UCL DEPARTMENT OF PHYSICS AND ASTRONOMY

UCL

2011–12 PHYSICS AND ASTRONOMY ANNUAL REVIEW

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Cover image: **The Dark Energy Survey (DES) Imaging Camera**

Dr Peter Doel and **Dr David Brooks** with one of the five lenses which will be installed in the wide field imaging camera for the DES project. The camera will be placed in the Blanco telescope in Chile and used to investigate dark energy in the Universe. The lens shown in this picture is the largest, measuring one metre in diameter. UCL has been heavily involved in the design, planning and construction of the camera, with the five lenses being installed into the camera barrel at UCL. The lenses were aligned to an accuracy of ~50 micrometers in tip/tilt and centering. For further details on this project, see the Headline Research (p7).

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

Welcome

It is an honour to write this introduction standing, to misquote Newton, on the shoulders of giants. Jonathan Tennyson finished his tenure as Head of Department in September 2011 and so the majority of the material contained in this Review records achievements under his leadership. In addition, **Tony Harker** is currently acting as Head of Department in many matters and will continue to do so until October 2012. This is due to my on-going commitments with the ATLAS experiment on the Large Hadron Collider (LHC) at CERN. I currently spend a large amount of my time in Geneva and I am very grateful to both Tony and Jonathan, as well as to other members of staff for helping to make this transition a success. In particular I would also like to thank **Hilary Wigmore** as Departmental Manager and **Raman Prinja** as the new Director of Teaching for their continued support.

> “Success in such long-term, high-impact projects requires sustained vision and dedicated work by excellent scientists over many years.”

Underpinning this success is the outstanding quality of scientific research and education within the Department. These form the very core of Departmental life and are fundamental to its continued growth and prosperity. Scientifically, 2011 has produced very many exciting results: the ATLAS experiment (mentioned above) has produced some very interesting results (see p12) and the telescope lenses for the Dark Energy Survey have now been delivered to Chile, I saw the crates drifting past my new office on the end of an impressively large crane! (see the front cover of this Review and p7).

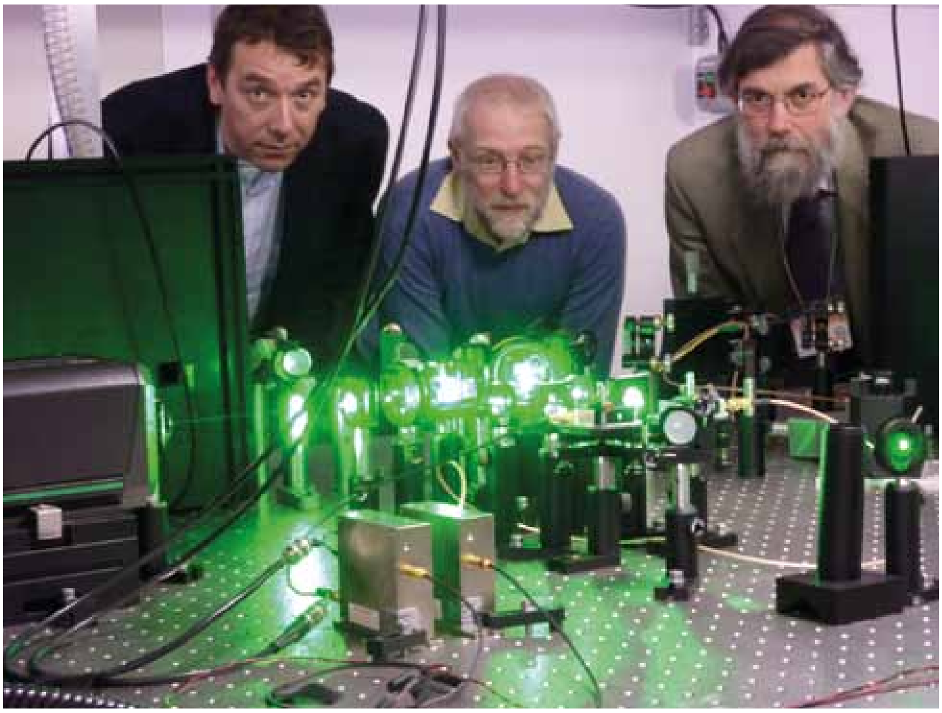
Welcome cont.

Additionally, we have key roles in two missions which have been selected by the European Space Agency as candidates for their 'Cosmic Vision' programme.

The EUCLID mission will target Dark Energy, whilst EChO plans to investigate planets beyond our solar system (see p27). Congratulations to **Giovanni Tinetti**, who was awarded the 2011 IoP Mosely Medal for her work in this area.

These science programmes continue to attract major research funding from a variety of sources. Success in such long-term, high-impact projects requires sustained vision and dedicated work by excellent scientists over many years. I am proud that UCL Physics and Astronomy is able to provide a platform for such success. Our strong engagement with science policy also contributes to this and was recognised in the case of **Jenny Thomas**, who this year was not only elected to a fellowship of the American Physical Society for her work in neutrino physics, but was also appointed CBE for services to science. Additionally congratulations to **Des McMorrow** and **Alex Shluger** who were also elected to fellowships of the American Physical Society for their work in X-ray diffraction and the atomic physics of surfaces respectively. Interactions with the London Centre for Nanotechnology (LCN) continue to bear fruit - one of my earliest engagements as Head of Department was to attend the LCN 5th anniversary celebrations, which was a very pleasurable introduction to the exciting physics in this area.

Although this is an uncertain time for undergraduate recruitment due to the impact of increased fees and other policy changes which are still to be fully understood, I am pleased to report that the size and strength of our undergraduate cohort, along with our level of applications both remain healthy. However there is no doubt that our incoming admissions tutor, **David Waters**, faces an interesting and challenging time. Our teaching remains excellent and I congratulate **Phil Jones**, joint recipient of the Faculty Teaching Award, as well as our students for their continued strong results.



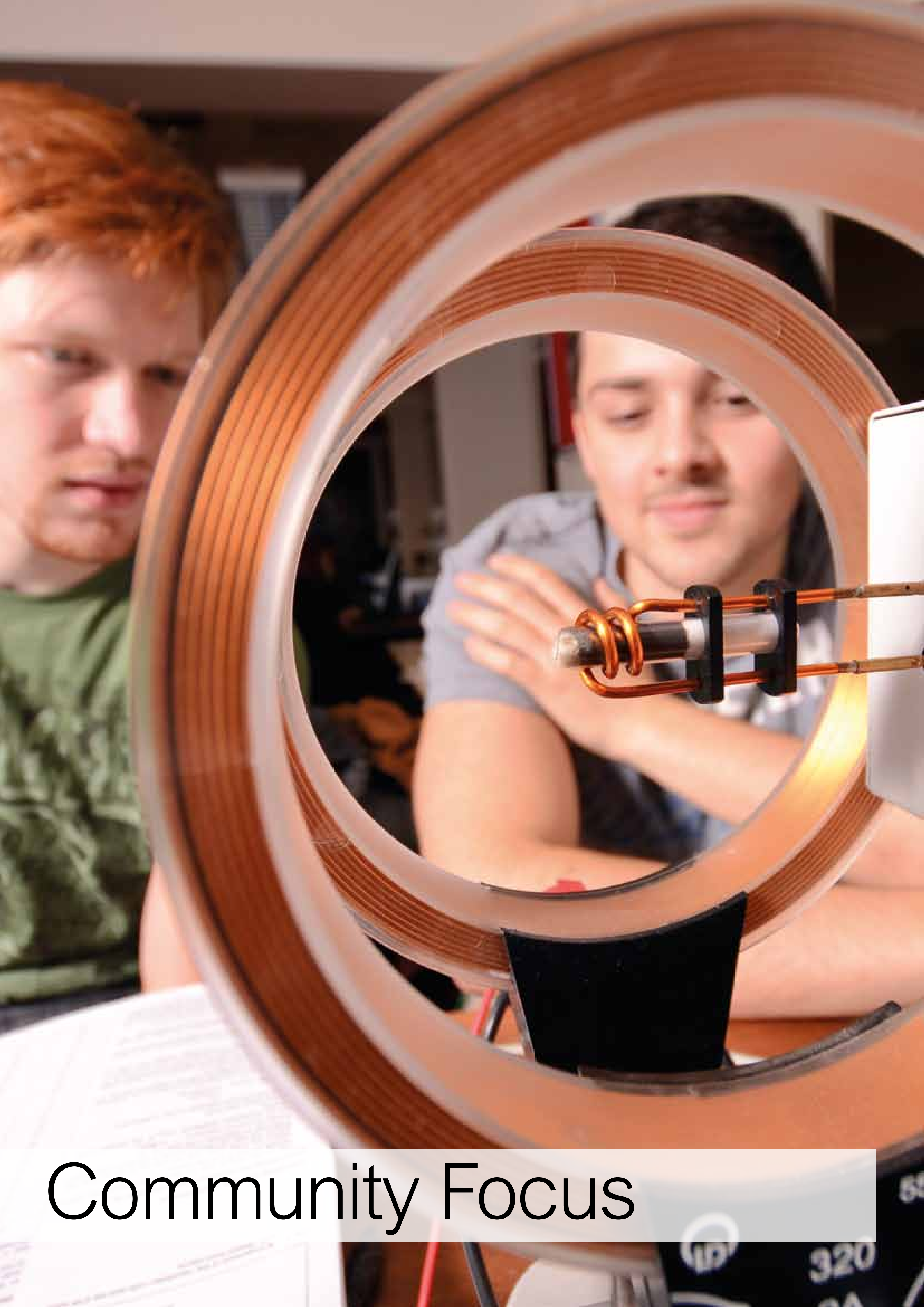
From left to right: ***Professor Jon Butterworth, Professor Jonathan Tennyson FRS and Dr Tony Harker. The laser beam shown in the foreground is used to explore quantum mechanics by levitating small objects such as glass spheres. A small-scale version of this experiment will be touring UK science festivals in 2012, see p8 for further details.***

On a postgraduate level, the UCL Impact Studentship scheme continues to have a huge and beneficial effect on our ability to recruit and support excellent PhD students. This has been enhanced by the gifts of three studentships from alumni, for which we are extremely grateful. Given the success of this scheme, UCL is now looking to extend the programme and further sponsorship would be very welcome.

As always, the continued growth of the department places a strain on our physical resources and the challenge of finding space remains very much on our minds. But in any case, I am confident that we will continue to grow as a centre of excellent physics at undergraduate, graduate and research levels and I very much look forward to the next few years.

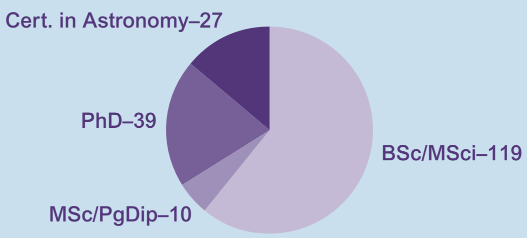
Professor Jonathan Butterworth
Head of Department

Community Focus

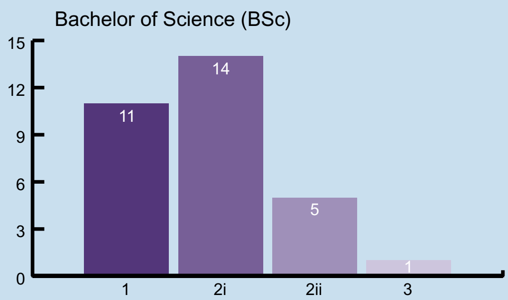


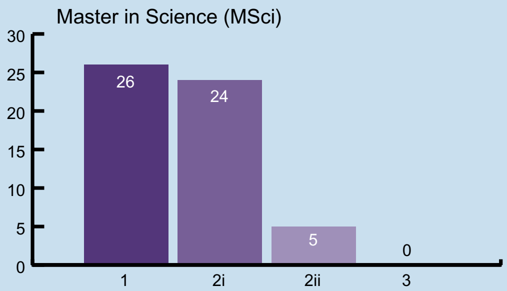
Teaching Lowdown

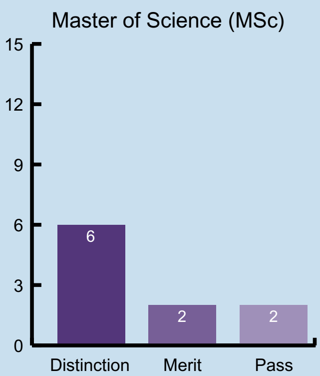
Intake

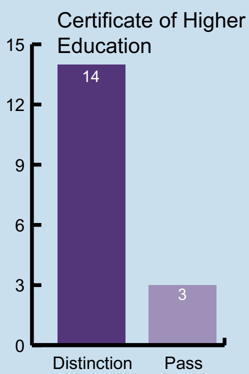


Awards









Students studying for the UCL Natural Sciences degree have the option of majoring in Physics or Astronomy. Currently just over ⅓ of these students study Physics and Astronomy modules as one of their two first year strands, with roughly ¼ choosing to major in Physics or Astronomy in their third year.

