my partner Pete Fitch, also a member of Physics and Astronomy, and the birth of our daughter Zoë (aka "the Fitchlet", thanks to **Tegid Jones**!), it was difficult to find the time, energy and concentration to do so. Looking for a more commercial role, I joined Donovan Data Systems as an analyst programmer, hoping to move into the business side of the company. When that did not materialise, I spent a couple of years selling large software systems. Through selling, I came into contact with many lawyers who were having a better time than I was, so I did a conversion course at the College of Law in London with sponsorship from Baker & McKenzie, who were the largest law firm in the world at the time.

"I love the work I do: it combines logic, commerce, people and challenges."

After a period working in the City as a lawyer specialising in technology, I joined BT, where I managed the rollout of a major communications system to the NHS. I then moved to Vodafone Global Enterprise, where I negotiated multinational technology and services contracts, and later to SunGard Public Sector where I led the commercial team through the sale to Capita. I recently joined IPL Information Processing Limited in Bath as General Counsel, and have expanded my remit to cover all the business services apart from finance.

I love the work I do: it combines logic, commerce, people and challenges. No two situations are ever the same. In a commercial negotiation, I enjoy using a constructive and creative approach to get both sides happy with the outcome.

Meanwhile, I'm delighted to say that Zoë has successfully completed her degree and PhD at Cambridge, in Physics (what else, it's in her genes from both parents). She has now left academia and works in the City.

Headline Research

Fundamental limitations for quantum and nanoscale thermodynamics

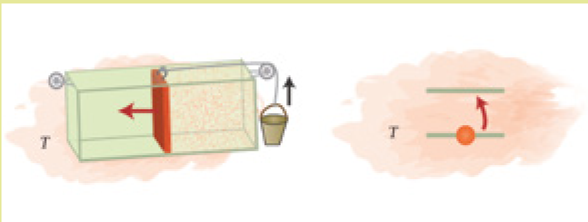
In an important theoretical breakthrough, researchers have established new laws in the rapidly emerging field of quantum thermodynamics. They argue that when applied to small systems, the present understanding of thermodynamics must be fundamentally modified.

The laws of thermodynamics govern much of the world around us, for example they tell us that a hot cup of tea in a cold room will cool down rather than heat up. However this only applies to large objects, when many particles are involved.

Small systems behave very differently due to quantum effects. In this breakthrough theoretical research, a new set of laws have been established which determine what happens to microscopic systems when they are heated and cooled.

It was found that one of the basic quantities in thermodynamics, the free energy, does not determine what can happen in small systems. Instead, several new free energies govern behaviour. In addition, microscopic heat engines are not as efficient as their larger counterparts.

Published by M. Horodecki, **J. Oppenheim**, 'Fundamental limitations for quantum and nanoscale thermodynamics', Nature Communications 3, 2059 (2013).



Credit: Lidia del Rio

Alumni Matters

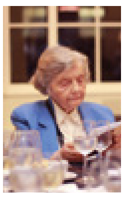
The first Physics and Astronomy Gala Dinner was held on the 25th of October 2013. It was an unprecedented opportunity for some thirty undergraduate and postgraduate students, thirty-six Alumni and twenty members of staff plus guests to come together for the Awards Ceremony. The evening began with a drinks reception, followed by the Gala Dinner and concluded with the 'After Dinner Speaker', which had been a feature of the previous annual alumni dinners.

It was an extremely uplifting experience to learn of the tremendous achievements of our students and to witness the Award Ceremony, with several awards and postgraduate studentships having been funded by our Alumni. Academics of my generation have perhaps an unspoken suspicion that we were much better behaved in our day. As I related in my introduction to Charlotte Nichol (née Waterhouse), our 'After Dinner Speaker'; in 1959, a certain Dr Peter Higgs was appointed as a temporary junior lecturer in the UCL Mathematics Department. He was asked to teach the mysteries of Lagrangian Mechanics to second year physics students and subsequently became the target of lighted paper darts aimed in his direction. At the end of the academic year, he accepted with alacrity a position at Edinburgh, where his work in 1964 won him this year's Nobel Prize in Physics, shared with Françoise Englert!

As the Alumni Co-ordinator, I was extremely pleased by the high attendance of Alumni in spite (or because) of the changed arrangements. Charlotte, accompanied by husband **Dr Ryan Nichol** and their remarkably well behaved six month old daughter, Evelyn, gave a wonderful speech describing life at the "White Board Face," as Deputy Head and physics teacher at an inner London state high school.

The After Dinner Speaker for the 2014 dinner will be Dr Chris Lintott, Chris graduated from UCL in 2006 with a PhD and is currently working as a researcher at Oxford University. He is a co-presenter of the BBC series The Sky at Night and co-authored 'Bang! – The Complete History of the Universe' with Patrick Moore and Brian May. The Gala was a most memorable event and I shall certainly be looking forward to the next one. I hope to see you there!

By Professor Tegid Wyn Jones



Credit: Michael Phillips Photography

Headline Research

The Move of the Muon g-2 Storage Ring

This summer saw the move of a unique piece of apparatus: a $30M, 17ton superconducting magnet that provides a magnetic field uniform to 0.00001% in a 100m circumference storage ring. The 3,200 mile journey from Long Island to Chicago went via the Atlantic and the Mississippi. The ring did not twist more than 3mm during the four week journey.

This ring will be used to measure the magnetic properties of a muon. The Uncertainty Principle of quantum mechanics allows a muon to emit and re-absorb other particles for a fleeting moment and this changes its magnetic properties. The effect is small, about 0.1%, but by measuring this very precisely, researchers can investigate whether anything unexpected is happening; particularly whether there are any new particles beyond those presently observed.

UCL recently joined the experimental team that will make this measurement and is helping to provide the detector electronics for the experiment.

Team Teaching Fellows

Over the past 24 months, Physics and Astronomy has sought to expand its teaching repertoire through the appointment of four additional Teaching Fellows. The Department now boasts a team of eight Teaching Fellows, all of whom have specific roles which utilise their expertise. They have made significant and innovative contributions to the delivery of the teaching curriculum.

Drs **Paul Bartlett**, **Daven Armoogum**, **Pam Donovan** and **Nick Nicolaou** have lead and co-ordinating roles in the teaching of undergraduate practical physics in years 1, 2 and 3. In particular they have introduced question and answer banks, detailed marking guides, online Data Retrieval Test methodology, formative peer assessment and personalised summary feedback linked to the students' Moodle gradebooks. **Dr Louise Dash** has primary responsibility for the delivery of computing tuition for years 1 and 2, and has fronted a recent transition to teaching Python-based courses.

Physics and Astronomy Teaching Fellows

(left to right) Steve Fossey, Stephen Boyle, Pam Donovan, Paul Bartlett, Elinor Bailey, Nick Nicolaou, Daven Armoogum, Louise Dash
Credit: Arne Wickenbrock

> "we can confidently look forward to providing our students with an excellent learning experience."

Mr Stephen Boyle and **Dr Steve Fossey** are based at the University of London Observatory (ULO), where they lead the practical astrophysics programmes for all undergraduate years. Steve Fossey has recently been heavily involved in the development of robotic observing at ULO (see page 5), while Stephen Boyle organises the third-year field trip to the Observatoire de Haute-Provence, in southern France. **Dr Elinor Bailey** is the most recently appointed Teaching Fellow; she will provide direct e-Learning support for staff wishing to incorporate e-tools in their lecture courses. The Teaching Fellows also support wider activities in the Department, including problem solving tutorials, UCAS Open Days and summer internships.

The dedication of the Teaching Fellows has been central to some of the recent teaching innovations in the Department.

Several examples of 'Good Practice' cited in the UCL Faculty Teaching Review, '2012/13 CALT-led MAPS Assessment and Feedback', originated from modules led by the Teaching Fellows. Furthermore, responses from the students to these initiatives have been overwhelmingly positive and when teamed with the extensively refurbished physics laboratories, we can confidently look forward to providing our students with an excellent learning experience.

By Professor Raman Prinja
Director of Teaching

Science in Action

Physics and Astronomy, like the wider UCL community, sees promoting science broadly as an integral part of the Department's responsibilities. There is a widely held appreciation threading through Departmental activities, that there is more to research than academic journals.

Some of the most exciting outreach work involves an element of risk. It is not always clear what is going to work, but without gambling, there is a danger that even cutting-edge research may come across as stagnant and stuffy. Conversely, a willingness to risk failure keeps things fresh and ultimately pays dividends. Risk is the driving force behind UCL initiatives such as the Bright Club, where comedians and researchers are thrown together in a mixed comedy-night-style running order. What is remarkable about this model is how quickly it has become popular, now regularly packing out the entire Bloomsbury theatre.

The thriving UK science festival scene is another successful example of the popularity of science. You might expect that only scientists turn up to a science festival, but that is not actually true; for instance, the British Science Festival literally go out of their way to attract brand new audiences, moving from city to city each year. Several members of the Department have worked with the Festival for a number of years; taking part in various events, ranging from straight-forward question and answer sessions, to theatre shows.

This year the Festival was held in Newcastle and while there were plenty of top-quality lectures, UCL staff were also to be found in the running order of a fused music-and-science line-up (**Dr Andrew Pontzen**) and a quiz-format comedy show (**Prof. Jon Butterworth**). The quiz attempted to show a bit of how science works by providing working scientists with a series of ostensibly pointless challenges. That is certainly a step away from the lecture hall. Examining the feedback from these sessions is fascinating in itself; people obtain a very different insight from seeing rough-around-the-edges science in place of the polished, tidy results that the media like to convey.

UCL outreach aspirations are not so different from research ambitions: attempting to balance the novel on firm foundations, to build something tangibly worthwhile. That is the thrill of academia, and the fact that UCL recognises it as such makes for an exciting future.

By Dr Andrew Potzen

Westminster meets the Large Hadron Collider

'**Collider**' is a major new immersive exhibition at the Science Museum, which blends theatre, video and sound art to recreate a visit to CERN and explore the LHC. On Monday 11 November 2013, the Parliamentary Office for Science and Technology hosted a special event for Lords and MPs, with guest of honour Professor Peter Higgs, to celebrate the opening of this ground-breaking exhibition.

UCL members of staff, **Prof. Jon Butterworth** and **Dr Gavin Hesketh**, as well as PhD students from the High Energy Physics Group (HEP) were on hand to discuss the Large Hadron Collider (LHC), their exhibition stall included electronics designed at UCL for the LHC, which ensures the ATLAS detector stays synchronised with the proton-proton collisions in the LHC happening every 50ns.

Academic Showcase

Staff News

Academic Appointments

2013 has been an extremely successful year in terms of recruitment, with a large number of outstanding researchers having joined the Department as permanent academic members of staff. Recruitment is a two way process, and a measure of the continuing success of the Department can be evidenced through the ability to attract highly esteemed academic members of staff. Each member of staff compliments and enhances the high-profile research portfolios of both the individual research groups and the Department as a whole.

Agapi Emmanouilidou (AMOPP):
Specialises in attosecond and strong-field science and interaction of matter with free-electron lasers, an EPSRC Research Fellow from UCL.

Jay Farihi (Astro):
Specialises in exoplanetary systems and the frequency and composition of extrasolar asteroids, from Cambridge University.

Thomas Greve (Astro):
Specialises in galaxy formation and evolution, an STFC Research Fellow from UCL.

Keith Hamilton (HEP):
Specialises in precision predictions for the LHC, from CERN Theory Division.

Christopher Howard (CMMP):
Specialises in experimental (nano)materials physics, from UCL/Linde LLC.

Benjamin Joachimi (Astro):
Works on large-scale structure cosmology with a focus on gravitational lensing and intrinsic galaxy alignments, from Edinburgh University.

Andreas Korn (HEP):
Specialises in ATLAS exotic searches and tracker upgrade, from the University of Edinburgh.

Isabel Llorente Garcia (AMOPP):
Specialises in magnetic traps for Biophysics, from Oxford University.

Gerd Materlik (CMMP/ LCN):
Professor of facilities science, applications and sources of synchrotron radiation and free electron lasers, from Diamond Light Source.

Andrew Pontzen (Astro):
Specialises in cosmology, from Oxford University.

Amélie Saintonge (Astro):
Specialises in galaxy evolution, from the Max Plank Institute for Extraterrestrial Physics.

Marzena Szymanska (AMOPP/ CMMP):
Specialises in quantum coherence in non-equilibrium light-matter systems, from Warwick University.

Pierre Thibault (CMMP):
Specialises in high-resolution X-ray imaging, from TU Munich.

Pavlo Zubko (CMMP/ LCN):
Specialises in complex-oxide thin films and heterostructures, from University of Geneva.