Student Accolades

Undergraduate Awards

Departmental Awards

Oliver Lodge Prize
Best performance 1st year Physics
Mr Stefan Blesneag

Halley Prize
Best performance 1st year Astronomy
Mr Sandor-Iozsef Kruk

C.A.R. Tayler Prize
Best 2nd Year Essay (joint winners)
Mr Liam Cooper & Mr Hao Ding

Wood Prize
Best performance 2nd year Physics
Mr Zhi Wong

Huggins Prize
Best performance 2nd year Astronomy
Mr Marco Rocchetto

David Ponter Prize
Most improved performance in Department, 2nd year
Mr Wei Wang

Corrigan Prize
Best performance in experimental work, 2nd year
Mr Mario Zacharias

Best Performance 3rd Year Physics
Mr Arnold Mathijssen

Best Performance 3rd Year Astronomy
Miss Shaghayegh Parsa

Additional Sessional Prize for Merit (3rd Year)
Most improved performance 3rd Year
Mr Pierre Deludet

Burhop Prize
Best performance 4th year Physics
Mr Jack Hansom

Herschel Prize
Best performance 4th year Astronomy
Mr Carl Salji

Brian Duff Memorial Prize
Best 4th Year project (joint winners)
Mr Alexander Bridi & Mr James Bush

William Bragg Prize
Best overall undergraduate
Mr Wei Chao Zhou

Tessella Prize for Software
Best use of software in final year Physics/Astronomy projects
Mr Dino Osmanovic

Faculty Awards

Dean's List
A commendation to undergraduate students of excellence.
Mr Shaun Gupta, Mr Christian Gutschow, Mr Jack Hansom, Mr Dino Osmanovic, Mr Mark Pickering & Mr Wei Chao Zhou

Jackson Lewis Scholarship (joint winners)
Mr Arnold Mathijssen (Physics & Astronomy) & Artiom Fiodorov (Mathematics)

Postgraduate Taught Prize
Mr Marian Breuer

Postgraduate Awards

Departmental Awards

Carey Foster Prize
Outstanding postgraduate research physics, AMOPP
Dr Tahir Shaaran

HEP Prize
Outstanding postgraduate research physics, HEP
Dr Matthew Mottram

Marshall Stoneham Prize
Outstanding postgraduate research physics, CMMP (joint winners)
Dr Dara McCutcheon & Dr Marc Warner

Harrie Massey Prize
Best overall MSc student
Ms Linda Cremonesi

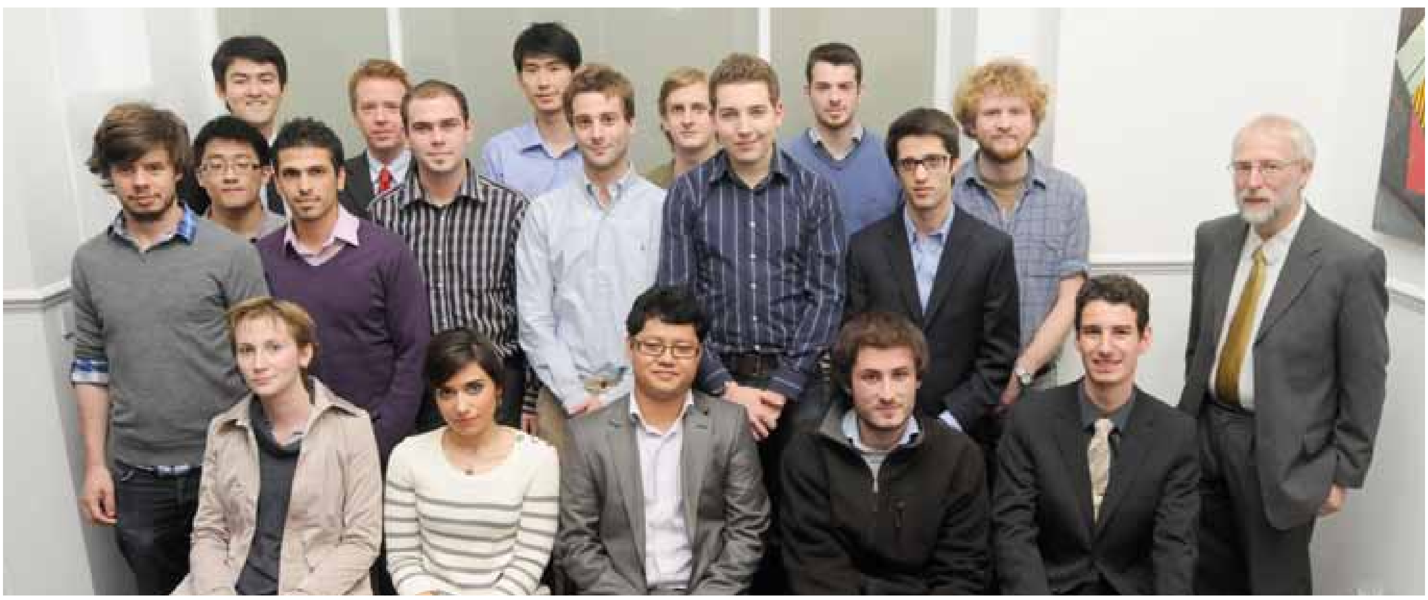
Jon Darius Memorial Prize
Outstanding Postgraduate Research, Astronomy
Dr David Kipping

Faculty Awards

Postgraduate Research Prize
Dr David Kipping

Outstanding PhD Theses Published

'**Springer Theses**' is a new series of publications from Springer, the series publishes the most outstanding PhD research from universities worldwide. **Dr Hannu Wichterich**'s thesis was the first from the Department to be accepted, **Dr David Kipping**'s work has also been published.



Physics and Astronomy prize winners 2011

Career Profiles

Kate Oliver

Communications, Events and Marketing Manager, UCL Engineering
(MSci Physics 2007)

I went off to study physics at UCL in 2004, with a dream of being a particle physicist and obtaining the Swedish prize. I rapidly realised that I didn't have the brain or maths to plug any holes in any theory. So I decided to concentrate on experiments instead, but still left rather disappointed that I wasn't going to change the world.

While I was knocking quantum physics into my skull though, I had also written about science for student magazines, and I thought that this might be something I could be superlative at. I submitted some comedy pieces to Null Hypothesis.co.uk, wrote some content for a coffee-table book, Defining Moments in Science and started reviewing for The Sky At Night Magazine. What's more, I got paid for it!

On the strength of my science writing experience, I started my first science communication job working at the European Synchrotron Research Facility (ESRF) in the French alps to promote their upgrade to European journalists. Through this job, I learnt French, a lot about X-rays, and a despair of English food! Since then I've written educational material for the Institute of Maths and its Applications, worked as a researcher in the science TV department of the BBC, and have now come full circle to work as the Communications Manager in UCL Engineering.

> "I went off to study physics at UCL in 2004, with a dream of being a particle physicist and obtaining the Swedish prize."

The highlights of my career so far have been visiting the Compact Muon Solenoid (CMS) cavern, writing the cover story for The Sky At Night (in the southern hemisphere) and winning the science pub quiz at the RI. I also occasionally write Physics World's Lateral Thoughts – keep an eye out for me!

Rebecca Duncan

Head of Progression & Independent Learning, Hampstead School
(BSc Astrophysics 2007)

When I was 18, my ambition was to join the Army as an accountant! If anyone had told me then that I would end up working at an inner city London school with a degree in Astrophysics from UCL, I'd have had them certified on the spot!

My decision to move into teaching came in my final year at UCL, whilst talking to a Canadian alumnus on a transatlantic call! I was working on behalf of UCL as a telephone fundraiser and discovered that entire boroughs of London had Physics classes being taught by non-specialists. The altruist in me balked at this and I applied for a place on the PGCE in Secondary Science Education (Physics) at the Institute of Education.

After completing training, I found myself thoroughly in the deep end; with a full timetable, my own classes and my very own lab. I've never worked so hard, or slept so little in my life! Every hour was a new deadline and precious, the students will be there whether you're ready for them or not and if you mess it up, it is the students who suffer. I loved (almost!) every minute, but found that it was a huge responsibility.

> "I am immensely proud of my degree from UCL and am eternally grateful to whoever it was that signed off my UCAS application."

In most other jobs, if you can't make it into work, you just work twice as hard when you get back, or work from home. Not so with teaching, you can't just shift the timetable back a day and you definitely don't want any students turning up at your door (plus being tired in front of a computer is manageable, but not so great in front of a class of 30 children with Bunsen burners!)

I decided to slow my pace down a little and what has eventually emerged is my perfect job. I am in charge of the school library, Head of Careers and organise work experience. I take much satisfaction in seeing the difference a really great placement can make to a student's attitude and aspirations. Plus I get my accountancy fix, as I am also responsible for students' Economic Wellbeing and Financial Capability education.

I am immensely proud of my degree from UCL and am eternally grateful to whoever it was that signed off my UCAS application. I recently popped in to the Department and whilst much has changed, it still felt a little bit like coming home (or possibly the prodigal daughter returning!). Certain elements of my job description can be attributed to the work I undertook at UCL; from working for the UCL library during the summer holidays, to conducting tours at the ULO. I truly love my job. Although working with tomorrow's generation is not easy, no two days are the same and every conversation you have with a student has the potential to be life changing – for better and for worse.

Students often ask me "If you've got a degree in Astrophysics why are you working in a library?". I smile and say that it's because I like the holidays, but in reality I am quietly moulding future UCL Physics and Astronomy candidates as it really is a degree that can take you anywhere. Even back to school…

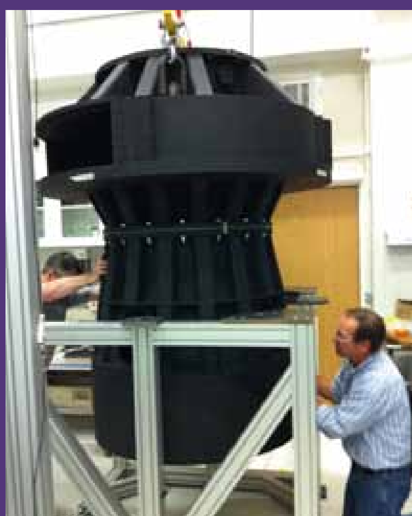
Headline Research

The Search for Dark Energy

Dark energy is thought to make up 74% of the Universe, with dark matter making up a further 22%, however the existence of both are yet to be definitively proven. Through the international Dark Energy Survey (DES) project, scientists hope to be able to test the existence of both components.

The first step in this project was to design and construct a wide-lens camera which will be installed in the Blanco telescope in Chile. This project brings together both instrumental and cosmology members of the Astro group; from the initial commissioning, to the intricate data analysis when the telescope is fully operational. **Professor Ofer Lahav** leads the project's science, **Dr Peter Doel** and **Dr David Brooks** used a specially adapted laboratory here at UCL to install the 5 lenses into the camera barrel (front cover).

The next step will be to ship the camera barrel to Chile for installation. DES will map 300 million galaxies, over ⅛ of the sky, with **Dr Sarah Bridle** and **Dr Filipe Abdalla** co-leading data analysis groups.



Science in Action

The Big Bang Fair

The Big Bang Fair is the UK's biggest single celebration of science and engineering for young people. The Fair takes place annually, at a different location every year. In 2011 the event came to London and members of the HEP group ran an experiment at the Institute of Physics (IOP) stand.

> "The team demonstrated some of the marvels of particle physics, focusing on the Large Hadron Collider (LHC) at CERN and how physicists plan to prove and weigh, or disprove the existence of the Higgs boson."

The team demonstrated some of the marvels of particle physics, focusing on the Large Hadron Collider (LHC) at CERN and how physicists plan to prove and weigh, or disprove the existence of the Higgs boson.

If physicists manage to create a Higgs boson event at the LHC, then it will not live long enough to be directly observed and will rapidly decay into a host of other particles. To find and weigh the Higgs, it is these other particles which will have to be observed. To demonstrate this, the team used 100 brightly coloured plastic balls and filled them to various weights, thus representing the different particles expected to be seen at the LHC. With a set of weighing scales, children could then work out the mass of the plastic Higgs boson by balancing it against the other types of particles.

Plastic balls and scales were used to demonstrate the method and mathematical calculations involved in the search for the Higgs boson at the LHC.

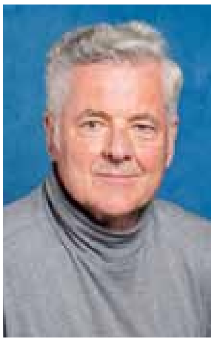
The Quantum Workshop

Dr James Millen has been awarded grants by both the Beacon Innovation Seed fund and the Institute of Physics to deliver 'The Quantum Workshop'.

This is a cutting edge experiment, consisting of a tiny glass sphere which is levitated by laser beams in the air. The experiment will be used to facilitate discussions with the public on quantum mechanics and other areas of physics.

The project is scheduled to appear at the Cheltenham and British Science Festivals, along with educational institutions such as the Science Museum.

Alumni Matters



By Professor Tegid Wyn Jones

The Annual Alumni Dinner took place on the 6 May 2011 and was attended by 33 guests – our largest number to date!

We were addressed by Professor Mike Charlton who graduated from UCL Physics with a BSc in 1978, and PhD in 1980. In an amusing speech he related how I was the first to meet him at UCL, and the last to see him off the premises in 1999! Mike paid tribute to his PhD supervisor, T Ceiri Griffiths and so great was our joint Welsh influence that he moved to Swansea University in 1999. Together with Ian Halliday, Mike rejuvenated the Physics department and is currently a leader of the project to produce anti-hydrogen at CERN.

Another highlight this year was the visit of José-Marie Griffiths to UCL. José-Marie graduated with a BSc from UCL Physics in 1973, followed by a PhD from UCL Information Science in 1977. Starting her career with the Imperial Cancer Research Fund Laboratories, she has become an internationally acclaimed policy expert, researcher and university administrator in the US and has served on several Presidential committees. Currently she is the Vice President for Academic Affairs at the prestigious Bryant University, Rhode Island and Vice Chairman of the US National Science Board. It was great to reminisce with her about UCL, alumni in the US and with her husband on Welsh Rugby! Jose-Marie's father was a soldier during WW2; after the war he became a leading member of the London Welsh Rugby Club. I am always pleased to welcome Alumni back to the Department.

> "I hope that many of you will attend our next alumni dinner, scheduled for Friday 4 May 2012."

Once again, I hope that many of you will attend our next alumni dinner, scheduled for Friday 4 May 2012. The after-dinner speaker will be Professor Cyril Hilsum CBE FRS FREng Hon FInstP. He graduated from UCL Physics in 1945, having spent two of his undergraduate years in Bangor, due to the UCL evacuation during the War. In a truly illustrious career, his last job was Director of Research at the GEC Hirst Laboratory. He is also a recipient of the Max Born prize, the Faraday Medal, the Glazebrook Medal and the Royal Society Royal Medal.

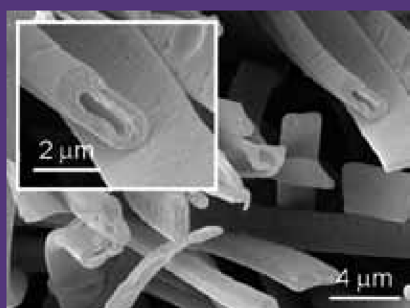
Headline Research

A Step Closer To Zero Carbon Emissions

A new technology has been developed which enables hydrogen to be stored in a cost-effective and practical manner, potentially facilitating the use of hydrogen as a carbon-free alternative to petrol.

The team of collaborators, including former EngD student **Dr Zeynep Kurban** and **Professor Neal Skipper**, developed a new nano-structuring technique called 'co-electrospinning'. Minute micro-fibres (30 times smaller than a human hair) are produced to encapsulate hydrogen-rich chemicals (hydrides). This encapsulation allows the hydrogen to be released at a significantly faster rate and lower temperature, while also protecting the hydrides from oxygen and water, making it possible to handle them safely in air. This new nano-material contains as much hydrogen as the tanks currently used in prototype hydrogen powered vehicles. It can also be formed into microbeads that can be poured and pumped like a liquid, and used to fill up tanks in a similar way to current fuels.

This technology is being taken to market by spinout company, Cella Energy Ltd, which has recently won the 2011 Shell Springboard Prize and Energy Storage Challenge.



In Memoriam

Professor Marshall Stoneham FRS
(1940–2011)

After a short illness, Professor Marshall Stoneham FRS sadly died on the 18 February 2011, aged 70. Though nominally retired from UCL, he remained highly active within the Department, as well as being President of the Institute of Physics.

A leader in his field, Marshall will be remembered for an enormously diverse range of contributions to theoretical materials physics. His books, most notably the definitive 'Theory of Defects in Solids', were highly influential. His status in the field was attested by the wide network of longstanding collaborators he maintained, and by a continuing flow of invitations to give keynote talks at international meetings.

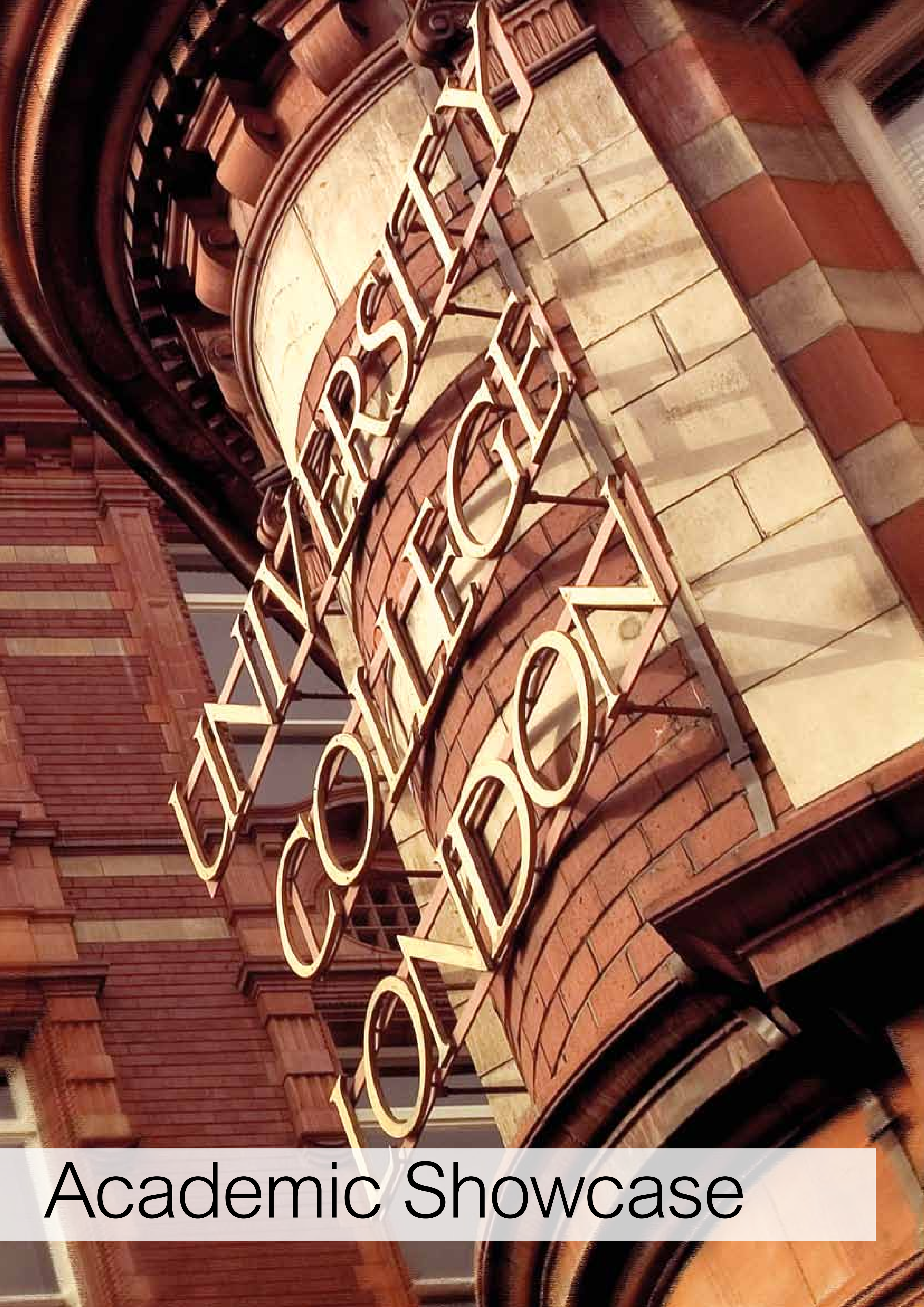
Born in 1940 in Barrow-in-Furness, he was educated at Barrow Grammar School for Boys and always spoke with pride of the three Fellows of the Royal Society whom it produced – a statistic he attributed to its excellent physics teaching. His undergraduate and postgraduate degrees were taken at Bristol University and in 1964 he joined the Theoretical Physics Division at the Atomic Energy Research Establishment, Harwell. He spent more than thirty years at Harwell, culminating in his role as Chief Scientist of AEA Industrial Technology.

Marshall joined UCL in 1995 as the first Massey Professor of Physics and Director of the Centre for Materials Research. He also joined the newly established CMMP group and, along with the group's first Head **Professor John Finney**, set about building it up into the major international research group the Department is able to boast about today. He also played a key role in establishing the London Centre for Nanotechnology (LCN). He personally developed diverse projects such as minimally invasive dentistry, odour recognition, diamond film growth and quantum information science- where his new ideas have led to a substantial and ongoing research programme.

Alongside his dedication to Harwell and UCL, he pursued outside interests at an exceptionally high level. He was a keen amateur horn player and musicologist, playing in a longstanding wind octet and even at one point performing the phenomenally difficult solo part of the Strauss Horn Concerto in concert. His prizewinning 'Wind Ensemble Sourcebook' was the fruit of many years research in libraries around the world. With his wife, Doreen Stoneham, he founded Oxford Authentication, a small company which has been highly successful in the authentication of fine-art ceramics by thermo-luminescence dating.

Marshall will be extremely missed as an outstanding mentor, an encyclopedic source of scientific knowledge, a wonderful collaborator whose incisive questioning rapidly established the viability of any idea, and a loyal friend to many in the scientific community.

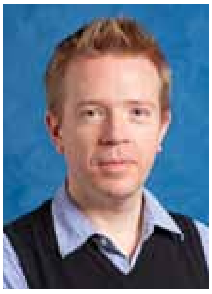
by **Professor Andrew Fisher**



Academic Showcase

Staff Accolades

Departmental Teaching Prize & joint winner of the MAPS Faculty Teaching Award



Dr Phil Jones

"…nominated by Physics and Astronomy undergraduate students for his inspirational teaching of the third year Lasers and Modern Optics Course…"

Institute of Physics (IOP) Moseley Medal

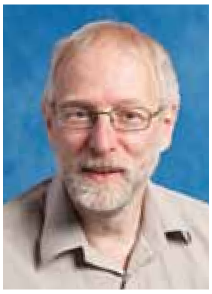
Dr Giovanna Tinetti

"For her work, pioneering the use of infrared, primary transit spectroscopy to characterise the molecular composition of extra solar planets."

Queen's Birthday Honours

Professor Jenny Thomas CBE

Awarded Commander of the Order of the British Empire (CBE) for "services to science"



Wolfson Research Merit Award

Professor Jonathan Tennyson FRS

For "Molecular line lists for extra solar planet and other hot bodies"

Fellowships of Learned Societies

Institute of Physics

Professor Tania Monteiro

American Physical Society

Professor Alex Shluger
Professor Des McMorrow
Professor Jenny Thomas CBE

Headline Research

Results from the Large Hadron Collider (LHC)

2011 has been a very exciting year for scientists working at CERN's LHC. Exceeding the most optimistic expectations, the LHC delivered billions of the world's highest energy proton-proton collisions.

The first analysis of this data by the ATLAS and CMS experiments produced tantalizing hints of the existence of the Higgs boson and excluded a wide range of theoretically allowed masses. This has left only a narrow strip between 115GeV and 127GeV, where a significant excess of events over the expected background was observed. This is broadly consistent with the theory expectations for the Higgs boson production.

The HEP group is playing a leading role within the ATLAS experiment in the areas of detector operation, online and offline event reconstruction, and simulation software. They are also in charge of several key measurements for the Higgs search. The team is frantically preparing for the 2012 data taking period, which is expected to provide three times more data than in 2011 and almost certainly the definitive answer for the existence of the Higgs boson.

Promotions

Promoted to Professor

Professor Nikos Konstantinidis

Professor Ruben Saakyan

Promoted to Reader

Dr Mario Campanelli

Retirements

Dr Malcolm Coupland

Dr Dave Tovee

Resignations

Dr Stephen Lynch

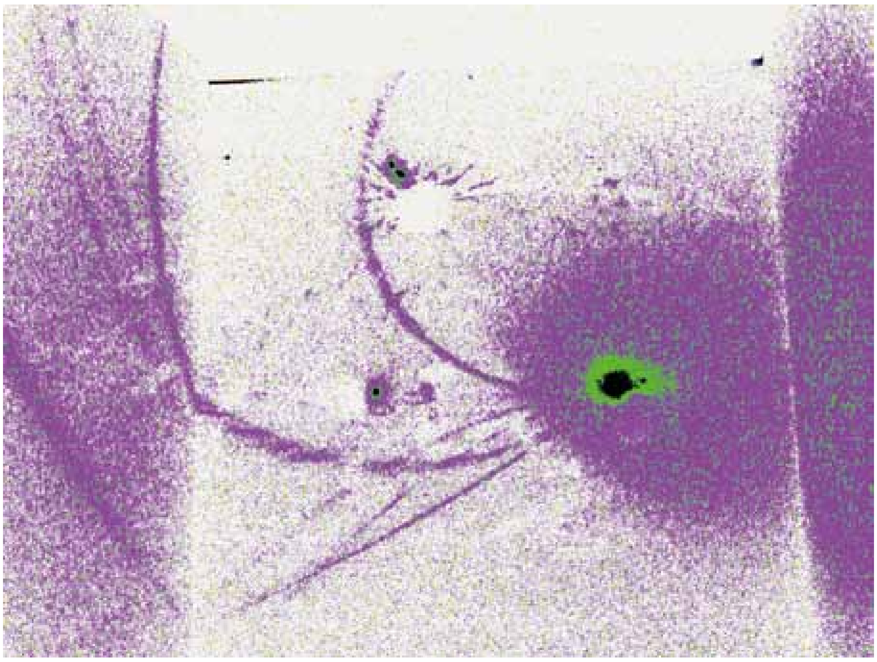
(to take a position as Senior Lecturer & EPSRC Advanced Research Fellow, Cardiff University)

Dr Christian Ruegg

(to become Head of the Laboratory for Neutron Scattering, Paul Scherrer Institute)

Artist in Residence Joins HEP Group

In February 2011, **Dr Andy Charalambous** joined the HEP group as their first Artist in Residence. He is the second to hold such a position within the Department, following Katie Paterson joining the Astrophysics Group last year.



This image, Neutrino 3, is a photographic print recording an 'event' from his installation work, Neutrino. In a dark room, lasers would invisibly flash through the gaps of a mobile. Occasionally they would hit the mobile and the resulting curved flashes of light would prove the existence of both the mobile and the lasers.

Headline Research

Saving the Second Law of Thermodynamics

S. Shabbir, **J. Anders** and co-workers, Landauer's Principle in the Quantum Regime, *Phys. Rev. E (Rapid Communication),* 83, 030102 (2011)

If heat could be converted completely into work, all of today's energy problems would be resolved. Unfortunately the second law of thermodynamics forbids exactly this.

However, it remains unclear to what extent the second law applies to systems that obey the rules of quantum mechanics. Indeed research in the past decade has suggested that this fundamental law of physics is broken in a strongly coupled quantum system, the quantum Brownian oscillator.

Dr J Anders and MSci Student, **S Shabbir**, collaborated with Augsburg University, Germany, to resolve this paradoxical situation. They realised that quantum correlations between the oscillator and its environment leave the system in a non-equilibrium, 'squeezed' state. Crucially, the squeezing process has an associated thermodynamic heat and entropy change. It turns out that when these contributions are treated properly, the second law violation disappears and standard thermodynamics is restored in the quantum regime.

Academic Appointments

Dr Frank Deppisch

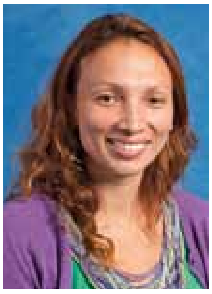
Lecturer joining the HEP group, previously based at The University of Manchester

Professor Andrew Green

Professor, a joint appointment between the CMMP group and LCN, previously based at The University of St Andrews

Dr Simon Jolly

Lecturer joining the HEP group, previously based at Imperial



Dr Alexandra Olaya-Castro

Lecturer joining the AMOPP group, previously based at UCL on a EPSRC Career Acceleration Fellowship

Dr Jonathan Oppenheim

Lecturer joining the AMOPP group, previously based at Cambridge

Dr Meera Parish

Lecturer, a joint appointment between the CMMP group and LCN, previously based at Cambridge

Headline Research

Minos Re-Enters the Faster than Light Neutrino Race

One of the most talked about physics results of 2011 was the surprising measurement that neutrinos may break the ultimate speed limit: the speed of light. The OPERA experiment measured the time taken by a beam of energetic neutrinos to travel 732km through the Earth from CERN to an underground laboratory in Italy. Much to everyone's surprise the measurement suggested that the neutrinos arrived 60 billionths of a second ahead of when they should if they were travelling at the speed of light.

Does this shocking result reveal new physics or merely experimental error? UCL's **Professor Jenny Thomas** and **Dr Ryan Nichol** are leading the effort to answer this question by repeating the measurement at the MINOS experiment in the USA. The scientific community are eagerly awaiting initial results, due in 2012, which will either confirm or refute the OPERA measurement – watch this space!

Doctor of Philosophy (PhD)

Matthew Austin
The nature and structure of the winds of galactic O stars
(Supervisor: Prof. R K Prinja)

Daniel Beecher
PDF and QCD effects in the precision measurement of the W boson mass at CDF (Supervisor: Prof. M A Lancaster)

Nikolaos Beglitis
First-principles studies of surface defects of model metal-oxide semiconductors
(Supervisor: Prof. A J Fisher)

Simon Binnie
Ab initio surface energetics: beyond chemical accuracy
(Supervisor: Prof. M J Gillan)

Nicholas Coppendale
Manipulation of molecular motion using a high-energy chirped laser system
(Supervisor: Prof. P F Barker)

Adam Davison
Exploring electroweak symmetry breaking with jet substructure at the ATLAS experiment
(Supervisor: Prof. J M Butterworth)

Alastair Dunn
A molecular dynamics study of diamond as a plasma facing material for fusion
(Supervisor: Dr D Duffy)

Joanna Fabbri
A mid-infrared study of dust emission from core-collapse supernovae
(Supervisor: Prof. M J Barlow)

Federica Fabrizi
Probing magnetism in magneto-electric multiferroics using circularly polarized x-rays (Supervisor: Prof. D F McMorrow)

Samuel Farrens
Optical detection of galaxy cClusters
(Supervisor: Dr F Abdalla)

Alex Harvey
Electron re-scattering from alligned molecules using the R-matrix method
(Supervisor: Prof. J Tennyson FRS)

Mathew Kallumadil
Towards a complete magnetic hyperthermia technology as a novel cancer treatment system
(Supervisor: Prof. Q A Pankhurst)

Angeliki Kiakotou
Neutrino masses from cosmological probes
(Supervisor: Prof. O Lahav)

David Kipping
The transits of extrasolar planets with moons (Supervisor: Prof. A D Aylward)

Donnacha Kirk
The practical use of cosmic shear as a probe of gravity
(Supervisor: Dr S L Bridle)

Aida Mehonic
The role of physics in epithelial homeostasis and development
(Supervisor: Prof. T A Duke)

Emily Milner
The intercalation and solvation of nanocarbons in ammonia and organic solvents
(Supervisor: Prof. N T Skipper)

William Nicholson
Studies of the martian upper atmosphere with the UCL Mars thermosphere and ionosphere general circulation model
(Supervisor: Prof. A D Aylward)

Immacolata Procino
Laser induced molecular axis alignment: Measurement and applications in attosecond science
(Supervisor: Dr J Underwood)

Alexander Richards
Simulation, software and first ATLAS physics
(Supervisor: Prof. J M Butterworth)

Tahir Shaaran
A rigorous treatment of excitation and quantum interference in laser-induced nonsequential double ionization of atoms and molecules
(Supervisor: Dr C Figueira De Morisson Faria)

David Stock
The cosmic origins of carbon and the evolution of dust, gas and the CNO elements in galaxies
(Supervisor: Prof. M J Barlow)

Marc Warner
Beyond classical computing: towards organic quantum information processing
(Supervisor: Prof. G Aeppli FRS)

Adam Williams
Positron ionizing reactions & positronium scattering (Supervisor: Prof. G Laricchia)

Headline Research

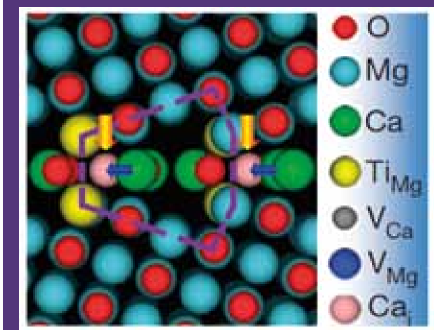
Complexity of Grain Boundaries in Ceramics: Electrons Reveal it All

K. P. McKenna, A. L. Shluger and co-workers, Atom-resolved imaging of ordered defect superstructures at individual grain boundaries, *Nature*, 479, 380–383 (2011)

Most solid materials are polycrystalline; they consist of a complex arrangement of grains within which atoms form a highly ordered structure. Grain boundaries are the extended defects formed at the interfaces between these grains, and they play a crucial role in determining the mechanical and electrical properties of materials. For this reason, there has been a great deal of scientific research directed towards understanding their atomic structure.