New academic members of staff

(Left to right) back row – Keith Hamilton, Amélie Saintonge, Thomas Greve
middle row – Benjamin Joachimi, Andrew Pontzen, Andreas Korn, Pavlo Zubko
front row – Marzena Szymanska, Christopher Howard, Isabel Llorente Garcia.
Credit: Arne Wickenbrock

Promotions

Filipe Abdalla (Astro): Reader in Astrophysics

Nick Achilleos (Astro): Reader in Planetary Physics

Jochen Blumberger (CMMP): Reader in Physics

Dan Browne (AMOPP): Reader in Physics

Carla Figueira De Morisson Faria (AMOPP): Reader in Physics

Bart Hoogenboom (CMMP): Reader in Nanoscale Biophysics

Philip Jones (AMOPP): Reader in Physics

Thanh Nguyen (CMMP): Professor of Nanomaterials

Giorgio Savini (Astro): Reader in Infrared Instrumentation

Alessio Serafini (AMOPP): Reader in Physics and Astronomy

Giovanna Tinetti (Astro): Professor of Astrophysics

David Waters (HEP): Professor of Physics

Long term Fellowships

Jay Farihi (Astro)

Benjamin Joachimi (Astro)

Andreas Korn (HEP)

Andrew Pontzen (Astro)

Amélie Saintonge (Astro)

Tim Scanlon (HEP)

Pierre Thibault (CMMP)

Giovanna Tinetti (Astro)

Retirements

Dr Ian Furniss (Astro)

Dr Tony Harker (CMMP & Deputy Head of Department)

Headline Research

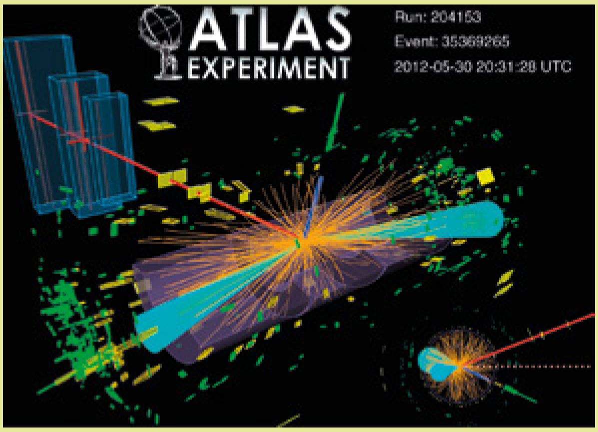
Higgs boson: the post-discovery era

Just over a year after the announcement of its discovery, the Higgs boson continues to dominate the headlines in particle physics.

Two major new results were announced in 2013: firstly, the spin and other intrinsic properties of the Higgs were measured. These determine the angular orientation of its decay products and were found to be perfectly consistent with the Standard Model predictions. Secondly, strong evidence in support of the Higgs decaying to fermions, specifically τ leptons, was reported. This also agrees with the theoretical predictions.

The Higgs discovery has opened up numerous opportunities for searching for massive, previously undiscovered particles decaying via Higgs bosons to interesting topologies. UCL researchers have taken the lead in this research, proposing the search for TeV-scale particles X, decaying to two Higgs bosons, which then decay to b—anti-b pairs.
(Cooper *et al*, Phys. Rev. D 88, 114005 (2013)).

This turns out to be one of the most sensitive topologies for the discovery of massive particles at the LHC in a variety of new physics models.



An ATLAS event with a Higgs → $\tau\tau$ candidate, where one τ decays to a muon and the other to an electron. The electron is indicated by a blue track and the muon indicated by a red track.

Staff Accolades

Daiwa Anglo-Japanese Foundation: Daiwa Adrian Prize

Awarded to **Professor Alex Shluger, Dr Peter Sushko and collaborators from the Tokyo Institute of Technology.**

For their work on the "Exploration of active functionality in abundant oxide materials utilising unique nanostructure: discovering novel properties of traditional materials and addressing the limited availability of technologically important elements through curiosity driven-driven research."

Institute of Physics (IoP): Chadwick Medal and Prize

Professor Jonathan Butterworth

"For his pioneering experimental and phenomenological work in high energy particle physics, especially in the understanding of hadronic jets."

In addition Dr John Morton was awarded the IoP Moseley Medal and Prize. John is a member of the UCL Electrical Engineering department but also has strong ties to Physics & Astronomy, with a laboratory in the Physics Building.

Institute of Physics (IOP): Physics World Top 10 Breakthrough of the Year

Awarded to the scientists working on the European Space Agency's Planck space telescope including **Dr Aurélien Benoit-Lévy, Dr Franz Elsner, Dr Jason McEwen, Dr Hiranya Peiris, Dr Giorgio Savini**

"To scientists working on the European Space Agency's Planck space telescope for making the most precise measurement ever of the cosmic microwave background (CMB) radiation."

Royal Society: Wolfson Research Merit Award

Professor Jonathan Oppenheim

For his work on "Quantum information science: Tools and applications for fundamental physics."

UCL Physics and Astronomy Departmental Teaching Prize

Dr Dan Browne

"…in recognition of his dedicated and inspirational teaching across all years of the undergraduate programme. The award acknowledges in particular Dan's success in delivering material in Advanced Quantum Theory at M-level…"

UCL MAPS Faculty Teaching Awards

Professor Tony Harker

"Tony's mathematica expertise is second to none and his package of undergraduate modules is rather unique in academia. The effort he has taken to develop interesting problems through which the students develop their skills is quite remarkable."

Mr Dominic Reeve

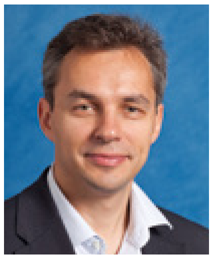
For "…great enthusiasm [in] his role as a teaching assistant...his accessible and engaging style ensures his teaching is leavened with a great sense of humour and fun."

UCL Provost's Teaching Award

Professor Andrew Fisher

The prestigious Provost's Teaching Awards celebrates those staff who have shown particular commitment to innovation in teaching and whose work has had significant impact on students. Andrew was one of six members of staff selected from the Experienced Academic Staff category.

Alex Shluger



Peter Shushko

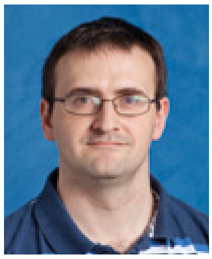
Jonathan Butterworth

Aurélien Benoit-Lévy

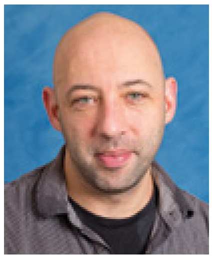
Franz Elsner

Jason McEwen

Hiranya Peiris

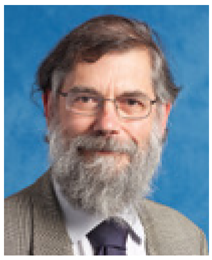


Giorgio Savini

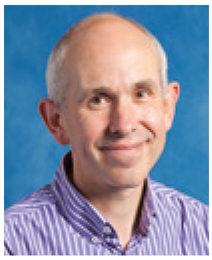


Jonathan Oppenheim

Dan Browne



Tony Harker



Andrew Fisher

Portrait of…

Dr David Cassidy

“The gravitational interaction of antimatter has never been conclusively observed before, and David’s experiment will be pioneering.”

When a stone is dropped from rest into a well, it is possible to determine the depth of the well by counting the number of seconds until you hear the splash. This simple demonstration is a classic example of the laws of physics and relies on the motion of a free falling object under the influence of gravity alone. This impressed David at the age of five years old when demonstrated to him on a school trip, and its underlying principles remain just as inspirational today, albeit far more complex!

Gravity is one of the most interesting phenomena studied by physicists and having recently joined the Department in April 2012, David plans to investigate the effect of gravity on antimatter. This is a new and exciting area of research that will incorporate other work already being conducted within Physics and Astronomy. The gravitational interaction of antimatter has never been conclusively observed before, and David’s experiment will be pioneering.

Positronium is an exotic atom, made half of matter (an electron) and half of anti-matter (a positron). Physics and Astronomy already hosts positron and positronium beams which are used for world leading scattering experiments and David will utilise recently developed positron trapping technology to build a new experiment which creates high density bursts of positronium atoms that may then be probed with lasers. This methodology takes a relatively weak positron beam and stores particles up until they are released in an intense burst; a rudimentary analogy would be filling a bucket of water with a dripping tap. The resulting ‘gas’ of positronium atoms may subsequently be driven to highly excited Rydberg states with pulsed lasers. They will then be manipulated with electrostatic fields to produce a slow beam, eventually allowing a gravity measurement and addressing the question of how anti-matter interacts with gravity.

Predictions of what should happen are hard to come by in the absence of a quantum gravity theory, however there are indications that antimatter and matter should exhibit identical gravitational interactions. At present, the standard model of particle physics is known to be incomplete, and the right way to extend it is not known. Therefore any observed difference between matter and antimatter gravity would be an important step toward resolving that dilemma.

David’s laboratory is now in the final stages of completion and he hopes to begin experiments in early 2014. The laboratory has been designed specifically to measure the effect of gravity on antimatter and whether positronium falls up, down or not at all, the scientific community are eagerly awaiting the results and analysis from this vanguard experiment.

Research Degrees

Doctor of Philosophy (PhD)

Ala'a Azzam
A linelist for the hydrogen sulphide molecule
(Supervisor Professor J. Tennyson)

Sarah Baker
Studies of jets, subjets and the Higgs search with the ATLAS detector
(Supervisor Professor J. Butterworth)

Richard Bean
Domain structure imaging by Bragg geometry x-ray ptychography
(Supervisor Professor I. Robinson)

Stephen Bieniek
Two b or not two b-jets: measurement of inclusive and dijet b-jet differential cross-sections with the ATLAS detector
(Supervisor Professor N. Konstantinidis)

Bo Chen
X-ray imaging of three-dimensional spatial structure of coatings
(Supervisor Professor I. Robinson)

Richard D'arcy
Optimisation of the COMET experiment to search for charged lepton flavour violation and a new simulation to study the performance of the EMMA FFAG accelerator
(Supervisor Professor M. Lancaster)

Anna Dejardin
Modelling the nanocantilever response to stressed networks of antibiotic binding events
(Supervisor Dr D. Duffy)

Charlotte Fléchon
Organic light-emitting diodes based on new promising materials
(Supervisor Professor F. Cacialli)

Marco Fritzsche
Homeostasis of the cellular actin cortex and its filament length-distribution
(Supervisor Dr G. Charras)

Adam Hawken
Constraining cosmology with statistics of the spatial distribution and shapes of galaxies
(Supervisor Professor O. Lahav)

Oskar Karczewski
Dust and star formation in NGC 4449
(Supervisor Professor M. Barlow)

Zermina Khan
Imaging biomolecules using frequency modulation atomic force microscopy in liquids
(Supervisor Dr B. Hoogenboom)

Conor Maher-McWilliams
Creation, trapping and manipulation of a cold argon gas
(Supervisor Professor P. Barker)

Philip Merchant
Excitations and criticality in quantum magnets
(Supervisor Professor D. McMorrow)

Mohammad Mohammady
Nuclear-electric spin systems, magnetic resonance, and quantum information processing
(Supervisor Professor T. Monteiro)

Kenan Mujkic
Inclusive measurement of the charm contribution to the structure function of the proton
(Supervisor Professor M. Wing)

Jack Mulroue
Ab initio study of the effect of charge localisation on the properties of defects in magnesium oxide and zirconolite
(Supervisor Dr D. Duffy)

Conn O'Rourke
Dye sensitised solar cells: a computational approach
(Supervisor Dr D. Bowler)

Kaveh Rahnejat
Scanning tunnelling microscopy studies of the graphitic superconductor CaC6
(Supervisor Dr M. Ellerby)

Benjamin Richards
Double beta decay of 48Ca with NEMO3 and calibration development for SuperNEMO
(Supervisor Professor R. Saakyan)

Marios Sergides
Optical manipulation of micro- and nano-particles using evanescent fields
(Supervisor Dr P. Jones)

Xiaowen Shi
Coherent x-ray diffraction imaging and ptychography on silicon-on-insulator nanostructures
(Supervisor Professor I. Robinson)

Susan Skelton
Applications of cylindrical vector beams for optical micromanipulation
(Supervisor Dr P. Jones)

Hemant Tailor
The statistical thermodynamics of stretched multi-stranded biomolecules
(Supervisor Professor I. Ford)

Umberto Terranova
Challenges in dye-sensitised solar cells: a theoretical study
(Supervisor Dr D. Bowler)

Marten Tolk
Improving exciton dissociation and charge transport in organic photovoltaic cells
(Supervisor Professor F. Cacialli)

Lianheng Tong
Non-adiabatic molecular dynamics and its applications in electron transport in nanostructures
(Supervisor Dr D. Bowler)

Po-hung Wang
A molecular dynamics simulation approach for calculation of gas diffusion rates in proteins with applications to hydrogenases and dehydrogenases
(Supervisor Dr J. Blumberger)

Peter Wijeratne
Measurements of the total transverse energy in pp collisions and a new technique for model independent missing transverse energy searches with ATLAS
(Supervisor Dr E. Nurse)

Matthew Wolf
Modelling of trapped hole polarons in oxides
(Supervisor Professor A. Shluger)

Charles Wood
Theoretical study of hydrogen storage in alkali- and alkaline-earth metal graphite intercalate compounds
(Supervisor Professor M. Gillan)

Hulya Yagsen-Appleby
Gaussian and covariant processes in discrete and continuous variable quantum information
(Supervisor Dr A. Serafini)

Japheth Yates
Influence of solar wind on the Jovian thermosphere
(Supervisor Dr N. Achilleos)

Doctor of Engineering (EngD)

Rosemary Paxman
Resonant cantilever sensing: From model systems to applications
(Supervisor Dr B. Hoogenboom)

Research Spotlight

Condensed Matter and Materials Physics (CMMP)

The Condensed Matter and Materials Physics group conducts a wide range of fundamental and applied research in the broad areas of quantum matter and information, magnetism, materials, biological physics, nanoscale imaging, organic electronics, and soft matter and disordered materials. They use a combination of experimental and computational methods, with many facilities based in the London Centre for Nanotechnology (LCN). The LCN project was conceived and initiated by members of CMMP and they played a leading role in the design and construction of the eight-storey Bloomsbury building which was opened in 2006. This building now provides state-of-the-art facilities for sample design, preparation and characterisation, and acts as a focus for university-wide nanoscience research across several departments. They also play a leading role in the development and use of national and international neutron and X-ray scattering facilities, for example the Diamond Light Source at the Harwell Science and Innovation Campus in Oxfordshire.

> "Complex oxides are an exciting class of materials that exhibit incredibly diverse functional properties including high-temperature superconductivity, ferroelectricity, and exotic magnetism."

One particular area of interest within the group lies in the design and application of new layered materials. These systems allow the creation of new structures and devices, which enables the observation and exploitation of new physical properties. **Dr Pavlo Zubko** and **Dr Christopher Howard** describe below some of the challenges and excitement in creating two very contrasting types of layered materials, based on oxides and carbon respectively.

Artificially layered oxides

Complex oxides are an exciting class of materials that exhibit incredibly diverse functional properties including high-temperature superconductivity, ferroelectricity, and exotic magnetism. The structural compatibility between many different materials in this class means that they can be assembled, like LEGO bricks, into complex artificially layered heterostructures, with a high degree of crystalline perfection. This opens up a seemingly endless set of possibilities for the creation of novel and highly multifunctional materials and gives us access to the fascinating new physical phenomena that appear in oxides which are engineered at the nanoscale.

One interesting and technologically important category of oxides, is the family of perovskite ferroelectrics. Among their many useful properties, their high dielectric permittivities are utilised in various types of capacitors, whilst their defining characteristic, the switchable spontaneous polarisation, is exploited in ferroelectric random access memories. Improvements in data storage capacity, as well the realisation of new devices such as ferroelectric tunnel junctions, requires the downscaling of ferroelectrics to thicknesses of just a few nanometres, motivating intense research on ferroelectricity in the so-called ultrathin limit. Dr Pavlo Zubko, together with colleagues at the University of Geneva, has been investigating artificially layered superlattices composed of alternating ultrathin layers of ferroelectric and dielectric oxides (figure 1a). The discontinuities in polarisation at interfaces between the polar ferroelectric and non-polar dielectric layers create strong internal electric fields which destabilise the homogeneous ferroelectric state and lead to the formation of regular nanoscale stripe domains (figure 1b). This domain structure is highly sensitive to applied electric fields and gives rise to a giant enhancement in the dielectric response due to tiny displacements of the densely packed domain walls. The periodic nature of the nanodomains makes them particularly well-suited for X-ray diffraction studies (figure 1c) and enables the field-induced domain-wall displacements to be probed experimentally, by monitoring the changes in the diffraction pattern from the domain structure. The periodicity of the domains, as well as the electrostatic interactions between neighbouring ferroelectric layers, can be controlled by changing the individual ferroelectric and dielectric layer thicknesses, making these artificially layered materials ideal for engineering tailored functional properties.

Project in Focus

The physics of layered materials

Aim
To create and exploit new layered materials and structures.

Results
Artificial oxide heterostructures that have been designed and tuned for a variety of novel properties; carbon-based materials that exploit the new physics of graphene.

UCL Involvement
UCL has state-of-the-art facilities for sample design, preparation and characterisation, and for theoretical modelling of materials properties.

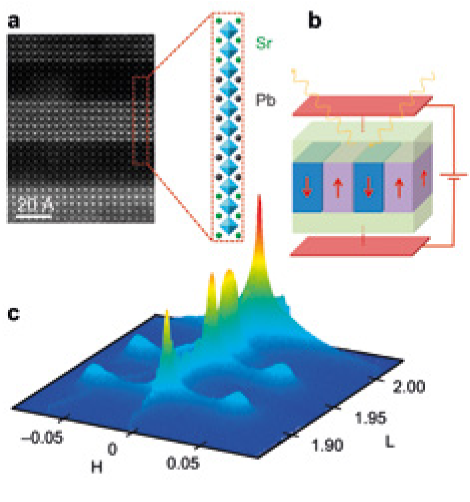


Figure 1.
a) Transmission electron microscopy image of a superlattice composed of alternating 2.4-nm-thick ferroelectric $PbTiO_3$ and dielectric $SrTiO_3$ layers.
b) The stripe domain structure that forms within the ferroelectric layers and its changes under applied bias can be probed using X-ray diffraction.
c) Diffraction pattern of a superlattice capacitor, showing two sets of diffuse superstructure peaks along H due to the ferroelectric nanodomains accompanying the superlattice Bragg peaks.

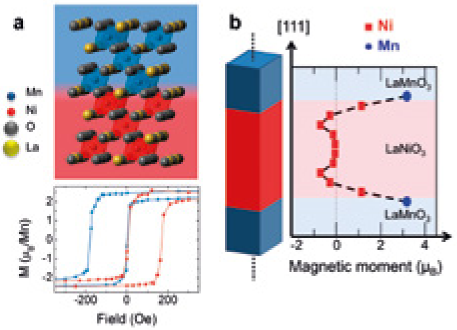


Figure 2.
a) In superlattices composed of ferromagnetic $LaMnO_3$ and nominally paramagnetic $LaNiO_3$ grown along the pseudocubic [111] direction (top), interfacial charge transfer leads to a new magnetic ground state and the appearance of exchange bias (bottom). The magnetisation-field loops were measured at 5 K for a superlattice composed of 7 unit cells of $LaNiO_3$ and 7 unit cells of $LaMnO_3$ per period after field-cooling the sample in +0.4 T (blue) and –0.4 T (red). b) One of the proposed magnetic structures: the magnetic moment within each layer of this superlattice, with 2 unit cells of $LaMnO_3$ and 10 unit cells of $LaNiO_3$ per period, was calculated using density functional theory at the Institute of Material Science of Barcelona.

Another exciting aspect of research on artificially layered oxides is that the properties of a heterostructure can often be very different from those of its individual constituents. Interfaces between chemically different compounds violate the symmetries of the bulk materials and allow for the emergence of new phenomena. For example, when ultrathin layers of ferromagnetic $LaMnO_3$ are interleaved with paramagnetic $LaNiO_3$ in superlattices grown along a specially chosen crystallographic direction (figure 2), electrons are transferred across the interface from the manganite to the nickelate layers. This modifies the magnetic interactions between the interfacial Ni and Mn ions, giving rise to a new magnetic structure within the nominally paramagnetic $LaNiO_3$ layers and leading to the appearance of exchange bias, manifested as a shift of the ferromagnetic magnetisation-field loop. Heterostructures involving other members of the rare-earth nickelates family which already exhibit magnetism and metal-insulator transitions in bulk should have even more interesting properties, as the bulk phases will compete with interface-induced effects.

Chemically doping graphitic materials

The most structurally simple and widely studied two-dimensional material is graphene. Graphene is a honeycomb atomic crystal of carbon that is only one atom thick, which has an extraordinary combination of physical properties. For example, it is many times stronger than steel, a better conductor of heat and electricity than copper, and is almost transparent to light. Graphene therefore has numerous potential applications, from displays and touch screens to ultra-strong composite materials. World-wide, scientists are devoting huge efforts to understand and control the properties of this material, and to develop methods for physically incorporating it into applications.

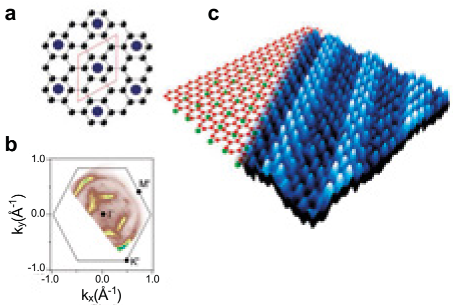


Figure 3.
a) Potassium ions (purple) on the surface of graphene's honeycomb arrangement of carbon atoms (grey). b) The Fermi surface of calcium doped graphite, revealed by photoemission experiments, showing the electronic states associated with the graphite (central features) and those arising from the calcium dopants (outer circle). c) Nanometer-scale charge-density waves on the surface of calcium-graphite. The STM data (blue) is shown together with a schematic of the positions of underlying lattice of calcium atoms (green) and carbon atoms (red).

Dr Christopher Howard and co-workers manipulate graphitic materials, a class which includes graphene that is stacked in layers (graphite) and rolled into tubes (nanotubes), by the process of chemical doping. This involves decorating the graphitic material with dopant atoms or molecules, for example simple metals. The highly tunable electronic structure of graphitic materials means they readily accept/donate electrons from/to the dopant species with the dopants then typically forming ordered arrays on the graphene surface (figure 3a), or between the sheets of graphite. Adding charge carriers in this way permits the tuning of properties for specific applications, and also enables the search for exotic electronic behaviour. In fact, people chemically dope graphite with lithium every day when a mobile phone battery is charged

At the highest electron concentrations, achieved by doping with calcium metal, graphite becomes a superconductor: once it is cooled below a critical temperature, T_C, it conducts electricity with no resistance.

The detailed electronic structure of this superconductor was measured using photoemission spectroscopy, a technique based on the photoelectric effect, with collaborators at Stanford University (figure 3b). The experiments illustrated the crucial role played by the electrons associated with the 2D arrays of calcium atoms in the superconducting mechanism. These results now lay down the framework to realising superconductivity in graphene itself, a major aim of the research group. Above T_C, Scanning Tunnelling Microscopy (STM) revealed that some of the electrons donated to the graphite spontaneously form striking nanometer-scale stripes (figure 1c). It was demonstrated that the stripes are a so-called charge-density wave. This is a novel electronic groundstate often found in low dimensional materials proximal to superconductivity, but it is the first time such a state was demonstrated in any graphitic material.

Key to harnessing the properties of graphene is developing industrially scalable methods to physically incorporate it into technological applications. For example, if graphite can be dissolved to form solutions of individual graphene sheets, such solutions can be used to efficiently paint graphene into thin films or embed it into composites. The stubborn insolubility of graphite can be overcome via chemical doping. Doping potassium atoms and ammonia molecules between graphite sheets expands the layer separation and weakens the interlayer attraction. The doped graphite then dissolves in organic solvents to form solutions of charged graphene. The presence of single-layer graphene in solution, was confirmed by neutron scattering conducted at the Institut Laue-Langevin in Grenoble (figure 4a) and corroborated by atomic force microscopy of dissolved graphene flakes dropped from solution onto a mica surface (Figure 4b).

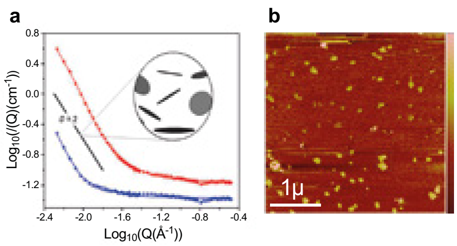


Figure 4. a) Small angle neutron scattering data of graphene solution at 0.1 wt % (red) and 0.01wt % (blue) concentration. The solid black line shown has a gradient D = 2 as expected for a solution of randomly oriented thin discs. b) Atomic force microscopy of single layer graphene flakes deposited from solution onto a mica surface.

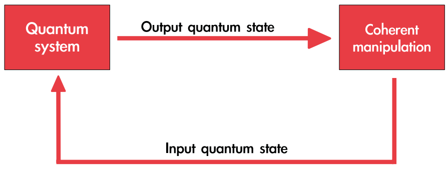
Atomic, Molecular, Optical and Positron Physics (AMOPP)

The AMOPP group perform high precision measurements, coupled with theoretical work, which is aimed at improving the understanding of fundamental processes. Their research can be applied to diverse areas such as the development and structure of the Universe, environmental change, and the behavior of biological systems. One relatively new and exciting area of research relates to quantum information and the development of quantum technologies. UCL hosts one of the UK's leading centres for research into quantum technologies and members of the AMOPP group investigate a wide range of research within the field of quantum information theory. Practical applications of quantum information theory are still in the development phase, but will harness the features of quantum mechanics and perform tasks which are hard, or impossible, with conventional technologies. Dr Alessio Serafini discusses progress in quantum technologies, as research is beginning to move towards experiments with a potential for practical impact.