The research team constructed a single grain boundary in the ceramic material magnesium oxide by precisely orienting and bonding two crystals together. The resulting bi-crystal was then characterised using a range of advanced electron microscopy techniques, complemented by theoretical simulations. The use of high energy electrons to probe the structure of the materials allows for spatial resolution, down to the scale of atoms (ten billionths of a cm).

These techniques revealed the chemical identities of all atoms inside the boundary. The results offer new insights into the complex interactions between impurities and grain boundaries in ceramics, demonstrating that atomic-scale chemical analysis of complex multicomponent structures in materials is now becoming possible.

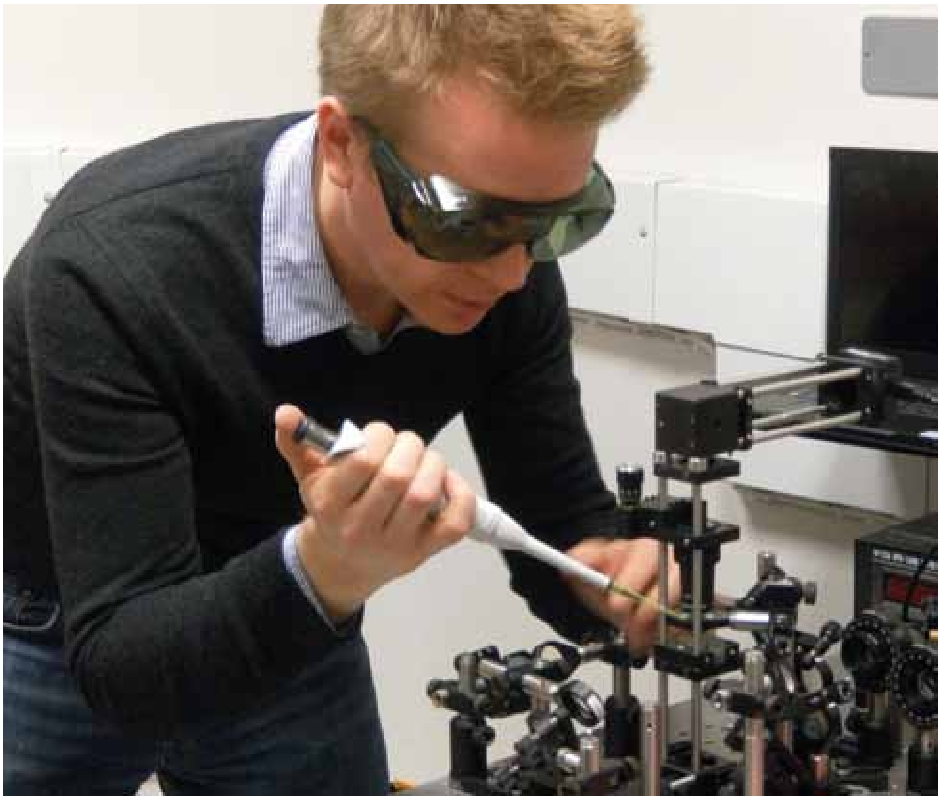


Portrait of Dr Phil Jones

Dr Phil Jones started his academic career by obtaining a BA degree in Natural Sciences at Cambridge University, after which he joined Imperial College to study for an MSc in Applied Optics. He followed this with a DPhil in Atomic & Laser Physics at Oxford University, before moving to UCL in 1998 with his then supervisor, Dr David Meacher.

Having tested out a number of reputable physics departments, Phil has remained at UCL ever since, working as a postdoc in **Professor Ferruccio Renzoni's** Laser Cooling Group until 2004, when he was offered a permanent position as a lecturer.

Phil's early research focused on laser cooling and trapping of atoms and in particular 'optical lattices': perfect crystals of atoms held together by laser light at a temperature a few millionths of a degree above absolute zero.



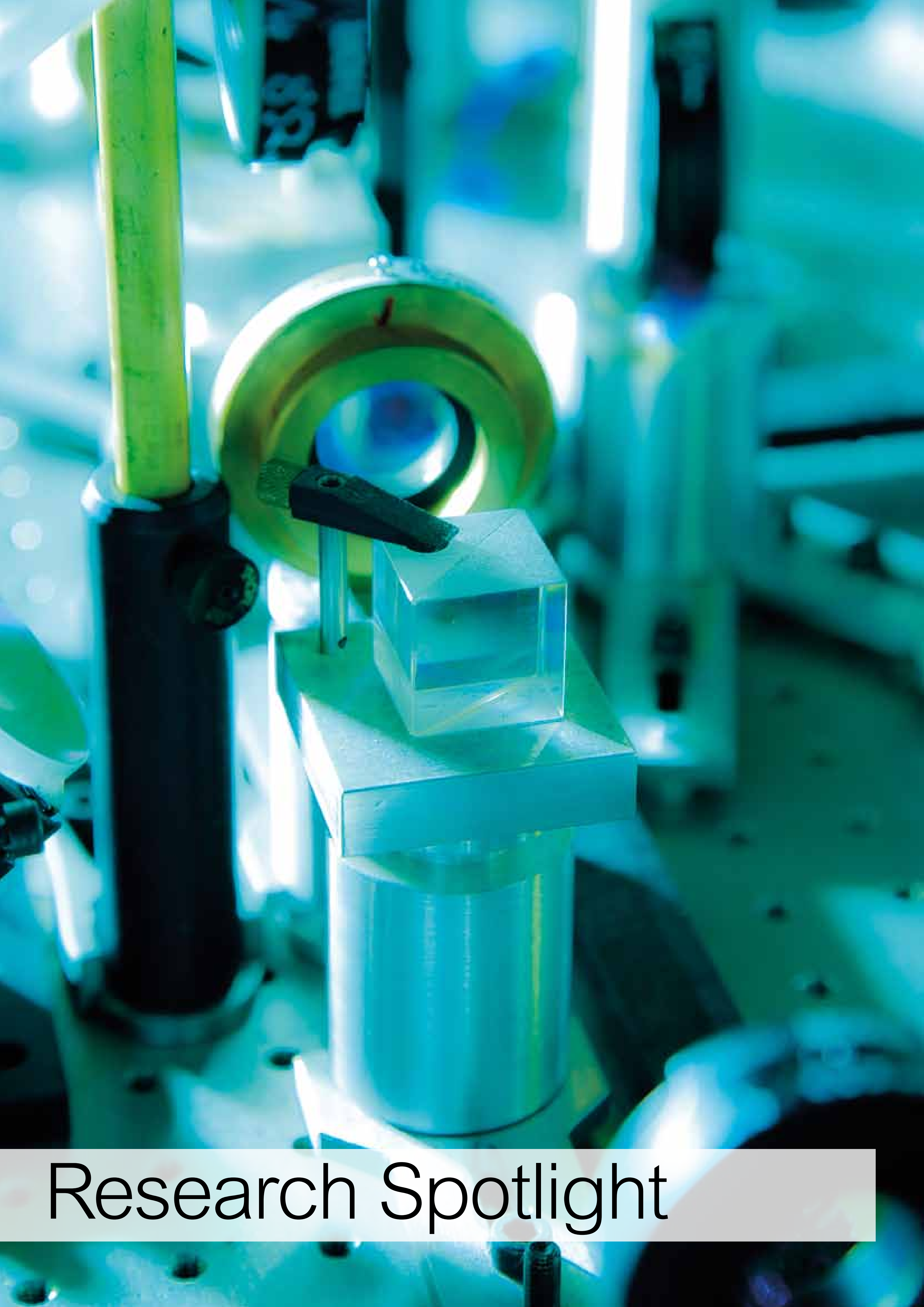
"Optical tweezers have a wide range of applications, Phil is particularly interested in using them to probe materials such as carbon nanotubes or plasmonic nanoparticles."

Since starting his own research group, Phil still uses light to exert a force on and trap matter, but now on objects rather larger then single atoms using 'optical tweezers'. This is a technique which allows microscopic objects to be picked up and moved around by a single focused laser beam. Optical tweezers have a wide range of applications, Phil is particularly interested in using them to probe materials such as carbon nanotubes or plasmonic nanoparticles.

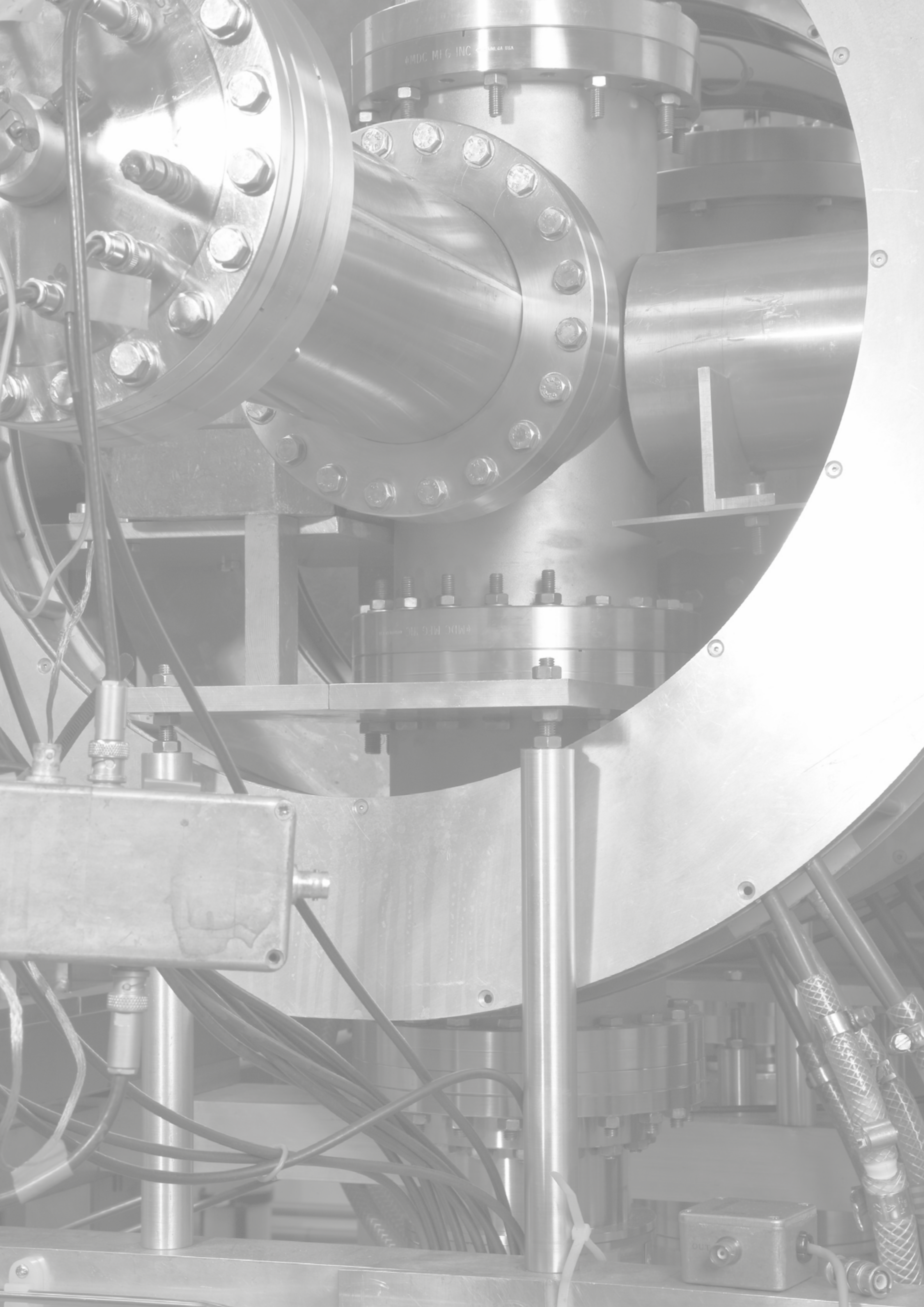
He also looks at biological objects, where they are especially promising for quantifying adhesive or motile forces. More recently, Phil's group has also been studying optical binding, a phenomenon where large numbers of microparticles self-organise into regular structures under the influence of laser light. Just as with cold atoms the colloidal particles can be held in an optical lattice, with the advantage that the individual particles can be seen under a microscope.

2011 has been an exciting year for Phil in terms of teaching. His class of undergraduate students elected him for the Departmental Teaching Award, and he also achieved recognition at Faculty level through the MAPS Faculty Award, made for outstanding provision of teaching. His class on Lasers and Modern Optics is extremely popular, and every year a significant number of students can be found swapping the pub for a laboratory tour on a Friday evening!

Phil's future research will continue to build on the optical trapping technique. He has recently started working as a consultant on a £1M project with the National Physical Laboratory, combining optics and acoustics to trap microscopic objects. Specifically, they will be trapping microscopic gas bubbles with laser light and pinging them with ultrasound. The frequencies of ultrasound produced in the bubble's response are very sensitive to its surroundings, so by recording the 'acoustic fingerprint' of a single calibrated bubble and then observing how it is altered by a change in the local environment, the project aims to turn the bubble into a microsensor. In the future these bubble sensors could be integrated into the 'lab-on-a-chip' technology and used for sensitive detection of trace amounts of chemical contaminants or antibodies.