> "…decisive advances with quantum hardware will only be possible if the control of coherent quantum resources is achieved."

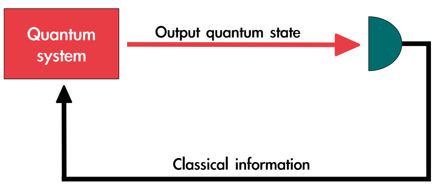
Quantum Control of Continuous Variables

Quantum systems hold considerable technological promise for a variety of applications such as information processing, secure communication and advanced sensing. However, decisive advances with quantum hardware will only be possible if the control of coherent quantum resources is achieved. As a result, most of the current research in applied quantum mechanics and quantum technologies is focused on quantum control. It is necessary to learn how to generate on demand, and maintain, fragile resources. For example: Squeezing (the compression of the uncertainty on a quantum variable, at the expense of noise on the conjugate variable), quantum entanglement (stronger than classical correlations) and quantum coherence (the property behind quantum interference effects).



In coherent feedback control, the quantum state enters as an input, a point-wise quantum process and is then fed back into the system to be controlled. No extraction of classical information is ever required in such set-ups.

On the theoretical side, a comprehensive framework of quantum control theory has emerged to support such experimental endeavors. Quantum control theory involves recasting and transposing problems from classical control theory into the quantum domain. Classical control techniques can be applied to most quantum control problems in finite dimension thanks to a general, and very elegant, group-theoretical approach whose backbone was established in the seventies. However this framework does not apply to the vast range of 'continuous' quantum variables with an infinite dimensional Hilbert space, these are amenable to remarkable experimental control. For example, quantum control theory in finite dimensions does not deal with the positions and momenta of particles, or quantum electromagnetic fields.



A measurement-based quantum feedback loop, on which part of Dr Genoni and Dr Serafini's research focuses. The control action depends on the classical information extracted from the system through a quantum measurement process.

> "…they have derived a necessary condition for the controllability of continuous variable systems under quadratic interactions."

Dr Alessio Serafini and Dr Marco Genoni, along with co-workers, have addressed this problem and made significant progress towards improving the understanding of quantum control conditions for continuous variable systems. They have developed a simple theoretical finding which will allow experimentalists to check whether, given their practical constraints on feasible interactions, they may be able to implement and sustain a quantum state on their system.

Project in Focus

Quantum control of continuous variables

Aim

To exert control over quantum systems and develop technologies which are capable of tasks beyond the scope of conventional technologies.

Results

Partial noiseless control of quantum variables. In a one-dimensional chain of interacting quantum harmonic oscillators, two controls acting on a single oscillator of the chain can implement a quadratic operation.

UCL Involvement

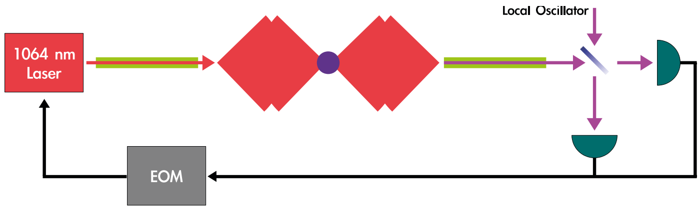
The theory was developed by UCL members of staff and has practical applications for experimental scientists.

Focusing on the problem of the noiseless (Hamiltonian) controllability of continuous variable systems, they considered whether it would be possible to implement any arbitrary noiseless operation on the system. This was an unprecedented standpoint and by focusing only on a given a set of dynamical controls, with an always-on dynamic and restricting quadratic interactions, the problem was simplified to looking at the group of canonical transformations. Following this, through a connection between controllability and the property of recurrence (the fact that any initial state evolves back to itself up to an arbitrarily small error after a certain time), they have derived a necessary condition for the controllability of continuous variable systems under quadratic interactions. Quadratic interactions are sufficient to create squeezing and entanglement, and to cool down quantum systems.

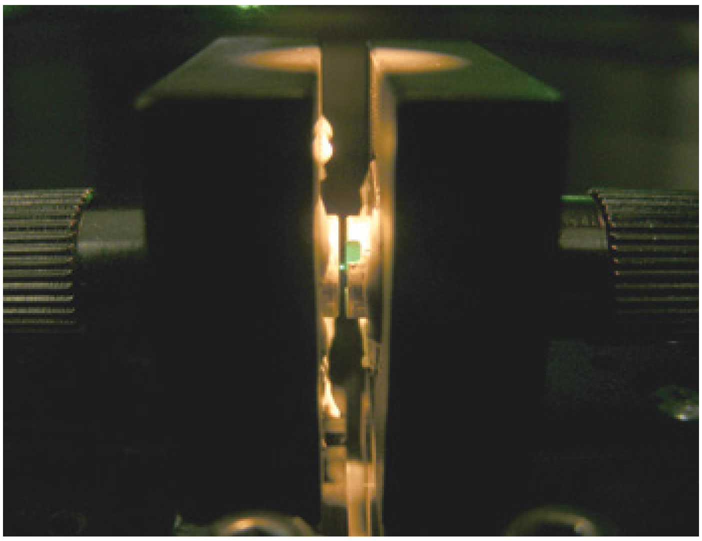
This result on noiseless control can be applied to show surprising possibilities; given a one-dimensional chain of interacting quantum harmonic oscillators, these techniques demonstrate that any quadratic operation, anywhere on the chain, may be implemented by only two controls acting on any single oscillator of the chain. This is a classic partial control scenario, where direct access to the quantum system is severely restricted, but full controllability on the many body system may still be established. The sufficient controllability criterion of Genoni and co-workers is also necessary for a single degree of freedom. Dr Serafini's team is currently investigating whether this may stand for many degrees of freedom.

Dr Serafini's team are also developing the theory of optimal feedback control of continuous variables. In feedback control set-ups, the system is observed by a continuous measurement process, with the present outcome informing the choice of future control operations on the system. This line pushes theoretical research past the relevant, but idealised noiseless scenario, and into the study of systems subject to realistic quantum noise. Furthermore, this kind of control focuses on target states rather than operations which ensures the stability of the target states, in the face of noise. As a result of this work, Dr Serafini and Dr Genoni were able to analytically determine the measurement which maximises squeezing and quantum entanglement at a steady state, at zero as well as at finite temperatures. At zero temperature, the optimal measurement scheme is a specific homodyne detection (a well known technique in quantum optics). At finite temperature, the optimisation turns out to be more exotic, involving correlated baths and the access to correlations between different environmental modes.

This theoretical research on quantum feedback control is now being experimentally tested at UCL as a result of a new, EPSRC-funded research collaboration with Professor Peter Barker and his research group. The aim of this joint project will be to apply optimised homodyne feedback control techniques to the cooling of an optically trapped ('levitating') bead at the micro-scale. Cooling the motion of such a massive object to the quantum ground state is of outstanding interest, not only for quantum sensing, but also as a probe for fundamental quantum gravity effects at low energies.



A schematics of the homodyne feedback scheme that will be applied to UCL's levitating bead experiment. The bead is trapped in an optical cavity, where leakage is continuously monitored through homodyne measurements. In turn, these control the trapping field via an electro-optical modulator.



The levitating microsphere in Prof. Barker's laboratory.

High Energy Physics (HEP)

High energy particle physics explores the most fundamental questions about the nature and evolution of the Universe, probing the most basic constituents of matter and how these elementary particles interact.

The Standard Model of particle physics has been remarkably successful at describing the visible Universe, and the unveiling of the Higgs boson at the Large Hadron Collider (LHC) last year, the cornerstone of the model, marked a crowning achievement. However despite its successes, the Standard Model does not readily provide a solution to the 80 year puzzle of 'dark matter'.

> "Understanding the nature of dark matter is one of the highest priorities in science."

By measuring the motion of stars and galaxies, the presence of much more mass than is visible, or can be accounted for by regular baryonic material, is inferred. An incredible 85% of the mass content of the Universe is in the form of this dark matter, created in the early Universe shortly after the Big Bang. Though we can see its gravitational influence on stars, galaxies, and even larger scale structures, as in figure 1, this exotic substance has never been experimentally observed. Understanding the nature of dark matter is one of the highest priorities in science.

Theoretical extensions to particle physics that go beyond the Standard Model provide compelling candidates for what dark matter is made of, with Weakly Interacting Massive Particles (WIMPs) particularly attractive. The HEP Group is involved in two complementary experiments seeking to find evidence for WIMPs. The first is at the LHC where the high energy collisions could create pairs of WIMPs that, although not detected directly, would leave a unique signature in the ATLAS experiment. This would be inferred through a collision apparently not conserving energy and momentum. The second involves directly observing the dark matter of the Milky Way galaxy by descending deep below the Earth's surface and using highly sensitive instruments to measure the primordial WIMP scattering in detector targets. Following results released in October 2013, the LUX experiment became the world leader in the direct search for dark matter. **Dr Chamkaur Ghag** and colleagues in the HEP Group played major roles in the experiment, he explains the significance of the results and future plans as LUX seeks to make the first definite discovery of dark matter.

Figure 1. An image of the Bullet Cluster showing two colliding clusters of galaxies. Despite the visible matter (pink) interacting and concentrating in the centre following collision, the mass of the system (blue) as determined through gravitational lensing, is nearly all contained in lobes. This is as expected if the bulk of this mass is non-baryonic dark matter, surviving the collision largely unaffected. **Credit: nasa.gov.**

Project in Focus

The LUX Dark Matter Experiment

Aim
To directly observe galactic dark matter particles, responsible for 85% of the matter content of the Universe.

Results
During its first science data taking campaign, LUX has set the world's best constraints on WIMP dark matter interactions, three times better than previous limits. In addition, claims by experiments postulating the existence of low-mass WIMPs have now been been excluded.

UCL Involvement
UCL lead one of the core analysis groups of the experiment, the Golden Group. They are responsible for characterising the raw detector signals, identifying WIMP-like events, and establishing the efficiency of the detector to dark matter interactions. UCL also contribute to the regular on-site operations and maintenance of the experiment.

The LUX Dark Matter Experiment

Measurements of galactic rotation curves tell us that dark matter exists in large extended halos that engulf the visible galaxies, and the Milky Way is no exception. As the solar system revolves around the centre of the galaxy, moving through this halo, the Earth is exposed to a flux of WIMPs that mostly pass straight through without interacting at all. However, a tiny fraction are expected to occasionally scatter elastically off atomic nuclei, producing small keV-sized signals. To stand any chance of detecting these rare low-energy events, experiments are constructed from extremely radio-pure materials and placed deep underground to suppress background noise from local radioactivity and cosmic radiation from space. With only one WIMP expected in a kg of target material per year, the detectors must also be massive whilst retaining the ability to reliably detect recoiling nuclei at unprecedented low energies.

The LUX experiment, housed 1.5 km underground in a former gold mine, is the largest detector of its kind, filled with 350 kg of liquid xenon and viewed by photosensors that record flashes of scintillation light produced when particles scatter in the detector. The xenon is held at -110 degrees Celsius in a titanium vessel, shown in Figure 2, and then immersed in a water tank. The detector was installed underground in 2012 and, following commissioning and calibration, the first WIMP search run began in April 2013, accruing 85 days of data.

> “Measurements of galactic rotation curves tell us that dark matter exists in large extended halos that engulf the visible galaxies, and the Milky Way is no exception.”

A critically important area of analysis for dark matter experiments, in particular the first data taking campaigns, is establishing the detector’s efficiency for WIMP detection. For LUX this is the responsibility of the ‘Golden Group’, led by UCL. Their work involves: identifying and characterising all the initial raw signals from the photosensors (figure 3), and selecting from these signals the WIMP-like single scatter ‘golden’ events. In addition, they analyse calibration and Monte Carlo simulation golden data sets to establish energy dependent acceptances, as well as determining the experiment’s efficiency. With the WIMP efficiencies established, the 85 days of science data was evaluated for evidence of a dark matter signal above the expected background. Figure 4 shows the results from this initial search. The rate of events detected was approximately 2 per day, making LUX the most radioactively quiet place on the planet at these low energies! This rate, along with the distribution of the events, was consistent with a background-only hypothesis.

With no positive detection we can place constraints, in terms of an interaction cross-section, on the probability of WIMP

Figure 2.
The LUX detector housed in a water tank 1.5 km underground in the Davis Cavern at the Sanford Underground Research Facility.
Credit: Matt Kapust, SURF.

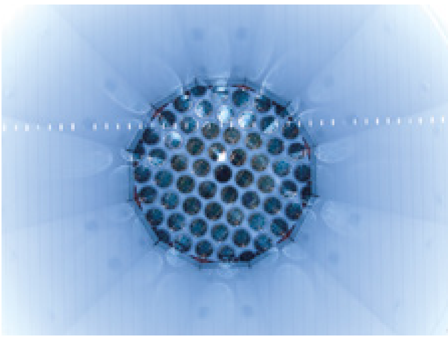


Figure 3.
One of two arrays of photosensors within LUX. These record the prompt scintillation and secondary electroluminescence photons produced following a particle scatter in the liquid xenon target.
Credit: Carlos Faham, LBNL.

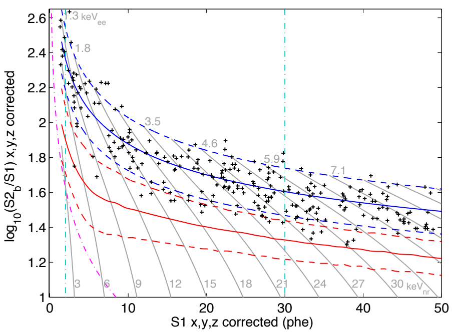


Figure 4.
The WIMP search data from LUX’s first science run. The black data points collected are clustered around the blue solid curve, indicating they are background and not signal. WIMPs would have appeared beneath the red solid curve.

scattering off nuclei as a function of WIMP mass. Strikingly, this short first science run has resulted in the most stringent ever placed on WIMP-nucleon scattering, establishing LUX as the world-leader in the race for WIMP detection.

An important further implication of this result comes from LUX’s sensitivity to low-mass WIMPs (<10 GeV/c^2). Such particles would produce a signal either very close to, or below the threshold of most detectors, yet several experiments have observed a modest excess of events for these masses, hinting at the existence of low-mass dark matter. However, as a result of its low energy threshold, LUX’s limit on low-mass WIMPs is over 20 times more sensitive than any other experiment, and the results comfortably exclude these positive claims.

> “LUX…will be starting from the position of world-leader, with every chance of being the first experiment to directly observe dark matter.”

With LUX now set to begin a much longer run in 2014, which will be at least five times more sensitive than already achieved, it will be starting from the position of world-leader, with every chance of being the first experiment to directly observe dark matter. The experiment will extend the reach of dark matter experiments in order to fully explore the theoretically favoured parameter space for dark matter, UCL is also playing a major role in the development of the next generation successor to LUX called ‘LZ’. This will build on the same xenon technology to develop a 7 tonne target. UCL is leading the research to ensure that the detector elements are free of radioactive impurities that lessen the sensitivity of the experiment. This forms part of an extensive programme of detector development within the HEP group, spanning a number of key technologies, including liquid argon time projection chambers and large scale water Cherenkov instruments for long baseline neutrino physics, to complement the existing suite of cutting-edge experiments.

Astrophysics

Project in Focus

Planck

Aim
Conduct the best possible measurements of the microwave sky.

Results to Date
Definitive results on the cosmological model, the physics of the Big Bang, the first full sky mass-map of the Universe, and the constituents of the Milky Way galaxy.

UCL Involvement
Five core team members of the High Frequency Instrument team, contributing to the characterisation of the detectors and cosmological analysis.

The Astrophysics group includes staff who are scientific co-investigators on various space missions. Described below are two of these missions and UCL's involvement. The first is an active mission which aims to explore the origins of the Universe itself, while the second is a mission in development which aims to explore the icy moons of the planet Jupiter.

> "The European Space Agency's Planck satellite is the first European mission to study the origins of the Universe."

The Planck Space Mission

The European Space Agency's Planck satellite is the first European mission to study the origins of the Universe. It surveyed the microwave sky from 2009 to 2013, measuring the Cosmic Microwave Background (CMB), the afterglow of the Big Bang, and the emission from gas and dust in the Milky Way galaxy. The satellite performed flawlessly, yielding a dramatic improvement in resolution, sensitivity and frequency coverage over the previous state-of-the-art full sky CMB dataset, from NASA's Wilkinson Microwave Anisotropy Probe.

The first cosmology data from Planck was released in March 2013, containing results ranging from a definitive picture of the primordial fluctuations present in the CMB temperature, to a new understanding of the constituents of the Galaxy. This article focuses on critical contributions to these results made by UCL members of staff.

Planck's detectors can measure temperature differences of millionths of a degree. To achieve this, some of Planck's detectors must be cooled to about one-tenth of a degree above absolute zero (colder than anything in nature) so that their own heat does not swamp the signal from the sky. **Dr Giorgio Savini** spent five years prior to the launch building the cold lenses, as well as testing and selecting all the other optical components which constitute the 'eyes' of the Planck High Frequency Instrument. During the first few months of the mission, he helped to analyse the data to ensure that the measurements taken in space and the calibration data on the ground were consistent.

UCL researchers, **Drs Hiranya Peiris**, **Jason McEwen**, **Aurélien Benoit-Lévy** and **Franz Elsner** played key roles in using the Planck cosmological data to understand the origin of cosmic structure in the early universe, the global geometry and isotropy of the universe, as well as the mass distribution of the universe as traced by lensing of the CMB. As a result of Planck's 50 megapixel map of the CMB, the baby picture of the Universe has sharpened, allowing the measurement of the parameters of the cosmological model to percent precision.

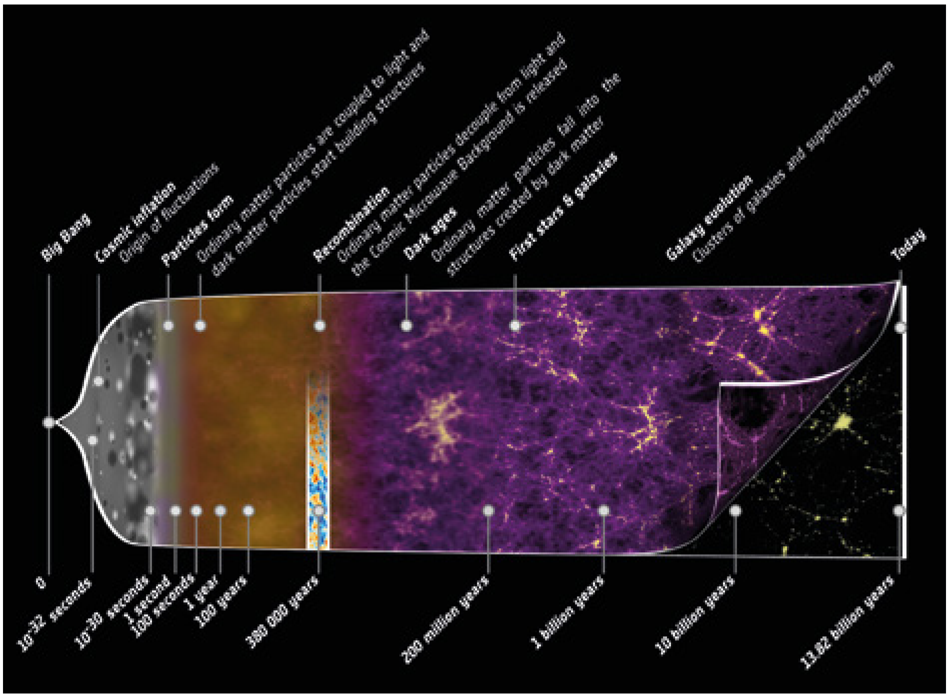
Artist's rendering of the Planck satellite with a view inside the telescope shields. The focal plane unit is visible as the golden collection of waveguide horns at the focus of the telescope positioned inside the thermal shields (external envelope). These protect the telescope from unwanted straylight and aids the cooling of the telescope mirrors by having a black emitting surface on the outside and a reflective one on the inside. For reference, the Earth and Sun would be located far towards the bottom left of this picture.

As an example, Planck has measured the age of the universe, 13.85 billion years, to half per-cent precision.

The precision of the measurements has also enabled scientists to rewind the story of the Universe back to just a fraction of a second (between 10^{-33} and 10^{-42} seconds) after the Big Bang. At that time, at energies

> "The Planck team was able to analyse these distortions, extract the lensing signature in the data, and create the first full-sky map of the entire matter distribution in the Universe."

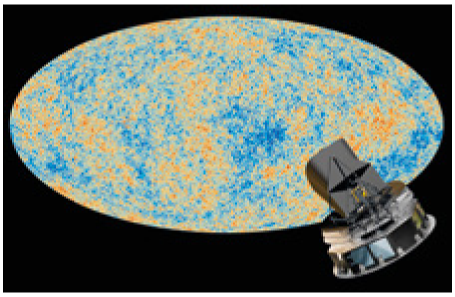
about a trillion times higher than produced by the Large Hadron Collider at CERN, all the structure in the Universe is thought to have been seeded by the quantum fluctuations of a so-called scalar field, the inflation. This theory of inflation predicts that the power in the CMB fluctuations should be distributed as a function of wavelength in a certain way. For the first time, Planck has detected, with very high precision, that the Universe has slightly more power on large scales compared with small scales – the cosmic symphony is very slightly bass-heavy, yielding a key clue to the origin of structure in the Universe. Inflation also predicts that the CMB fluctuations will have the statistical properties of a Gaussian distribution.



This illustration summarises the almost 14-billion-year long history of the Universe. It shows the main events that occurred between the initial phase of the cosmos, where its properties were almost uniform and punctuated only by tiny fluctuations, to the rich variety of cosmic structure that we observe today, from stars and planets to galaxies and galaxy clusters.

Planck has verified this prediction to one part in 10,000 – this is the most precise measurement available.

As the CMB photons travel towards Earth, their paths are slightly bent by massive cosmological structures that they have encountered on the way, such as clusters of galaxies. This effect, where the intervening (dark) matter acts like a lens (only caused by gravity, not glass) on the photons, slightly distorts the CMB. The Planck team was able to analyse these distortions, extract the lensing signature in the data, and create the first full-sky map of the entire matter distribution in the Universe, through 13 billion years of cosmic time. A new window on the cosmos has been opened up.

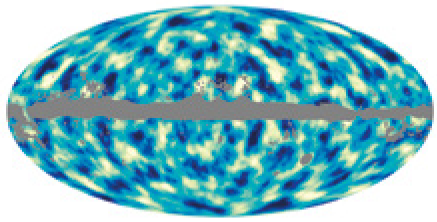


The anisotropies of the Cosmic Microwave Background (CMB) as observed by Planck. The CMB is a snapshot of the oldest light in the Universe, imprinted on the sky when the Universe was just 380,000 years old. It shows tiny temperature fluctuations that correspond to regions of slightly different densities, representing the seeds of all future structure: the stars and galaxies of today.

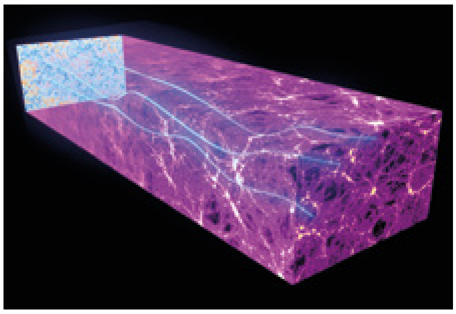
Einstein's theory of general relativity describes the local curvature of space-time but it cannot tell us about the global topology of the Universe. It is possible that the Universe might have a non-trivial global topology, wrapping around itself in a complex configuration. It is also possible that the Universe might not be isotropic, i.e., the same in all directions. The exquisite precision of Planck data allowed fundamental assumptions to be put to the test. The Planck team concluded that the Universe must be close to the standard topology and geometry, placing tight constraints on the size of any non-trivial topology; some intriguing anomalies remain at the largest observable scales, requiring intense analysis in the future.

Aside from additional temperature data not included in the first year results, the upcoming Planck data release in summer 2014 will also include high resolution full-sky polarisation maps. This additional information will not only allow improvements to the measurements of the cosmological parameters but will also probe the structure of the Milky Way Galaxy; investigating its magnetic fields and the distribution and composition of dust molecules.

There is a further, exciting possibility: if inflation happened, the structure of space should be ringing with primordial gravitational waves. Their detection has recently been claimed by a US-Canada-UK Consortium with a South-Pole based experiment (BICEP2) observing a particular pattern in the polarised light of the CMB. It should be possible for Planck to solidly confirm this in the next polarisation data release.



This all-sky image shows the distribution of dark matter across the entire history of the Universe as seen projected on the sky. It is based on data collected with ESA's Planck satellite during its first 15.5 months of observations. Dark blue areas represent regions that are denser than the surroundings, and bright areas represent less dense regions. The grey portions of the image correspond to patches of the sky where foreground emission, mainly from the Milky Way but also from nearby galaxies, is too bright, preventing cosmologists from fully exploiting the data in those areas. The image was compiled by analysing the tiny distortions imprinted on the photons of the Cosmic Microwave Background (CMB) by the gravitational lensing effect of massive cosmic structures. As photons travelled through these structures, which consist primarily of dark matter, their paths were bent, slightly changing the pattern of the CMB.



This artist's impression shows how photons in the Cosmic Microwave Background (CMB) are deflected by the gravitational lensing effect of massive cosmic structures as they travel across the Universe. Gravitational lensing creates tiny, additional distortions to the mottled pattern of the CMB temperature fluctuations. Planck cosmologists have extracted a map of this gravitational lensing effect covering the whole sky for the first time, providing a new way to probe the evolution of structure in the Universe over time.