Research Spotlight


AMDC MFG INC

Atomic, Molecular, Optical and Positron Physics (AMOPP)

The AMOPP group is one of the most diverse in the UK, with research activities spanning the range from the fundamental to the applied. Its members study theoretically and experimentally, the interactions of atoms and molecules with light, electrons and positrons. Their research impacts on problems in astrophysics, biological physics and environmental science, among others.

> "The preponderance of matter over antimatter in the Universe is one of the most fascinating mysteries in science today."

One area of study is the interactions of positrons (the anti-electrons) and positronium (a matter-antimatter composite made up of an electron and a positron) with atoms and molecules. The Group, established around 40 years ago by Professor Ceiri Griffith, Dr Godfrey 'George' Heyland and **Professor John Humberston**, remains a pioneer and an international leader in the field. During this time, theoretical and experimental methods have evolved from lifetime studies of β^+ emitted by radio-isotopes embedded in dense media, to the production of beams of positrons and of positronium which enable investigations at well-defined energies and under single collision conditions. **Professor Gaetana Laricchia** and her team: **Dr Simon Brawley**, and PhD students **Piers Fransman** and **Michael Shipman** describe recent experimental progress.

Matter vs Antimatter

The apparent preponderance of matter over antimatter in the Universe is one of the most fascinating mysteries in science today. Positrons are the antimatter counterpart to electrons (same mass, opposite charge), with which they eventually annihilate, releasing energy which is usually in the form of two gamma-rays of equal energy, according to the well-known equation $E = mc^2$, where m is their rest mass and c the speed of light. The annihilation probability depends on the relative velocity of the electron and the positron and, in many situations in nature, positrons may survive numerous collisions with matter prior to annihilation, exciting and/or ionising it along the way, or capturing from it an electron to form positronium (Ps). This is an atom-like bound-state of a positron and an electron, structurally analogous to hydrogen with the positron replacing the proton – a classical representation is given in Figure 1.

Approximately 80% of gamma-rays detected in positron emission tomography (a medical imaging technique known as PET) and 95% of the gamma-rays released from the centre of the Milky Way are the result of Ps decay. Once formed, Ps has ample time to interact with matter before annihilating because its lifetime, although of the order of (0.1-100) nanoseconds, is still millions of times longer than typical scattering times. For these reasons, knowledge of how Ps itself interacts with matter is important also for improving radioprotection in PET, or for learning about the environment in which positrons annihilate in outer space.

Project in Focus

Positron and positronium collisions

Aim
To advance the understanding of the interactions of positrons and positronium with atoms and molecules.

Results to Date
New advances concern positron-induced ionisation (with and without positronium formation, recently including excitations of positronium and/or of the target) and positronium scattering.

UCL Involvement
UCL is a pioneer and an international leader in the field.

The Positron and Positronium Beams at UCL and their Surprising Results

At UCL, beams of slow positrons (e+) are obtained from a β^+ emitter (usually Na-22) in conjunction with a so-called 'moderator' (typically a tungsten foil or a film of frozen krypton), from which a small but significant fraction of the positrons emerge with much reduced energies. Electric and magnetic fields are then used to accelerate, confine and transport them away from the high background near the source to an interaction region (a gas cell or jet). Ps atoms formed travelling in the forward direction may be further collimated so as to define a beam whose energy may be adjusted via that of the incident positrons. A second gas region inserted downstream provides the target to the Ps projectiles

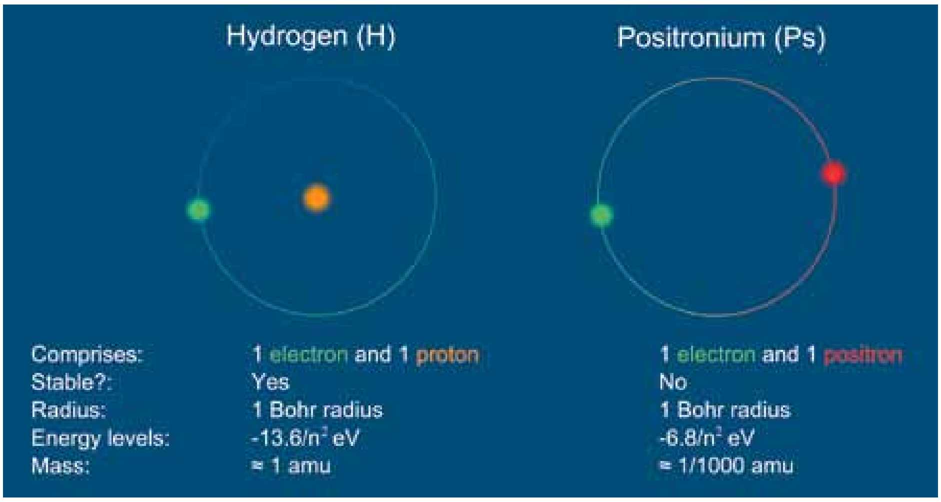


Figure 1. Classical pictures of H and Ps comparing some of their properties.
Note: 1 eV = 1.60×10^{-19} J; n denotes the atomic state (n = 1 being the lowest energy state); 1 atomic mass unit (amu) = 1.66×10^{-27} kg.

and different detectors help in unravelling the various reactions. In this way, Ps collision processes may be investigated as a function of energy and insights gained about how Ps itself interacts with matter. Figure 2 shows the current Ps beam at UCL.

Experimentally, one of the simplest quantities to be determined is the total cross-section, a measure of the overall interaction probability between two colliding particles. Neutral projectiles (such as Ps) may justifiably be expected to scatter very differently from charged projectiles (like the positron or electron). Table 1 summarises the dominant interactions at play for these projectiles: polarisation describes the

> “Ps scatters overall with a similar probability to that of a bare electron travelling at the same velocity.”

distortion of the electron-cloud induced by electric interactions between the colliding particles; the static interaction refers to that between the projectile and the (screened) nuclear charge of an undistorted target; exchange is a purely quantum mechanical phenomenon with no classical analogue, arising from the symmetry-properties of the wavefunction of a system (projectile + target) containing two or more identical particles. For the neutral Ps atom, it had been expected that the dominant interaction would be via exchange, however recent work at UCL has found that Ps scatters overall with a similar probability to that of a bare electron travelling at the same velocity.

Figure 2. The current Ps beam at UCL.

Projectile	Static	Polarisation	Exchange
Electron	Attractive	Attractive	Yes
Positron	Repulsive	Attractive	No
Positronium	-	-	Yes

Table 1. First order interactions of various projectiles with a neutral matter atom or molecule.

Examples of this rather unexpected result are shown in Figures 3 and 4. Similarities have been noted over the whole velocity range (from 0.6 to 4 a.u., where 1 a.u. = 2200000 ms^{-1}) and all targets so far investigated (He, Ne, Ar, Kr, Xe, H_2, H_2O, N_2, O_2, CO_2, SF_6). The correspondence extends even to velocities near prominent features in the electron data, such as the Ramsauer-Townsend minimum (as for Ar around 0.2 a.u. in Figure 3) and resonances (as in CO_2 around 0.6 a.u. in Figure 4). The former is due to the incoming and outgoing waves of the projectile propagating in-step (resulting in a seemingly transparent target to the projectile) and the latter to the temporary trapping of the projectile by the target at a specific energy. Whilst the physical reason for these observations is not yet fully understood, it has been suggested that the key might be in the polarisation of the Ps, resulting in the electron in Ps being on average closer to the target during a collision. Further work is underway to delve into this hypothesis (and others) but already the observations provide the means to obtain fair estimates of positronium total cross-sections for countless other atoms and molecules, based on the huge body of data which is available for electron scattering.

In the case of positron projectiles, a recent focus has been ionisation (with and without Ps formation), together with the excitation of Ps or of the target. The total ionisation cross-section is determined by counting the individual ions from all ionising processes; the direct ionisation cross-section is measured by detecting ions in coincidence with the scattered positron; and the positronium formation cross-section is determined via the simultaneous detection of an ion and an annihilation gamma-ray. Excitations of Ps or the target are examined by monitoring in coincidence the low energy photons emitted upon de-excitation.

Recently, Ps formation in an excited state (2P) has been found to increase fourfold from He to Xe, whilst that of ionisation simultaneous with the excitation of the molecular ion exceeds electron impact results by up to a factor of ~3 for CO_2 and ~5 for N_2.

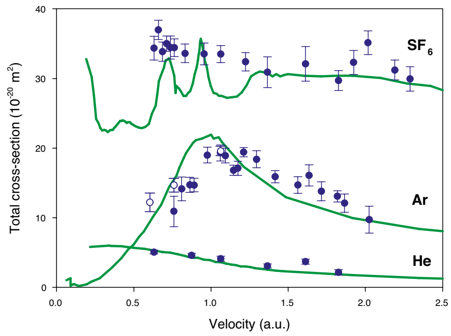


Figure 3. Examples of Ps and electron total cross-sections for some targets (1a.u. of velocity = 2200000 ms^{-1}). Circles: Ps total cross-section; green line: electron total cross-section. In all cases, despite the major differences between projectiles, the Ps total cross-section is similar in shape and magnitude to the total cross-section of electrons travelling at the same velocity.

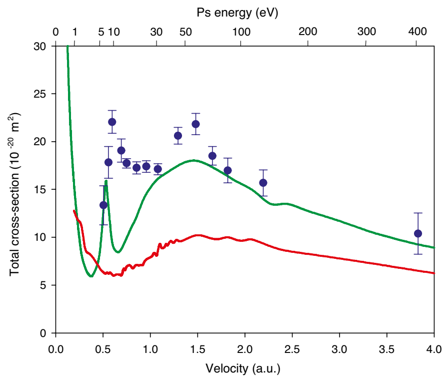


Figure 4. A comparison of experimental Ps total cross-sections and those for electrons and positrons for CO_2. Circles: Ps total cross-section; green line: electron total cross-section; red line: positron total cross-section. An enhancement is seen for Ps around 0.6 a.u., near the well-known $^2\Pi_u$ resonance for electron collisions.

It has been proposed that the enhancement is due to ‘accidental resonances’ between the ionic states accessed via Ps formation and the potential energy curves of the neutral molecule. In future plans, as a test, targets will be examined for which, according to this supposition, ionisation–excitation should not play as prominent a role.

High Energy Physics (HEP)

High energy particle physics teaches us about the underlying nature of the physical universe, and the forces and laws that govern its development, from the first moments of the big bang, through to the present day, and far into the future.

The Large Hadron Collider (LHC) at CERN is the world's highest energy collider probing an entirely new energy region for fundamental particle physics. In the past year, world media have been full of LHC Higgsteria, speculating on the existence of the Higgs boson. The desire to answer fundamental questions — such as the origin of mass and the nature of the neutrino is what excites people and drives the subject, but to achieve these aims often requires paradigm shifts in technology that have a much wider benefit for everyone. There are many examples: the world wide web was invented in CERN in 1991 and given away for free; mass production of superconducting magnets was made a reality by the Tevatron accelerator in the late 1970's, resulting in the economical production of hospital MRI magnets; and more recently, grid computing technology has been utilised by many disciplines, particularly in the health sector.

Physicists are already looking beyond the LHC, which in itself took 20 years to reach fruition. They are developing technologies which will drive discoveries 10-30 years down the line, in which a future generation of UCL undergraduates will ultimately become involved. The LHC is the highest energy collider in the world and much of what is known about fundamental particles has been learnt from studying these highest energy collisions. However, studying very rare interactions such as those of the neutrino at lower energies can also provide exciting insights into particle physics. The knowledge from these rare interactions has come from developing proton accelerators of the highest intensity, rather than energy. The future of high energy physics will require the development of smaller, cheaper accelerators capable of achieving even higher energies than the LHC, whilst simultaneously providing much greater intensities of protons, neutrinos, neutrons and muons than is presently possible.

The UCL particle physics group is heavily involved in a number of cutting edge accelerator projects: **Dr Simon Jolly** describes these below.

High Power Proton Accelerators for Neutrino Physics & Nuclear Power

The next generation of high energy physics experiments will require high intensity beams (100 mA) accelerated to energies from a few GeV to tens of TeV and then focussed down to sub-millimetre focal points. In order to provide these high intensity beams, a new generation of high power proton injectors — comprising the first 20 metres or so of the accelerator — is required. The start of the accelerator complex is critical in establishing a beam of sufficient intensity and appropriate stability for further acceleration.

> "We hope to be able to determine whether there is a matter/anti-matter difference in the neutrino sector."

Project in Focus

Future Accelerators

Aim
To develop accelerator technology and facilities for both HEP research and wider applications, such as cancer treatment and safe nuclear power.

Results to Date
Installation of the first sections of the FETS high power proton injector at RAL; preliminary stages of UCLH proton therapy facility.

UCL Involvement
Leading contributions at four separate facilities: building UK's first proton therapy facility; development of FETS diagnostics; leading UK effort on both plasma wakefield acceleration and muon-to-electron conversion experiments.

UCL is involved in developing these new accelerators in a facility at the Rutherford Appleton Laboratory called the Front End Test Stand (FETS) (Figure 1). The FETS design will be used as the basis for Europe's next generation high intensity neutron source (the ESS at Lund, Sweden) and in part, for the new injector (LINAC-4) for the upgraded LHC, as well as for the ISIS spallation neutron source at RAL. The UCL group, led by **Dr Simon Jolly**, is heavily involved in the diagnostic systems for the accelerator particularly for the 324 MHz, 3 MeV Radio Frequency Quadrupole (RFQ), which both accelerates and focuses the beam. The diagnostic measurements of the beam's profile and emittance are key to ensuring that the beam's stability can be controlled to achieve the high energies and high intensities required for physics exploitation.