The Jupiter Icy Moons Explorer (JUICE)

In February 2013, the European Space Agency (ESA) announced which scientific experiments would make up the payload for the JUpiter ICy moons Explorer (JUICE) spacecraft. JUICE is the first large-class mission in ESA's Cosmic Vision 2015-2025 programme. Planned for launch in 2022 and arrival at Jupiter in 2030, it will spend at least three years observing the gas giant and three of its largest moons, Ganymede, Callisto and Europa. It is believed that

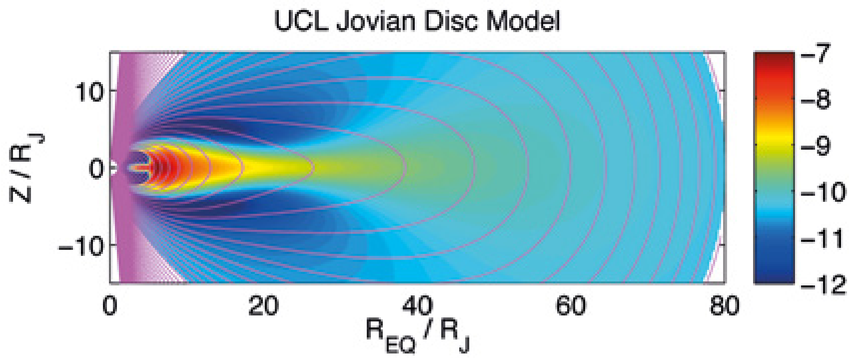
> "Throughout its mission, JUICE will also observe and monitor Jupiter's atmosphere and magnetosphere."

these moons have water oceans beneath their icy surfaces. JUICE will map geological features on their surfaces, obtain information about their interiors and investigate the potential for hosting life in their oceans.

The mission's scientific payload will include a magnetometer (which measures magnetic field), as well as particle instruments which measure the energies and densities of charged particles, such as electrons, protons, sulphur ions and oxygen ions. Also onboard will be imaging cameras, spectrometers, laser altimeters and a radar instrument, capable of 'seeing through' some of the surface ice on these moons. All of these instruments are being developed by scientific teams from sixteen European countries, the US and Japan, through corresponding national funding.

Throughout its mission, JUICE will also observe and monitor Jupiter's atmosphere and magnetosphere. In addition JUICE will study the interaction between the planet's magnetic field and all four Galilean satellites, the three icy moons and the volcanic moon, Io. The spacecraft will perform a dozen flybys of Callisto, the most heavily cratered object in the Solar System, and will fly past Europa twice in order to make the first measurements of the thickness of its icy crust. JUICE will end up in orbit around Ganymede, where it will study the moon's icy surface and internal structure, including its subsurface ocean.

Ganymede is also an important and unique target for the mission, it is the largest moon in the Solar System, and the only one known to generate its own magnetic field. JUICE will be ideally suited to observe the unique magnetic and plasma interactions between Ganymede's own magnetic field and the field in Jupiter's magnetosphere. Critical for these magnetic observations will be the JUICE magnetometer, known as JMAG. The development of JMAG is being led by Imperial College (PI: Prof. Michele Dougherty) and has scientific Co-Investigators from UCL (**Nicholas Achilleos**, and Dr Christopher Arridge, UCL Mullard Space Science Laboratory).



The UCL Jovian Magnetodisc model was used as part of the successful proposal for the JMAG instrument. This figure is a 'slice' of constant longitude from the model, with Jupiter represented by the small white circle at the origin, and the equatorial plane represented by the horizontal line Z = 0. The color scale shows the pressure in Jupiter's magnetosphere due to a plasma of hot particles (electrons, protons and oxygen ions), while the magneta curves represent magnetic field lines generated by the planet's internal source and by the electric current that flows through the plasma outside the planet.

Project in Focus

The Jupiter Icy Moons Explorer (JUICE)

Aim
Exploration of the interaction between Jupiter's magnetic field and icy moons.

Results to Date
Selection of mission and instruments for scientific payload.

UCL Involvement
Co-Investigator status on JMAG, the JUICE magnetometer.

Biological Physics (BioP)

The BioP group aims to undertake research in which physics of the highest academic quality is applied to address critical biological questions. It forms a network between experimental and theoretical physicists from different research groups in the Department, for whom biological problems are either the main focus and/or a significant application of their research activities.

> "Fluorescence microscopy provides valuable information about the location, number and arrangement of these complexes in the cell."

Working at the interface of physics, engineering and biology, **Dr Isabel Llorente-García** explains how ultrasensitive fluorescence-imaging detection, combined with magnetic force sensing, can be used to investigate how viruses enter cells. This work is in collaboration with Prof. Mark Marsh (LMCB, UCL), Dr Sonia Contera (Oxford Physics) and **Dr Phil Jones** (UCL Physics).

Understanding how viruses enter live cells

Molecular complexes that perform vital functions in live cells can be labelled with fluorescent tags, which emit light when illuminated by the appropriate excitation light. Fluorescence microscopy then provides valuable information about the location, number and arrangement of these complexes in the cell. When carried out in live cells (in vivo), it allows dynamic monitoring, maintaining the native biological context and functionality in the living cell.

In tailor-made magnetic trapping potentials, magnetic forces can be used to trap and manipulate micrometre-sized particles in solution. Prior to the magnetic trapping process, the particles can be functionalised and attached to the biological complexes of interest. The magnetic traps can then be employed to exert and measure forces relevant to the function of the molecular complexes in the cell. This enables live-cell force-spectroscopy experiments to be conducted at the single-molecule level.

Viral infections remain a serious threat to human health. For instance, HIV infects approximately two million people a year and kills a similar number. Viruses hijack fundamental cellular processes to replicate and cause infection. They exploit specific cell-surface receptor molecules to penetrate the cell-membrane barrier of new host cells, by mechanisms which are not well understood. Using HIV entry as a model system and applying the above mentioned biophysical techniques at the single-molecule level in live cells, will provide unparalleled insight into the mechanisms of viral infection.

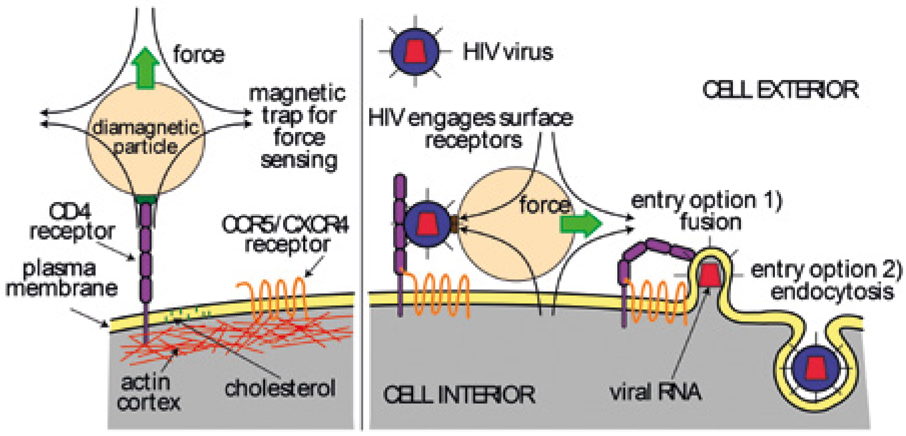
Project in Focus

Fluorescence microscopy, magnetic force sensing and manipulation for the study of receptor-mediated virus entry

Aim

Investigating the mechanisms of viral infection.

The UCL MAPS faculty awarded a UCL Excellence Fellowship to **Dr Isabel Llorente-García**, who joined UCL in May 2013. The aim is to develop a biological physics research program and strengthen interactions between UCL Physics and the future Francis Crick Institute, due to open in 2015.



HIV entry into immune cell via interaction with surface receptors. Magnetic force sensing.

Research Statistics

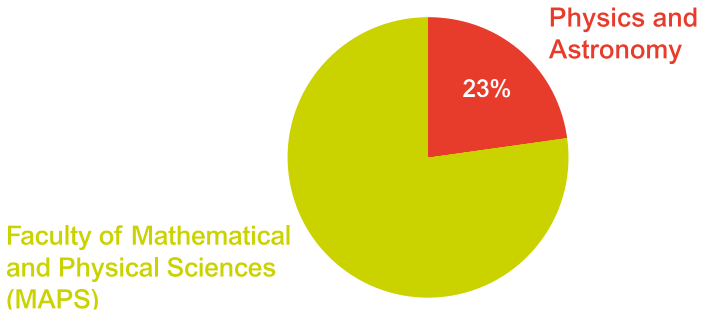
Research Statistics
Jan 2013– Dec 2014

Publication Summary

Research Group	Number of publications in refereed journals
Astro	177
AMOPP	95
CMMP	145
HEP	135

Active Grants and Contracts

In the last financial year (Aug 2012 – Jul 2013), The MAPS faculty as a whole yielded £43,155,000, with the Department of Physics and Astronomy contributing £9,842,000 (23%) of the total research income for the MAPS faculty.



Astrophysics

Euclid Implementation Phase (UKSA) PI: Dr Filipe Abdalla, £545,348

University Research Fellowship (URF) (Royal Society) PI: Dr Filipe Abdalla, £504,594

UCL Astrophysics consolidated grant (STFC) PI: Dr Nick Achilleos, £52,668

Impact studentship: David Johnson – improving the representation of the thermosphere and ionosphere for space weather (UK Met Office) PI: Dr Anasuya Aruliah, £31,627

ATMOP: advanced thermosphere modelling for orbit prediction (EU FP7) PI: Prof. Alan Aylward, £204,412

ESPAS: near-Earth space data infrastructures for e-science (European Commission FP7) PI: Prof. Alan Aylward, £197,306

UCL Astrophysics consolidated grant (STFC) PI: Prof. Michael Barlow, £52,889

COGS – capitalising on gravitational shear (EU FP7) PI: Prof. Sarah Bridle, £1,050,000

Large scale structure insights into the origins of cosmic acceleration (Royal Society) PI: Dr Sarah Bridle, £11,920

Another way of seeing – contemporary art responds to planetary science (STFC) PI: Dr Andrew Charlambous, £2,625

BigBoss UK development (FQXi) PI: Dr Peter Doel, £52,774

Dark energy spectrographic instrument development (STFC) PI: Dr Peter Doel, £33,206

PATT linked grant (STFC) PI: Prof. Ian Howarth, £13,294

Leverhulme Early Career Fellowship (Leverhulme Trust) PI: Dr Caitriona Jackman, £56,088

RAS Fellowship: energy release from magnetospheres (Royal Astronomical Society) PI: Dr Caitriona Jackman, £50,895

Cosmology: from galaxy surveys to dark matter and dark energy (STFC) PI: Prof. Ofer Lahav, £468,087

DESPEC: spectroscopic upgrade of the dark energy survey (STFC) PI: Prof. Ofer Lahav, £141,585

Leverhulme Trust senior research fellowship - the dark energy survey and beyond (Royal Society) PI: Prof. Ofer Lahav, £101,260

TESTDE: testing the dark energy paradigm and measuring neutrino mass with the dark energy survey (European Commission FP7) PI: Prof. Ofer Lahav, £1,812,291

UCL Astrophysics consolidated grant (STFC) PI: Prof. Ofer Lahav, £732,484

Early Career Fellowship: probing cosmological structure through novel signal processing methods (Leverhulme Trust) PI: Dr Jason McEwen, £46,000

Newton Fellowship: probing cosmological structure through novel signal processing methods (Royal Society) PI: Dr Jason McEwen, £106,000

Europlanet RI - European planetology network research infrastructure (European Commission FP7) PI: Prof. Steve Miller, £222,209

Comets as laboratories: observing and modelling commentary spectra (STFC) PI: Prof. Steve Miller, £185,912

The Miracle Consortium: modelling the Universe - from atomic to large scale structures (STFC) PI: Prof. Steve Miller, £557,483

Cosmic Dawn – understanding the origins of cosmic structure (EU FP7) PI: Dr Hiranya Peiris, £1,119,800

Cosmological constraints on the very early universe (Royal Society) PI: Dr Hiranya Peiris, £12,000

Detecting signatures of eternal inflation using WMAP and Planck data (FQXi) PI: Dr Hiranya Peiris, £64,189

Philip Leverhulme Prize - Hiranya Peiris (Leverhulme Trust) PI: Dr Hiranya Peiris, £70,000

Travel for collaboration on exoplanets (FQXi) PI: Dr Hiranya Peiris, £3,047

RS Fellowship: Connecting physics and galaxy formation (Royal Society) PI: Dr Andrew Pontzen, £452,692

The E-Merlin Legacy CYG OB2 Radio Survey: Massive star feedback and evolution (STFC) PI: Prof. Raman Prinja, £400,466