These high intensity proton beams are vital components in two future UCL projects, led

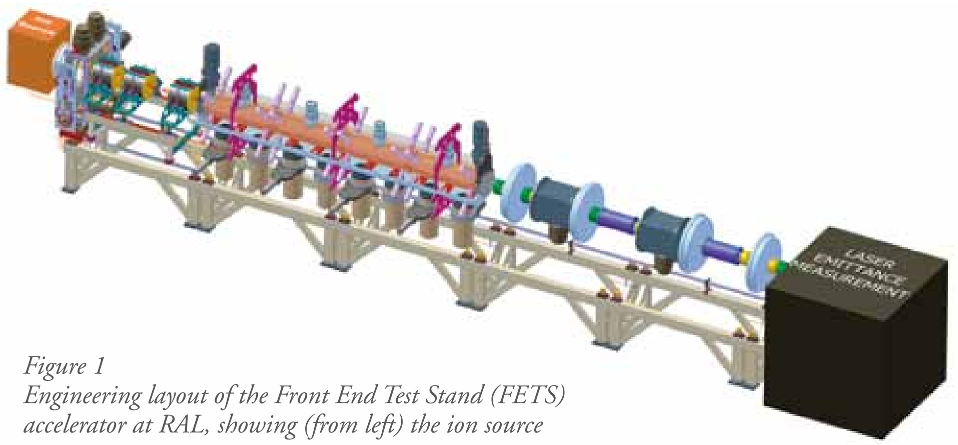


Figure 1
Engineering layout of the Front End Test Stand (FETS) accelerator at RAL, showing (from left) the ion source

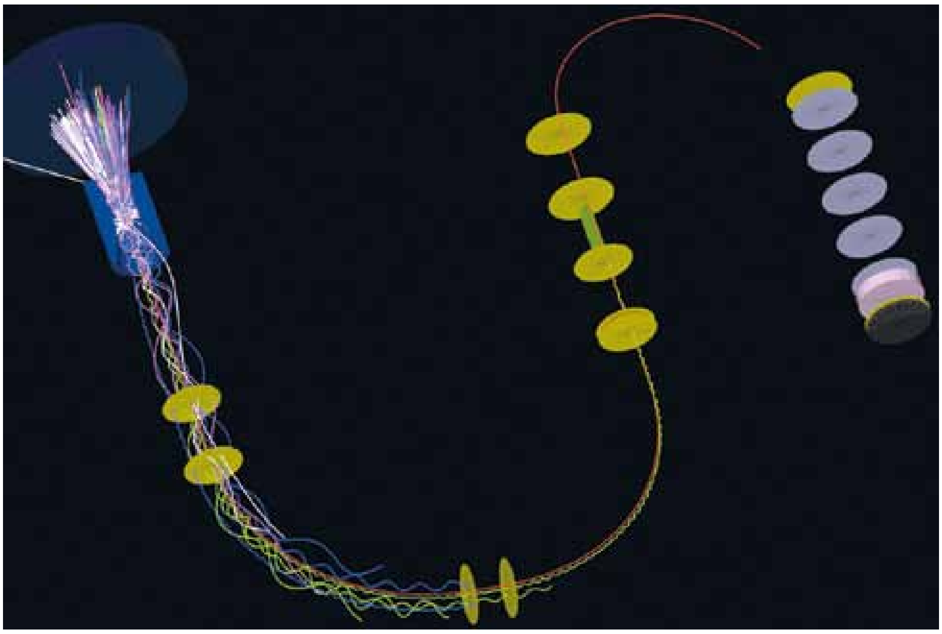


Figure 2
A schematic of the COMET experiment showing the interaction of a high intensity proton beam (from the left of the figure) with a target producing muons and pions. The muons and their decay products are tracked using the detectors on the right of the figure.

by **Dr Ryan Nichol**, **Professor Jenny Thomas** and **Professor Mark Lancaster**. A high intensity proton beam incident on a stationary target will produce a large number of charged pions which will decay to muons and muon neutrinos. It has already been observed, through the phenomena of 'neutrino oscillations', that a neutrino beam of a given flavour (e.g. a muon neutrino) is actually a superstition of three distinct quantum states and a beam's flavour at a given time and distance depends on three factors: the relative fractions (defined by a mixing matrix) of these three quantum states; the masses of the three quantum states; and crucially, a parameter which encodes whether (neutrino) matter and (neutrino) anti-matter are exact mirror opposites of each other. By measuring the evolution of the neutrino beam's flavour extremely accurately, over long distances (several hundred km), we hope to be able to determine whether there is a matter/anti-matter difference in the neutrino sector. It is such a difference that is needed to help explain why we live in a universe dominated by matter and why all the anti-matter created at the start of the universe disappeared in the time it takes to make a cup of tea. We are yet to observe any phenomena that have a sizeable asymmetry between matter and anti-matter and we hope the mysterious neutrino world will provide precisely this type of phenomenon and high intensity proton beams with MW of power are needed to do this.

Such MW proton beams are also needed to produce large numbers of muons, the group will study these decays in exceptional detail in order to elucidate the physics above LHC energies. So far, after 60 years of experimentation, every muon decay ever observed has been accompanied by neutrinos. However in all theoretical models explaining the fundamental unification of forces, it is predicted that, although extremely rare, muons should decay without accompanying neutrinos. Different theoretical models exist which vary by many orders of magnitude in their predictions for the rarity of such decays: from the extremely rare — about 1 in 10 billion — to the exceptionally rare i.e. 1 in 10^{18}! Therefore to pin down the nature of the underlying physics, we need to able to make studies of up to 10^{18} muons (this is almost 0.2 µg of muons) in a controlled environment which requires a MW beam of protons to strike a target 24/7 for a year. This study will be done with the COMET experiment (Figure 2) and will look for the neutrinoless transition of muons (in a muonic atom) to electrons that are released with a distinct energy almost equal to the rest mass of the muon.

In addition to their use in particle physics, high power proton beams have the potential to play a critical role in future energy provision. Conventional nuclear reactors burn uranium but alternatives need to be found: there is justifiable public apprehension about long term waste disposal, the potential for accidents and nuclear proliferation. Thorium offers a very attractive alternative as it does not produce plutonium, so cannot be weaponised and requires an external source of intense neutrons to become fissile. These are provided by a high power proton beam striking a spallation target, controlling the reactor and allowing it to be switched on and off. The same beam of neutrons can also be used to transmute the long-lived radioactive waste to much less harmful, shorter-lived isotopes, significantly reducing the difficulties of long term waste disposal.

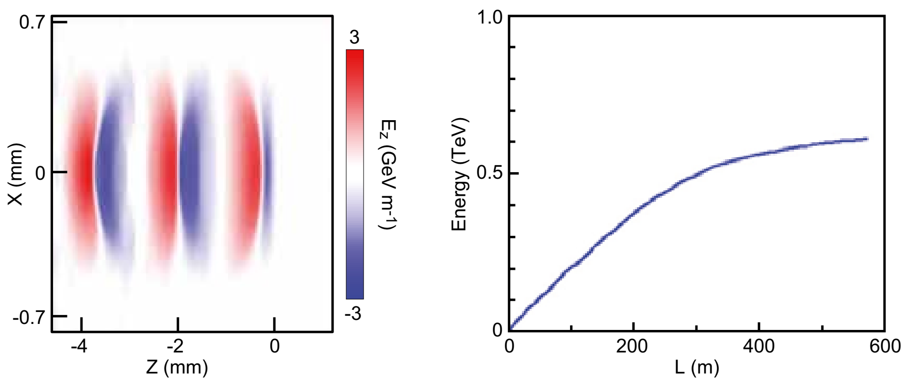


Figure 3
Accelerating field (left) and energy gain (right) produced by a plasma wakefield accelerator.

Proton Driven Plasma Wakefield Acceleration

Whatever the LHC may find, it is almost certain that we will need to both go to higher energies and probe the phenomena in more detail to elucidate what the underlying theories are.

For example, if the Higgs is discovered at the LHC, it will be vital to determine whether the Higgs decays precisely as we think it should, requiring an accelerator to collide electrons and positrons at high energies. The cost of going to higher energies is largely in civil engineering as it will not be economically viable to build future accelerators larger than the LHC. Therefore it is vital that accelerators of the next generation are much smaller. To achieve higher energies in shorter distances requires a much higher electric field gradient, of the order of GeV per metre, as opposed to the tens of MeV per metre which is possible at present. One potential method of achieving this is called plasma wakefield acceleration. This would allow the required energies to be reached in a few hundred metres rather than tens of kilometres.

> “Whatever the LHC may find, it is almost certain that we will need to both go to higher energies and probe the phenomena in more detail to elucidate what the underlying theories are.”

This new technique makes use of the enormous electric fields that can be generated within plasmas. A plasma is created by heating a gas until the electrons become energetic enough to travel freely, leaving the gas fully ionised. By forcing the electrons out of certain regions of the plasma, leaving only the positively-charged ions, enormous electric fields in the GV per metre range can be produced. Stimulating this charge separation with a beam of charged particles, or a high power laser, leads to an oscillating electric field called a wakefield which can be used to accelerate another beam of charged particles (Figure 3). So far this technique has largely been confined to theoretical simulations and it is vital that the technique is demonstrated experimentally if it is to form the basis of next-generation high energy accelerators.

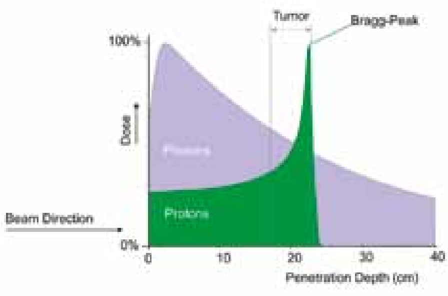


Figure 4
Dose deposition for X-rays and protons: note the sharp Bragg Peak in the proton energy loss curve.

UCL is playing a leading role in such an experimental test. The Proton Driven Plasma Wakefield Acceleration (PDPWA) experiment at CERN will use the existing CERN SPS accelerator (that is also used to inject beam into the LHC) to drive a plasma wakefield within a 10 m plasma cell. A 10 MeV electron bunch will be injected behind the protons: as the proton beam loses energy creating the plasma wakefield, the electron bunch will be accelerated.

The UCL group, led by **Professor Matthew Wing**, is helping to develop the plasma cell, as well as designing the diagnostic systems to measure the beam energies. Observing significant energy changes of about 1 GeV in the electron beams would validate the concept and pave the way forward for far cheaper and higher energy particle accelerators.

The UCL Proton Therapy Cancer Facility

Modern cancer treatment is largely a combination of tried and tested techniques: chemotherapy is used to poison the cancerous cells, combined with radiotherapy to irradiate the tumour with 6-14 MeV X-rays. In some cases, the majority of the tumour can also be removed through surgery. The shortcomings of these techniques are well known: surgery is invasive and healthy tissue can often be removed at the same time; chemotherapy poisons the entire body, rather than only the cancerous tissue; and radiotherapy damages the surrounding tissue, in some cases irreparably, due to the width of the X-ray beam and the dose deposition profile of X-rays in matter. Radiotherapy requires beams from as many as 6 different directions, which overlap to give a more precise dose to the tumour. However, a new facility is planned for UCLH that will

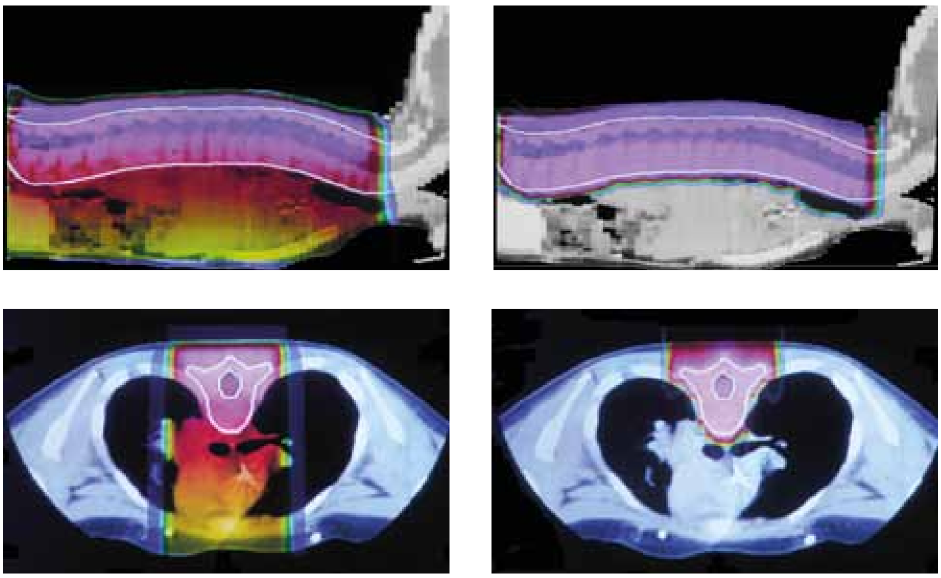


Figure 5
Dose deposition cross-sections for treatment of child medulloblastoma of the spine, using conventional radiotherapy (left), and proton therapy (right). Note the enormous reduction in dose to vital and sensitive organs such as the heart and bowels.

Figure 6
Artists impression of the new UCLH proton therapy cancer facility.

utilise protons in place of X-rays.
The idea to use protons has its roots in particle physics research: the first proton accelerator for treating cancer was built by the Fermilab High Energy Physics Laboratory in Chicago and deployed in California in the late 1980's. Sadly the UK has been slow to catch up but, along with Manchester, UCL has recently been given the funds from the NHS to provide the UK's first high energy proton therapy centres.

Proton therapy is an advanced form of radiotherapy, which can target tumours far more precisely than conventional methods. It is particularly beneficial for many child cancer cases, but is also used to treat brain cancers, head and neck cancers and sarcomas. The reason for the significant improvement in treatment of protons over X-rays is due to the beam size and the dose deposition profile of protons. Proton beams can be made much smaller than conventional radiotherapy beams: while an X-ray beam is normally a few centimetres in diameter, proton beams can be focused down to fractions of a millimetre, but the main advantage comes from the energy deposition profile. X-rays deposit energy broadly uniformly along their path, which means that tumour and surrounding tissue receive a similar dose.
Protons, on the other hand, deposit a significant fraction of their energy in the last few millimetres of their path: this is called the Bragg peak and means the damage to surrounding tissue is significantly reduced (Figures 4 & 5). This is particularly important for treating brain or spinal cancers in children, where damage to growing organs or surrounding areas of the brain can have permanent side effects.

There are currently no high-energy proton therapy facilities in England. Clatterbridge in Merseyside offers low energy eye treatments and patients who require treatment for other tumours must be treated conventionally or sent abroad. The UCL facility will treat as many as 2,000 patients per year, including many children from Great Ormond Street. It will be based on a site as large as a football pitch, close to the main UCL campus.

An artist's impression of the new UCLH proton therapy centre is shown in Figure 6. The centre will bring together some of the world's leading specialists in complex cancers and construction is due to begin in 2012, with the first patients hopefully being treated in 2017. Along with a number of other departments within UCL, the HEP group is heavily involved in the development of the UCLH facility. The group is bringing its expertise from high energy particle physics accelerators and detectors to help in the accelerator design and particularly in providing diagnostic detectors that can monitor the level of secondary radiation, from neutrons. The design of the facility is a challenging project, since protons are delivered to the patient through 200 tonne gantries that are 3 stories tall, but a successful facility will provide cutting edge treatment to patients in the UK for the first time.

Condensed Matter and Materials Physics (CMMP)

The CMMP group is one of the largest condensed matter groups in the UK, currently comprising around 90 members. Their research spans a wide spectrum of subjects including quantum computing, organic electronics, superconductivity, the physics of the Earth's deep interior, biomagnetism and nanoscale imaging. The group plays a leading role in many national and international projects, such as the development and exploitation of x-ray and neutron scattering instruments. In addition to this, they are among the founding members of the London Centre for Nanotechnology (LCN), a multidisciplinary enterprise concerned with the design, fabrication and analysis of nanoscale systems for the purposes of information processing, healthcare, energy and environment. They also play an important part in the Thomas Young Centre (TYC), an interdisciplinary alliance of London research groups, working to address challenges of society and industry through materials modelling and the theory and simulation of materials.

One topic of interest to the group is the study of organic semiconductors. These materials display a variety of novel physics and have potential applications ranging from light-emitting diodes (LEDs), to applications for energy generation (such as photovoltaic diodes, PVDs), logics (i.e. field-effect transistors, FETs), photonics (optical amplifiers, lasers) and potentially, single-photon emitters for quantum cryptography and related areas. **Professor Franco Cacialli** leads a research group which focuses on organic conjugated semiconductors. He describes the group's current research in this article.

Organic Semiconductors and Nanostructures: From Displays to 'Quantum' Optoelectronics and Photonics

The most interesting physical properties of these materials are determined by the formation of a partially delocalised π-electron system that originates from the lateral overlap of the p orbitals, directed perpendicularly to the bonds between adjacent carbon atoms. In the case of linear polymers, which often include aromatic rings as in poly(p-phenylene vinylene), PPV, and analogues, the π-orbital develops along the chain, with an intrinsic one-dimensional (1D) character. However, the effective delocalisation of the orbital or 'conjugation' does not extend for the whole polymer chain, it is interrupted by morphological defects, such as kinks and twists of the chain, or chemical defects, such as differently bonded carbons, carbonyl moieties, cis linkages, or substitutions which limit the extent of the electron (or hole) wavefunction.

> "Conjugated polymers, oligomers and derivatives can be regarded as portions of graphene"

Polymeric semiconductors are then, by their very nature, disordered materials, containing conjugated segments of different lengths, and hence with different electronic properties. In addition, the 1D character of the π-orbital is substantially reduced in the solid state or in solutions prepared with poor solvents, where the molecules' close proximity may favour the formation of relatively extended inter-chain states and excitations such as aggregates and excimers. Further confinement of the excitations, either charged or neutral, may arise from self-localisation induced by geometric relaxation of the soft polymeric chains, and from electron correlation effects. The latter are evident, for example, in the relatively high binding energy (> 0.2 eV) of electron-hole pairs (excitons). Strong non-linear effects, ultrafast thermalisation of optically excited states, and disorder-mediated processes, are other important aspects of the physics of these systems. In spite of a relatively localised extent of the wavefunction of charged excitations in most (amorphous) polymeric semiconductors, electric charge can move through the extensive π-electron system and transfer between different molecules, under the action of an electric field. When electrons and holes collide, they can bind together to form excitons that can decay radiatively.

Project in Focus

Photophysics and device applications of organic semiconductors and related nanostructures

Aim

To achieve greater understanding of the physics underpinning nanostructures of solution-processed advanced materials for optoelectronics and photonics. This will facilitate new and improved applications.

Results to Date

Organic LEDs with visible and near-infrared emitting spectra, white-emitting light-emitting diodes, solar cells, nanostructuring of organic semiconductors via optical near-field and scanning thermal probes, high-mobility semitransparent field-effect transistors.

UCL Involvement

Spans across several departments and faculties. Activities range from investigation of the theoretical aspects of the basic energetics of the materials, to the synthesis and characterisation of novel materials and their incorporation in devices (displays, solar cells, photodetectors, transistors, optical amplifiers, and lasers).

It is possible, therefore, to use these materials to fabricate light-emitting devices. Conversely, excitons can be generated by absorbing light and then be ionised at polymer/polymer or electrode/polymer interfaces, allowing for fabrication of photovoltaic cells.

The possibility of turning these interesting properties into useful devices is important and goes beyond the relevance of the application as such. In the first place, it creates the motivation for substantial research investment. Secondly, some devices are in fact specialised scientific tools in their own right, allowing sophisticated measurement of certain material properties. This is the case, for example, of the charge mobility in Field-Effect Transistors (FETs), of the luminescence efficiency and time decays in Light-Emitting Diodes, LEDs, of charge generation via exciton splitting processes in PV cells, and of spontaneous emission rates in optical microcavities.

Interestingly, conjugated polymers, oligomers and derivatives can be regarded as ‘portions of graphene’, the very material that has been at the focus of much attention (and a Nobel prize for physics) in the last few years.

From Supramolecular Architectures to Device Physics and Nanostructures

The group’s primary focus of interest is the control of the nature and fate of the excited states generated in these materials, with a view to device applications: from LEDs and displays, to energy (PVDs and thermoelectrics) and quantum devices (e.g. optical amplifiers, lasers, photodetectors, single-photon emitters). In practice, the research branches out into three powerfully interconnected directions: supramolecular architectures, materials and device physics, and nanostructuring of soft matter via non-conventional lithographic techniques such as scanning near-field optical lithography (SNOL) or scanning thermochemical lithography (SThL).

Supramolecular Architectures and Interactions

The focus of this activity is on investigation of the influence of supramolecular architectures and interactions (driven by secondary, non-covalent forces) on the photophysical properties of the materials. This will elicit a deeper understanding of their properties, leading to an enhanced control of the device properties.

The electronic and optical properties of conjugated polymers (CPs), are in fact controlled both by the primary molecular structure and by supramolecular interactions in a way similar to that in which secondary and ternary structures are fundamental to the function of proteins. The ability to manipulate the local molecular environment is thus crucial to access fundamentally new classes of organic functional materials with unprecedented properties and performance. Although there has been much progress in the last twenty years on the nanoscale control of the local environment for functional molecules, this still requires more research on the interactions between other molecular units or species, and with the electrodes. The influence of such interactions is wide ranging, affecting properties as diverse as luminescence, electrical transport, and chemical and mechanical stability. Accurate control of such interactions is needed to allow optimum exploitation of the properties of molecular materials, not only in today’s most common optoelectronic devices such as LEDs, FETs, and PVDs, but also in emerging applications.

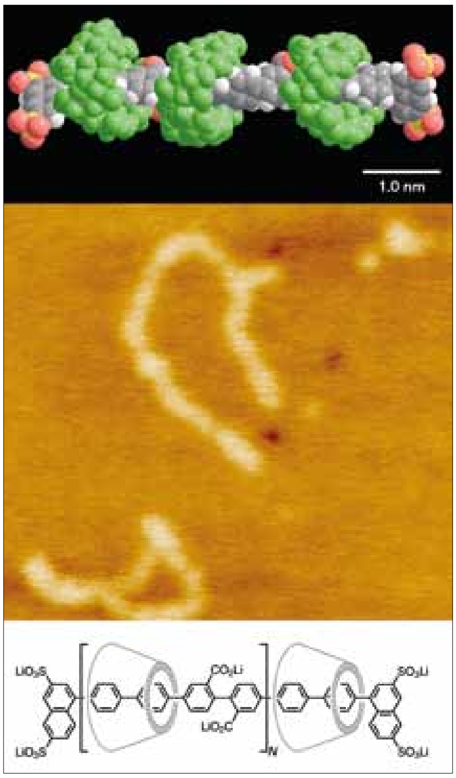


Figure 1
The centre-figure is an atomic force microscopy image of poly-p-phenylene (PPP) rotaxanes, whose chemical structure is shown at the bottom. The top image shows the van der Waals surface of the energy-minimized structure of arotaxane with two rings threaded on each polymer chain. (Reprinted with permission from Nature Materials, 1, 160 - 164 (2002)).

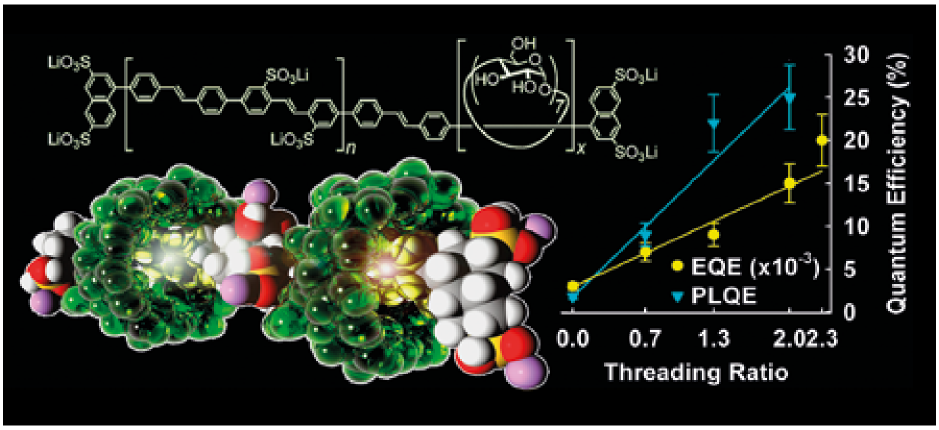


Figure 2 Chemical structure (top), artistic rendering (bottom), and luminescence efficiencies (EL and PL, right) of a cyclodextrin-threaded poly(p-phenylene vinylene-derivative rotaxane. (Reprinted with permission from Nano Letters, 8, 4546-4551. Copyright 2008 American Chemical Society).

Here, as a model system the team have worked mostly with rotaxanes (Figure 1). These are inclusion complexes in which conjugated polymers are threaded through cyclodextrin rings, and then capped at the end to prevent unthreading, according to a synthetic route developed by colleagues at the Department of Chemistry at Oxford. With their help, **Professor Cacialli**'s team have been able to show that when various families of polymers are threaded inside cyclodextrins, these act as spacers which prevent the close face-to-face alignment of the rings. They result in materials with higher luminescence efficiency and a blue-shifted emission, which is also tuneable as a function of the 'threading ratio' i.e. the number

"The ability to manipulate the local molecular environment is thus crucial to access fundamentally new classes of organic functional materials"

of rings per polymer repeat unit. In addition to confirming the effectiveness of the cyclodextrins at suppressing the detrimental intermolecular interactions, the Team, in collaboration with colleagues in Milan, discovered, for example, that rotaxanes feature strongly reduced charge dissociation and polaron formation upon photoexcitation.

This leads to unprecedented ultra-broad gain bands in blends of rotaxanes with commercial emissive conjugated polymers.

This result is of vital interest to both optical amplifiers, and lasers (both optically and electrically pumped). Potentially there is a high technological impact for optical telecommunications and optical materials since the polymeric composite materials reported there have highly controlled optical properties and

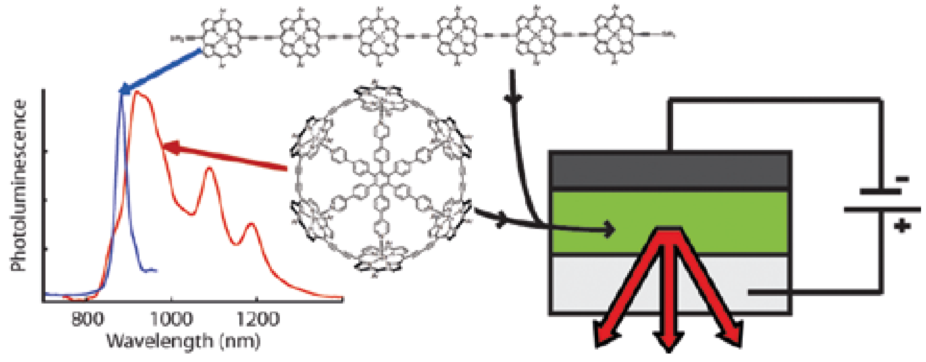


Figure 3
Near-infrared emitting materials and light emitting diodes (Reprinted with permission from Nano Letters, 11, 2451-2456. Copyright 2011 American Chemical Society.).

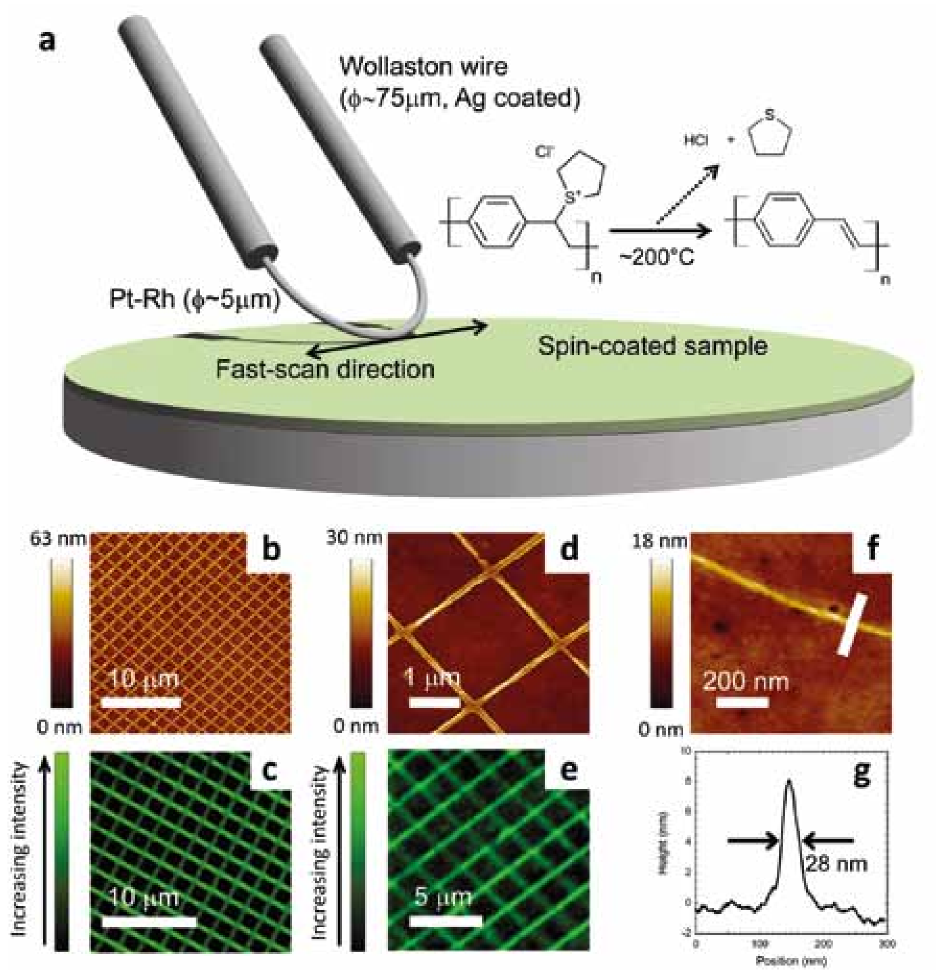


Figure 4
Construction of a nanoscale device by thermal patterning of a polymer. a) A schematic of the device (a Wollaston wire probe). The inset shows the thermal conversion route of the precursor polymer, PXP, to fully conjugated PPV, which happens optimally at ~200°C.
b) Atomic force microscopy (AFM) image, and c) confocal fluorescence of a square grid of PPV structures with line spacing of 2µm produced by scanning the probe in two perpendicular directions at 230°C and 10µm/s each line represents a double scan (trace and retrace) of the probe. d) AFM and e) confocal fluorescence images taken of a similar set of structures drawn at 5µm/s and 250°C. f) AFM image of an isolated line drawn in PPV (single scan). The lines were drawn at a temperature of 250°C and a scan speed of 5µm/s on a 15nm thick film. g) The cross-section reveals a line width (full-width at half-maximum, FWHM) of 28nm. (Reprinted from Nature Nanotechnology 4, 664-668 (2009) and Adv. Mat. 21, 1279-1285 (2011)).

could realistically lead to disrupting technologies such as single broadband optical amplifiers covering the entire visible region. For example, these can be applied for data transmission by wavelength division multiplexing in plastic optical fibres (POFs), thereby providing a solution to the long-standing issue of the higher attenuation losses of POFs compared to silica-based fibres. Tuneable optically pumped lasers could also benefit from these findings because the ultra-broadband systems described have potential for the fabrication of solid-state, compact, optically pumped tuneable lasers (CW or pulsed). These could realistically be pumped by GaN LEDs, or lasers, thereby providing a variety of new sources easily tuneable over the entire visible spectrum. Furthermore, due to the reduced charge-generation and the resulting prevention of the related suppression of stimulated emission, these systems represent a significant step towards the realisation of an electrically pumped organic laser.