UCL Astrophysics consolidated grant (STFC) £203,329 PI: Prof. Raman Prinja

Royal Society Fellowship PI: Dr Amelie Saintonge, £464,523

Star formation efficiencies and XCO in intermediate mass galaxies (STFC) PI: Dr Amelie Saintonge, £655

A study of galactic polarized dust with blast pol (Leverhulme Trust) PI: Dr Giorgio Savini, £80,621

A super-resolution mid-IR thermal camera telescope for Earth observation and stand-off imaging (Royal Society) PI: Dr Giorgio Savini, £14,120

BETTII – the balloon experimental twin telescope for far infrared interferometry (STFC) PI: Dr Giorgio Savini, £115,636

FISICA – far infra-red space interferometer critical assessment: scientific definition and technology development for the next generation THZ space interferometer (EU FP7) PI: Dr Giorgio Savini, £253,541

Impact Studentship: Paul Moseley - novel qf quasi-optical components for the thz astronomy (ESA) PI: Dr Giorgio Savini, £29,813

Modular wide field of view rf configurations (ESA) PI: Dr Giorgio Savini, £54,706

UCL Astrophysics short-term visitor programme 2010-2012 (STFC) PI: Dr Giorgio Savini, £44,489

Echo study (STFC) PI: Prof Bruce Swinyard, £7,057

EcHO study support (UKSA) PI: Prof. Bruce Swinyard, £85,919

Impact Studentship: Silvia Martinavarro - for Infrared and sub-millimetre study of evolved stars (STFC) PI: Prof. Bruce Swinyard, £30,288

The Science of EcHO (Exoplanet Characterisation Observatory) (STFC) PI: Prof Giovanna Tinetti, £77,871

RS Fellowship: exploring extrasolar words: from terrestrial planets to gas giants (Royal Society) PI: Prof. Giovanna Tinetti, £428,241

RS Fellowship: the exoplanet revolution (Royal Society) PI: Dr Giovanna Tinetti, £310,508

Impact Studentship: Camilla Danielski – probing the atmospheres of extrasolar worlds around m dwarfs (Associacao Solidariedade E Esperanca) PI: Prof. Serena Viti, £25,000

Impact Studentship: Antonios Makrymallis – time senses analysis of chemical models of star forming regions (Columba Systems Ltd.) PI: Prof. Serena Viti, £31,627

Investigating the formation of glycolaldehyde in space (Leverhulme Trust) PI: Prof. Serena Viti, £117,898

LASSIE – laboratory astrochemical surface science in Europe (EU FP7) PI: Prof. Serena Viti, £145,179

The early stages of star information: Glycolaldehyde and its isomers as dense core tracers (STFC) PI: Prof Serena Viti, £1,774

Impact Studentship: Willhelmus Messelink - advanced optical fabrication techniques (Zeeko Ltd) PI: Prof. David Walker, £29,811

AMOPP

Dynamics of information in quantum many-body systems (Royal Society) PI: Dr Janet Anders, £389,692

Low power sub-wavelength resolution fluorescence imaging (BBSRC) PI: Dr Angus Bain, £118,922

Cavity optomechanics: towards sensing at the quantum limit (EPSRC) PI: Prof. Peter Barker, £814,269

Hybrid superconductor-semiconductor devices for majorana fermion detection (EPSRC) PI: Prof. Sougato Bose, £36,831

Nanoelectronic based quantum physics – technology and applications (EPSRC) PI: Prof. Sougato Bose, £441,672

Nonclassicalities and quantum control at the nanoscale (EPSRC) PI: Prof. Sougato Bose, £1,166,350

PACOMANEDIA: partially coherent many-body non-equilibrium dynamics for information applications (European Commission FP7) PI: Prof. Sougato Bose, £933,809

Gravitational free fall experiments with positronium (Leverhulme Trust) £147,622 PI: Dr David Cassidy

Production and manipulation of Rydberg positronium for a matter-antimatter gravitational freefall measurement (EPSRC) PI: Dr David Cassidy, £693,517

Career Acceleration Fellowship (CAF): Ionisation of multi-electron atomic and molecular systems driven by intense and ultrashort laser pulses (EPSRC) PI: Dr Agapi Emmanouilidou, £994,556

Control and imaging of processes triggered by x-ray pulses in multi-centre molecules (EPSRC) PI: Dr Agapi Emmanouilidou, £309,665

Orbit-based methods for multi-electron systems in strong fields (EPSRC) PI: Dr Carla Figueira De Morisson Faria, £313,960

Career Acceleration Fellowship (CAF): star formation and the ism evolution of galaxies across cosmic time (STFC) PI: Dr Thomas Greve, £471,898

Impact Studentship: Agata Pawlikowska - bubbles: sensors for the micro-world (NPL Management LTD) PI: Dr Philip Jones, £54,359

Impact Studentship: Chris Fury – sono-acoustical trapping of microbubbles (NPL Management) PI: Dr Philip Jones, £35,430

Positronium - matter interactions (EPSRC) PI: Prof. Gaetana Laricchia, £468,305

Quantum dynamics in atomic molecular and optical physics (EPSRC) PI: Prof. Tania Monteiro, £167,723

CAF – Exploiting quantum coherent energy transfer in light-harvesting systems (EPSRC) PI: Dr Alexandra Olaya-Castro, £973,877

Phonon-assisted processes for energy transfer and sensing (EU FP7) PI: Dr Alexandra Olaya-Castro, £184,320

Fellowship: quantum information science: Tools and applications for fundamental physics (EPSRC) PI: Prof Jonathan Oppenheim, £984,329

Quantum information, entanglement and cryptography (Royal Society) Fellowship, PI: Prof Jonathan Oppenheim, £207,957

Wolfson Research Merit Award (Royal Society) PI: Prof Jonathan Oppenheim, £60,000

University Research Fellowship: quantum Information, Entanglement and Cryptography (Royal Society) PI: Prof. Jonathan Oppenheim, £203,957

Control of atomic motion with AC fields (Royal Society) £12,000 PI: Prof Ferruccio Renzoni

Exploring stochastic thermodynamics with optical traps (Leverhulme Trust) PI: Prof Ferruccio Renzoni, £149,040

Magnetic sensor systems for the detection of metallic objects – identifying and characterising materials using magnetic field interrogation (Atomic Weapons Establishment) PI: Prof Ferruccio Renzoni, £141,070

Modelling condensed matter systems with quantum gases in optical cavities (EPSRC) PI: Prof. Ferruccio Renzoni, £806,753

COSMA – coherent optics sensors for medical applications (European Commission FP7) PI: Prof. Ferruccio Renzoni, £23,550

UK APAP Network (STFC) PI: Prof. Peter Storey, £27,006

A calculated methane line list for characterising exoplanets and brown dwarfs (STFC) PI: Prof. Jonathan Tennyson FRS, £380,702

ESip - efficient silicon multi-chip system-in-package integration - reliability failure analysis and test (Technology Strategy Board) PI: Prof. Jonathan Tennyson FRS, £283,488

EXOMOL - molecular line lists for exoplanet atmospheres (European Commission FP7) PI: Prof. Jonathan Tennyson FRS, £1,878,425

High accuracy line intensities for carbon dioxide (NERC) PI: Prof. Jonathan Tennyson FRS, £219,065

Impact Studentship: Duncan Little – ionisation reactions and DSMC (Themisys Ltd.) PI: Prof. Jonathan Tennyson FRS, £32,126

Impact Studentship: Dan Underwood – sulphur trioxide/oxide high-temperature spectroscopic databases (Technical University of Denmark) PI: Prof. Jonathan Tennyson FRS, £32,126

Phys4Entry - planetary entry integrated models (European Commission FP7) PI: Prof. Jonathan Tennyson FRS, £144,832

SUP-VAMDC: support at the virtual atomic and molecular data centre (EU FP7) PI: Prof Jonathan Tennyson FRS, £97,434

UCL Astrophysics consolidated grant (STFC) PI: Prof Jonathan Tennyson FRS, £222,822

UK R-Matrix atomic and molecular physics hpc code development project (UK-Ramp) (EPSRC) PI: Prof. Jonathan Tennyson FRS, £300,012

Wolfson Research Merit Award: molecular line lists for extra solar planet and other hot bodies (Royal Society) PI: Prof. Jonathan Tennyson FRS, £72,000

CMMP

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

Computer simulation of redox and hydrolysis reactions in enzymatic systems (Royal Society) PI: Dr Jochen Blumberger, £202,106

Development of microscopic gas diffusion-reaction model for a h2 producing biocatalyst (EPSRC) PI: Dr Jochen Blumberger, £171,252

Impact Studentship: a computational investigation of charge transfer in organic semiconducting materials (PNNL) PI: Dr Jochen Blumberger, £31,482

Impact Studentship: modelling electron transport in multi-heme proteins (PNNL) PI: Dr Jochen Blumberger, £47,042

URF Extension – Understanding gas transport in hydrogenases through novel computer simulations (Royal Society) PI: Dr Jochen Blumberger, £339,813

Complementary Zinc-oxide optoelectronics (Leverhulme Trust) £245,618 PI: Prof Franco Cacialli

CONTEST: collaborative network for training in electronic skin technology (European Commission FP7) PI: Prof. Franco Cacialli, £480,418

Global engagement for global impact: strategic interaction with China, India, Germany and USA (EPSRC) PI: Prof Franco Cacialli, £2,046

Impact Studentship: Giuseppe Maria Paterno – nanoscale characterisation and radiation damage testing of organic solar cells using neutron scattering techniques (STFC) PI: Prof Franco Cacialli, £42,676

SUPERIOR - supramolecular functional nanoscale architectures for organic electronics: a host-driven network (European Commission FP7) PI: Prof. Franco Cacialli: £314,284

Impact Studentship: directing crystal growth with functional surfaces (PNNL) PI: Dr Dorothy Duffy, £29,543

Modelling nano-ferroelectrics (NPL Management Ltd) PI: Dr Dorothy Duffy, £30,000

Studies of domain dynamics in nano-ferroelectrics (NPL Management Ltd) £31,505 PI: Dr Dorothy Duffy

Impact Studentship: Jake Stinson - stability of hydrated sulphuric acid molecular clusters, and the nucleation of stratospheric aerosols for climate control (PNNL) PI: Prof. Ian Ford, £42,626

Nanoparticle probes carrying single DNA molecules for biomolecular detection (Royal Society) PI: Prof Thanh Nguyen, £12,000

URF Extension: nanomaterials for biomolecular sciences and nanotechnology (Royal Society) PI: Prof Thanh Nguyen, £347,058

UCL Additional sponsorship (EPSRC) PI: Prof Thanh Nguyen, £5,622

Ex nihilo crystal structure discovery (EPSRC) PI: Prof. Chris Pickard, £1,590,546

Support for the UKCP consortium (EPSRC) PI: Prof Chris Pickard, £6,457

TOUCAN: towards an understanding of catalysts and nanoalloys (EPSRC) PI: Prof. Chris Pickard, £269,504

Quantum feedback control of levitating opto-mechanics (EPSRC) PI: Dr Alessio Serafini, £579,937

EngD Studentship: advanced gate stack and dielectric in resistive memory material (International Sematech) PI: Prof. Alexander Shluger, £48,047

EngD Studentship: Jonathan Cottom – ab-initio simulations in bulk and interface defects (Infineon Technologies Austria AG) PI: Prof. Alexander Shluger, £30,000

Impact Studentship: Ashley Garvin - laser materials interaction (PNNL) PI: Prof. Alexander Shluger, £34,200

Impact Studentship: David Gao - using computation in component development (Chevron Oronite Company LLC) PI: Prof. Alexander Shluger, £133,010

MORDRED- modelling of the reliability and degradation of next generation nanoelectronic devices (European Commission FP7) PI: Prof. Alexander Shluger, £387,031

Case Studentship: Radhika Patel – in situ studies of clay hydration for sustainable oil and gas exploration (M-I Drilling Fluids UK Ltd.) PI: Prof. Neal Skipper, £27,000

Anna Kimmel: group leader for functional materials group agreement (NPL Management) PI: Peter Sushko, £37,510

Charge donors and traps in complex oxides (Royal Society) PI: Dr Peter Sushko, £322,387

ENGD Studentship: Oliver Dicks – tuning electronic properties of thin films and interfaces using defects (Argonne National Laboratory) PI: Dr Peter Sushko, £38,947

Heavy metal ions studentship (IHI Corporation) PI: Dr Peter Sushko, £30,000

Multiscale modelling of metal-semiconductor contacts for the next generation of nanoscale transistors (EPSRC) PI: Dr Peter Sushko, £292,850

Theoretical modelling of amorphous electrides, electride surfaces, and quasi-two-dimensional active materials (Tokyo Institute of Technology) PI: Dr Peter Sushko, £257,273

University Research Fellowship: electron gas in reduced ionic insulators and semiconductors (Royal Society) PI: Dr Peter Sushko, £485,269

HEP

Development and maintenance of atlas run time tester (STFC) PI: Prof. Jonathan Butterworth, £253,337

Electroweak symmetry breaking and jet physics with atlas at the LHC (Royal Society) PI: Prof. Jonathan Butterworth, £86,247

Small items of research equipment (EPSRC) PI: Prof. Jonathan Butterworth, £23,068

IPPP Associateships 2011-12 (University of Durham) PI: Dr Frank Deppisch, £8,000

Systematic treatment of effective operators in neutrinoless double beta decay (Royal Society) £5,950 PI: Dr Frank Deppisch

UK Involvement in direct dark matter searches (STFC) PI: Dr Chamkaur Ghag, £93,748

University Research Fellowship: Higgs physics and the mystery of particle masses (Royal Society) PI: Dr Gavin Hesketh, £532,834

Dorothy Hodgkin Fellowship: investigating the neutrino with MINOS and liquid argon detector technology (Royal Society) PI: Dr Anna Holin, £463,226

Front end test stand continuation (STFC) PI: Dr Simon Jolly, £45,046

ATLAS upgrade (Phase 1) (STFC) PI: Prof Nikos Konstantinidis, £245,246

ATLAS upgrade (Phase 2) (STFC) PI: Prof Nikos Konstantinidis, £91,435

Experimental particle physics at UCL (STFC) PI: Prof. Nikolaos Konstantinidis, £3,249,880

Higgs-Zap - understanding the origin of mass with the Atlas Experiment at the Large Hadron Collider. Dr Ilektra Christidi (European Commission FP7) PI: Prof. Nikolaos Konstantinidis, £33,750

Beam diagnostics for PETS and PXIE (STFC) PI: Mark Lancaster, £128,859

University Research Fellowship extension - neutrino and cosmic ray studies with minos, anita and cream tea (Royal Society) PI: Dr Ryan Nichol, £315,804

Higgs studies and a search for dark matter at the Atlas experiment (Royal Society) Fellowship, £274,702 PI: Dr Emily Nurse

Training network for Monte Carlo event generators for LHC physics (EU FP7) PI: Dr Emily Nurse, £177,938

University Research Fellowship: search for a vector boson fusion produced Higgs boson at Atlas (Royal Society) PI: Dr Emily Nurse, £406,633

Determining the properties of the Higgs boson (Royal Society) £71,371 PI: Dr Andrew Pilkington

Establishing the nature of electroweak symmetry breaking (Royal Society) Fellowship, £484,076 PI: Dr Andrew Pilkington

Supernemo demonstrator module construction (STFC) PI: Prof. Ruben Saakyan, £297,427

Determining the true nature of the Higgs-like particle (Royal Society) Fellowship, £482,706 PI: Dr Tim Scanlon

Feasibility studies for mega-tonne scale neutrino detectors (Royal Society) PI: Prof Jennifer Thomas CBE, £12,000

MINOS+ (STFC) PI: Prof Jennifer Thomas CBE, £239,618

MINOS and physics preparation Research Associate (STFC) PI: Prof. Jennifer Thomas CBE, £155,756

Research Associate to work on Minos (STFC) PI: Prof. Jennifer Thomas CBE, £114,442

Wolfson Research Merit Award: **New frontiers in neutrino physics -** (Royal Society) PI: Prof. Jennifer Thomas CBE, £75,000

IPPP Associateships 2009-10 (University of Durham) PI: Prof. Robert Thorne, £17,000

Particle physics phenomenology (STFC) PI: Prof. Robert Thorne, £343,107

Terauniverse – exploring the terauniverse with the LHC, astrophysics and cosmology (European Commission FP7) PI: Prof. Robert Thorne, £356,475

Experimental particle physics consolidated grant 2012 – 2016 (STFC) PI: Dr David Waters £4,340,016

Impact Studentship: Guillaume Eurin – low background physics and the search for neutrinoless double-beta decay (Centre National de la Recherché Scientifique) PI: Dr David Waters, £31,627

Supernemo commissioning and sensitivity demonstration (STFC) PI: Prof David Waters, £420,768

GridPP4 Tranche 1 London Grid UCL Grant (STFC) PI: Dr Ben Waugh, £7,500

Enhanced European coordination for accelerator research and development (EU FP7) PI: Prof Matthew Wing, £93,794

European XFEL clock and control system (European X-Ray Free-Electron Laser Facility GmbH) PI: Prof. Matthew Wing, £686,926

Impact Studentship: Scott Mandry – diagnostics for a proton-driven plasma Wakefield Experiment (Max Planck Institute For Physics) PI: Prof. Matthew Wing, £31,627

Photon-driven plasma wakefield acceleration – a new route to a TEV E^+E^- collider (STFC) PI: Prof Matthew Wing, £21,977

Headline Funding

Professor Ofer Lahav

European Research Council (ERC)

'Testing the dark energy paradigm and measuring neutrino mass with the Dark Energy Survey' (TESTDE)

£1,812,291

Observations of distant supernovae have established that the Universe is not only expanding but also accelerating. However, the causes of this acceleration and the composition of the Universe are currently unknown. Dark energy is thought to make up 70% of the Universe, with dark matter comprising a further 25%, and the remaining 5% in baryons.

The international Dark Energy Survey (DES) is a photometric survey of the southern sky, which aims to test the existence of both components.

DES is already producing good quality data with the camera instrument (partially built at UCL) on the Blanco telescope in Chile. Observations began in September 2012.

The TESTDE project will use data taken from DES to test modified General Relativity models, as alternatives to Dark Energy. The project will also pioneer a measurement of the currently unknown neutrino mass from DES, as well as developing new approaches to photometric redshifts.

Staff Snapshot

Head of Department
Professor J. M. Butterworth

Deputy Head of Department
Professor A. H. Harker
(1/10/2004 until 30/9/2013)

Professor R. K. Prinja (from 1/10/2013)

Astrophysics
Head of Group:
Professor M. J. Barlow

Professors:
M. J. Barlow, I. D. Howarth, O. Lahav, S. Miller, R. K. Prinja, J. M. Rawlings, B. M. Swinyard, S. Viti

Professorial Research Fellow:
D. D. Walker

Readers and Senior Lecturers:
F. Abdalla, N. Achilleos, A. L. Aruliah, A. P. Doel, I. Furniss, H. Peiris, G. Savini

Lecturers:
J. Farihi, T. Greve, B. Joachimi, A. Pontzen, A. Saintonge

Senior Research Associates:
F. Diego, M. Matsuura, J. Yates

Research Associates:
M. Banerji, A. Benoit-Levy, T. Bisbas, F. Elsner, S. Feeney, D. Fenech, J. Frazer, P. Guio, M. Hirsch, C. Jackman, S. Jouvel, D. Kirk, A. Leonard, M. Manera Minet, A. Merson, F. Poidevin, N. Roth, B. Rowe, I. Sadeh, T. Spain, S. Thaithara Balan, I. Waldmann, P. Woods

Support Staff:
D. Brooks, J. Deacon, J. Fabbri, K. Nakum, M. Rangrej, A. Val Baker

Atomic, Molecular, Optical and Positron Physics
Head of Group:
Professor G. Laricchia (until 31/8/2013)

Professor P. Barker (from 1/9/2013)

Professors:
P. Barker, S. Bose, G. Laricchia, T. S. Monteiro, J. Oppenheim, F. Renzoni, J. Tennyson FRS

Readers:
A. J. Bain, D. Browne, C. Figueira de Morisson Faria, P. H. Jones, A. Serafini

Lecturers:
D. Cassidy, A. Emmanouilidou, S. Hogan, A. Olaya-Castro, M. Szymanska, J. Underwood

Senior Research Fellow (Crick):
I. Llorente Garcia

Senior Research Associate:
S. Yurchenko

Research Associates:
D. Ballester, L. Banchi, A. Bayat, S. Brawley, C. Coppola, A. Deller, F. Fassioli-Olsen, M. Genoni, A. Gerakis, C. Hill, S. Hutchinson, V. Laporta, C. Lazarou, L. Lodi, S. Lopez Lopez, R. Marsh, J. Millen, D. Monahan, E. O'Reilly, O. Polyansky, A. Rahman, M. Scala, M. Trivedi, C. Vaillant, T. Wall, A. Wallis, A. Wickenbrock, A. Yachmenev, C. Zagoya Montiel

Support Staff:
J. Dumper, R. Jawad, C. Johnston

Condensed Matter and Materials Physics
Head of Group:
Professor N. Skipper

Professors:
G. Aeppli, S. Bramwell, F. Cacialli, A. J. Fisher, I. J. Ford, A. Green, A. H. Harker, D. F. McMorrow, T. T. K. Nguyen, C. J. Pickard, I. K. Robinson, A. Shluger, N. T. Skipper

Readers and Senior Lecturers:
J. Blumberger, D. R. Bowler, D. Duffy, C. Hirjibehedin B. W. Hoogenboom, P. Sushko, S. W. Zochowski

Lecturers:
M. Buitelaar, M. Ellerby, C. Howard, M. Parish, S. Schofield, P. Thibault, P. Zubko

Senior Research Associate:
M. Watkins

Research Associates:
K. Fraser, S. Hepplestone, A. Kimmel, A. Kubas, N. Kuganathan, S. Ling, M. Martinez Canales, L. Santarelli, N. Seidler, G. Schusteritsch

Most Research staff are employed through the LCN

Support Staff:
C. Jordan, J. Rooke

High Energy Physics
Head of Group:
Professor M. A. Lancaster

Professors:
J. M. Butterworth, N. Konstantinidis, M. A. Lancaster, R. Saakyan, J. A. Thomas, R. S. Thorne, D. Waters, M. Wing

Readers:
M. Campanelli, R. Nichol

Lecturers:
F. Deppisch, C. Ghag, K. Hamilton, G. Hesketh, S. Jolly, A. Korn, E. Nurse

Royal Society Research Fellows:
A Pilkington, A. Holin (Dorothy Hodgkin)

Principal and Senior Research Associates:
R. Flack, P. Sherwood, B. Waugh

Research Associates:
A. Basharina-Freshville, S. Bieniek, M. Cascella, B. Cooper, R. D'arcy, A. Davison, L. Deacon, A. Desai K. Gregersen, J. Harz, W-C. Huang, E. Jansen, K. Laney, R. Litchfield, A. Martyniuk, J. McFayden, P. Motylinski, L. Reichhart, S. Torre, D. Wardrope, L. Whitehead

Support Staff:
D. J. Attree, G. Crone, J. Grozier, T. J. Hoare, C. Johnston, E. Motuk, B. Simmons, M. Warren

Teaching
Director of Teaching:
Professor R. K. Prinja

Director of Postgraduate Studies:
T. S. Monteiro

Director of Undergraduate Laboratories:
F. Renzoni

Director of University of London Observatory: I. D. Howarth

Manager of University of London Observatory: P. K. Thomas

Laboratory Superintendent:
D. Thomas

Senior Teaching Fellow:
P. Bartlett

Teaching Fellows:
D. Armoogum, E. Bailey, S. J. Boyle, M. Coupland, L .Dash, P. Donovan, S. J. Fossey, N. Nicolaou

Laboratory and Computing Technicians:
B. T. Bristoll, M. Pearson, T. Schlichter, M. A. Sterling, K. Vine

Admissions Tutors:
F. Cacialli (MSc), M. M. Dworetsky (Astronomy Certificate), R. S. Thorne (Postgraduate Research), D. Waters (Undergraduate)

Programme Tutors:
D. Duffy (MSc), M. M. Dworetsky (Astronomy Certificate), I. Furniss (Astronomy), S. W. Zochowski (Physics)

Maps Workshop
Superintendent:
R. Gollay

Technicians:
J. Benbow, J. F. Percival

Administration
Departmental Manager:
H. Wigmore

Examinations Co-ordinator and IT Support:
K. Heyworth

Grants Officer:
J. Barrett / R. Walker

Accounts Officer:
L. Duffy

Finance Officer:
D. Buck

Finance and Postgraduate Administrator:
N. Waller / J. Davies

Undergraduate Administrator:
S. Lo

Teaching Support Administrator:
C. Jordan

Group Administrator Astro:
K Nakum / A. Val Baker

Group Administrator AMOPP & HEP:
C. Johnston

Group Administrator CMMP:
C. Jordan

Departmental Computing Manager:
B. Waugh

Safety & Facilities Manager:
L. Bebbington

Science Centre Organiser:
S. Kadifachi

Visiting Professors and Emeritus Staff
A. Aylward, A. Boksenburg, F. W. Bullock, D. H. Davis, M. M. Dworetsky, R. S. Ellis, M. Esten, J. L. Finney, M. J. Gillan, W. M. Glencross, T. C. Griffith, C. Hilsum, J. W. Humberston, T.W. Jones, G. E. Kalmus, M. Longair, K. A. McEwen, B. R. Martin, D. J. Miller, W. Newell, G. Peach, P. G. Radaelli, A. C. Smith, P. J. Storey, D. N. Tovee, C. Wilkin, D. A. Williams, A. J. Willis

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