Materials and Device Physics

Over the last year, a special focus has been placed on materials with relatively low energy gaps, which emit or absorb in the near-infrared (NIR) region of the electromagnetic spectrum. These are particularly significant for LEDs as the region between 700 and 1000 nm provides a window of semitransparency in biological tissues, thus providing both illumination and imaging technology. Additionally they also have photovoltaics applications, as NIR materials can be combined with visible absorbing materials to achieve a better exploitation of the solar spectrum. Members of the CMMP group have been working on a large collaborative project (ONE-P) and have researched a large number of materials provided by EU collaborators. They have achieved success in particular with porphyrins-based materials and Se-containing ones, but collected a much larger set of data that is currently being analysed in what is probably the largest comparative study ever assembled on low-energy gap conjugated polymers.

Nanostructuring

Conventional high-resolution patterning techniques such as electron beam lithography or focused ion-beam (FIB) lithography are far too aggressive for organic semiconductors (OS), which are susceptible to degradation when exposed to energetic beams or subsequent chemical treatments. Instead, the Group has shown over the years that near-field optical microscopes operating in the UV, or thermal fields as applied with scanning probes, can generate nanoscale patterns (despite the much larger probes dimension), as illustrated in Figures 4 and 5. The technique is capable of achieving nanoscale resolution and high write speeds simultaneously.

Figure 5
Artist's impression of the nanoscale patterns generated by scanning probes.

Astrophysics (Astro)

The Astrophysics Group is one of the largest in the UK, consisting of 50 academic, research and support staff, along with 35 PhD students. The work carried out is diverse; ranging from instrumentation to data acquisition and analysis, as well as theoretical modelling. The group is involved in a number of high-profile international projects such as the Dark Energy Survey (DES), along with the Herschel and Planck space missions. 2011 has been an exciting year, with the Optical Corrector for the DES project being shipped to the Blanco 4-m telescope in Chile (see the Headline Research on p7 and the front cover of this Review), as well as exciting, yet surprising results from the Herschel space mission through the discovery of large quantities of dust particles in the ejecta from Supernova 1987A.

Present and Future Space Missions

The Herschel Space Observatory was launched in 2009 and is optimised to detect faint light from dust particles and molecules around stars and in star-forming regions and galaxies. Dust particles are an important component of the interstellar medium found within galaxies, and are crucial to the formation of Earth-type planets, although their origin is still uncertain. While mapping our satellite galaxy, the Large Magellanic Cloud, at far-infrared wavelengths with its PACS and SPIRE instruments, Herschel detected cold dust emission from supernova (SN) 1987A. A detailed analysis showed that about half a solar mass of dust has formed in the supernova's ejecta, equivalent to 170,000 Earth masses! If a substantial amount of the dust survives future shock interactions with the interstellar medium, then supernovae could account for a large fraction of the dust found in the Universe.

Additionally 2011 was a particularly active year for two new space missions in which the group has major involvements; final approval from the European Space Agency (ESA) was received for the Euclid cosmology mission, whilst ESA Phase Zero approval was given for the EChO Exoplanet Characterisation Observatory. Euclid is planned for launch in 2019 and will study dark energy via deep imaging and spectroscopy of distant galaxies. EChO is planned for launch in 2022 and will study the atmospheres of transiting exoplanets as they pass in front of and behind the stars they orbit. With over 700 exoplanets already discovered and many more exoplanet discoveries expected in

Project in Focus

Characterising exoplanets

Aim

Observing and understanding the chemical composition of exoplanet atmospheres.

Results to Date

First discovery of water vapour, methane and carbon dioxide in an exoplanet atmosphere. A dedicated space mission to study exoplanet atmospheres, EChO, selected by the European Space Agency.

UCL Involvement

Leading authors or co-authors of four Nature papers announcing these discoveries. Leading the science and the payload study of EChO consortium (UK, France, Italy, Spain, Germany, Denmark and US).

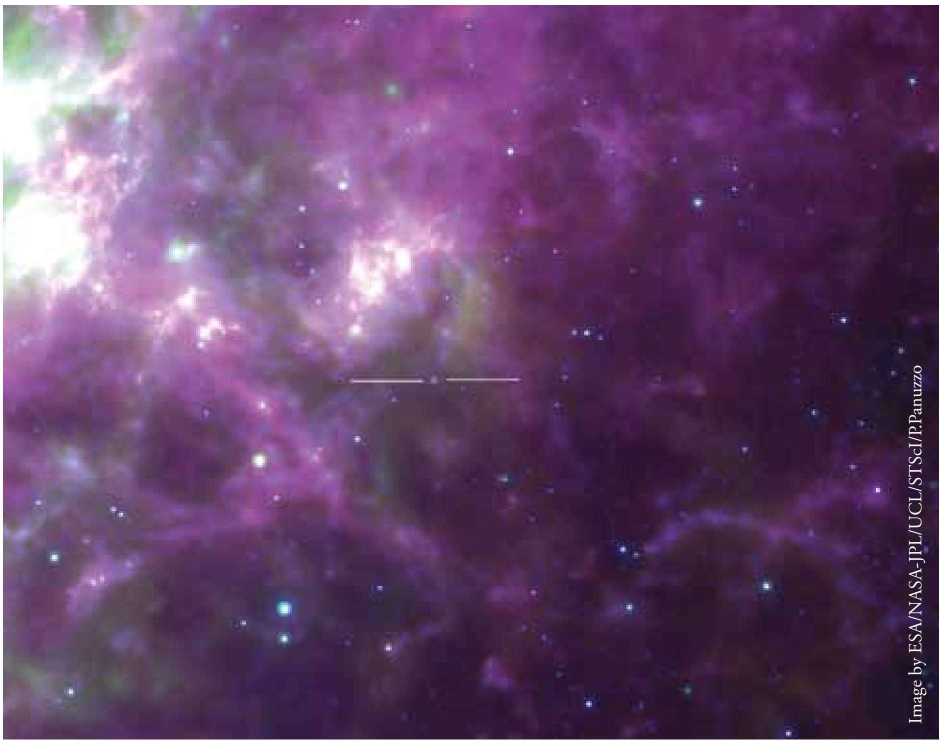


Figure 1
Large quantities of dust particles in the ejecta from Supernova 1987A have been detected by the Herschel Satellite. This has provided a vital clue to their origin.

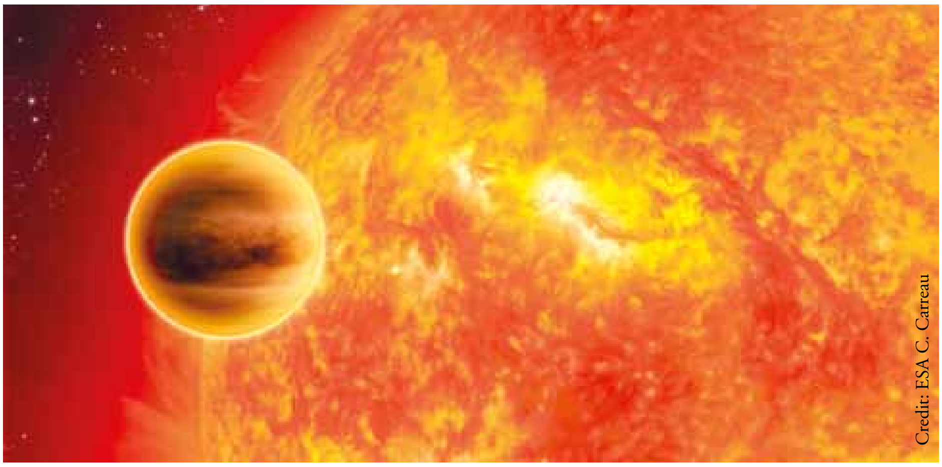


Figure 2
Artist's impression of the hot-Jupiter HD189733b. This is the first time molecules such as water vapour, methane and carbon dioxide have been discovered in the atmosphere of an exoplanet.

the near future, research in this area has gained steadily in prominence.
Dr Giovanna Tinetti, who is leading the EChO payload consortium, including several European countries (UK, France, Italy, Spain, Germany, Denmark, US) describes below some of the current research in this exciting area, along with future plans.

What are Exoplanets made of?

The science of exoplanets, i.e. planets orbiting a star different from our own Sun, is one of the most rapidly changing and exciting areas of astrophysics. A combination of ground-based surveys and dedicated space missions has resulted in the confirmed detection of over 700 planets.

It now seems likely that nearly all stars support planetary systems. Since 1995, the number of planets known has increased by two orders of magnitude. NASA's Kepler mission has opened up the possibility of discovering Earth-like planets in the habitable zone around some of the 100,000 stars it is surveying during its 3 to 4-year lifetime. In addition, the new ESA-Gaia mission is expected to discover thousands of new planets.

Among the exoplanets known, eccentric planets no longer appear to be oddities, nor do planets with two 'Suns'. Furthermore 'super-Earths', planets with up to ten Earth masses, appear to be common around other stars but are completely absent in our Solar System. The smallest exoplanet known today is Mars-sized, and a potential candidate for habitability has already been identified, planet GJ 581d. Interestingly, this planet does not orbit a canonical G-type star like our own Sun, but rather a much dimmer and colder M-dwarf, clearly challenging any geocentric concept of habitability.

Now the key challenge is moving on from simple discovery, important though that remains, to characterisation: what are these planets actually like, and why are they as they are? As more is learnt about the atmospheres and surfaces of these remote bodies, we will begin to build up a clearer picture of their construction, history and suitability for life. It is in characterising more bodies, in different environments, that a detailed planetology will be taken out of the Solar System and into the Galaxy as a whole.

The observation of the exoplanet atmospheres is at the cutting edge of exoplanet science as first attempts at characterising their chemical composition and temperature profiles are currently

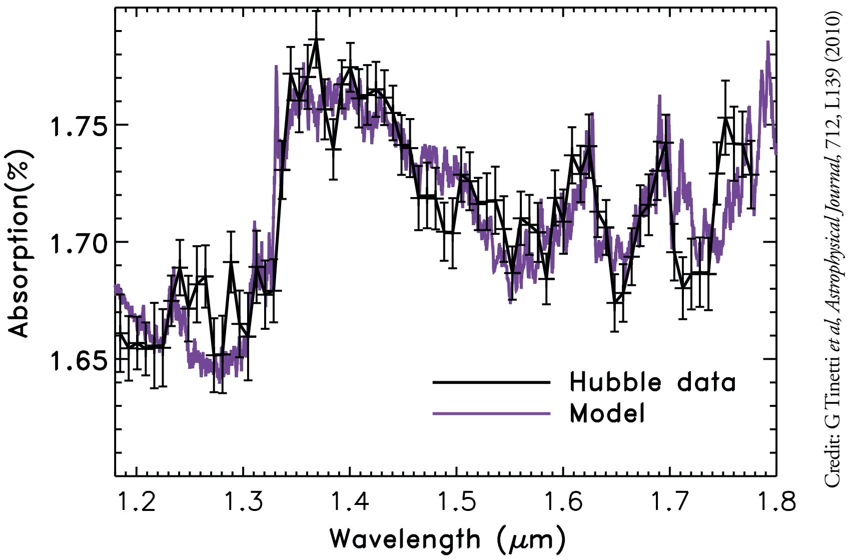


Figure 3
Observed and modelled spectrum of the exoplanet XO-1b. The spectrum was recorded with the Hubble Space Telescope during the primary transit of the planet. This observed spectrum can be explained by water vapour, methane, carbon dioxide and monoxide as the major, active atmospheric components.

under way. The ability to detect planetary atmospheric features, which only have a contrast of around 10^{-4} compared to the radiation coming directly from the host star, is quite a challenge. However, for exoplanets whose orbits are aligned so that they cross the surface of their mother star when viewed from Earth, this has proved to be possible. This is achieved by measuring the dip in the stellar light-curve when the planet transits in front of the star (or disappears behind it) and repeating the measurement at different wavelengths. In the past few years, the exoplanet team here at UCL has been in the vanguard of this new phase of 'exoplanet characterisation', which requires a combination of skills and expertise that range from solar system science (**Professor Alan Aylward, Professor Steve Miller** and **Dr Nick Achilleos**) to statistical astrophysics (**Professor Ofer Lahav** and PhD students **Ingo Waldmann** and **Morgan Hollis**), from ground-based observations (**Dr Steve Fossey**) to spacecraft measurements (**Dr Giovanna Tinetti** and **Dr David Kipping**), and from spectroscopy (**Professor Jonathan Tennyson**) to instrument building (**Professor Bruce Swinyard, Dr Giorgio Savini**).

Discovery of Water, Methane and Carbon Dioxide in an Exoplanet Atmosphere

Using data from the Hubble and Spitzer satellites and ground-based telescopes, **Dr Giovanna Tinetti**, along with international collaborators, has pioneered the use of transit techniques in the infrared where molecular features are the most prominent. As a result of these observations, molecules such as water vapour, methane and carbon dioxide have been discovered for the first time in the atmosphere of an exoplanet.

Characterisation began with a handful of hot giant, gaseous planets, the so called hot-Jupiters. Other planets, such as GJ1214b, are now within reach with current telescopes. This planet appears to be somewhere in between a rocky planet and a gaseous one, with a temperature of boiling water.

> "This activity is underpinned by UCL's world-leading ability to produce the huge lists of wavelengths where hot molecules absorb or emit light."

This activity is underpinned by UCL's world-leading ability to produce the huge lists of wavelengths where hot molecules absorb or emit light. These are essential when interpreting the results of exoplanet space mission projects and ground-based observations (**Professor Tennyson**, **Dr Sergei Yurchenko** and the ExoMol team – see Grant Highlight on P35).

Searching for Exomoons

A series of new techniques have been developed at UCL which enable researchers to derive robust and accurate planetary and orbital parameters (**Professor Ofer Lahav**, **Dr David Kipping** and **Ingo Waldmann**). Among the applications, Dr David Kipping is leading the search for moons orbiting exoplanets, hence exo-moons. Given the right conditions, exomoons may be as fruitful a location for the development of pre-biotic or biotic activity as exo-Earths.


Credit: NASA

Figure 4
Artist's impression of an exoplanet with an exomoon.

A Dedicated Space Mission to Discover the Composition of Exoplanets

Dr Giovanna Tinetti and **Professor Bruce Swinyard** are leading the effort for a new space mission, called EChO, the Exoplanet Characterisation Observatory. This is currently being assessed by the European Space Agency.

> "EChO will provide an unprecedented view of the atmospheres of planets around nearby stars."

EChO is currently in phase zero and will compete with the other three mission candidates for a launch in 2022. EChO will provide an unprecedented view of the atmospheres of planets around nearby stars. It will study planets that span a range of masses (from gas giants to super-Earths), stellar companions and temperatures (from hot to habitable).

EChO will inherit the technology of Kepler that achieves exquisite photometric precision at the 10^{-4} to 10^{-5} level in the observation of the target star, and extend that capability into the infrared. EChO will place our solar system in context and will address fundamental questions such as: what are the conditions for planet formation and the emergence of life?

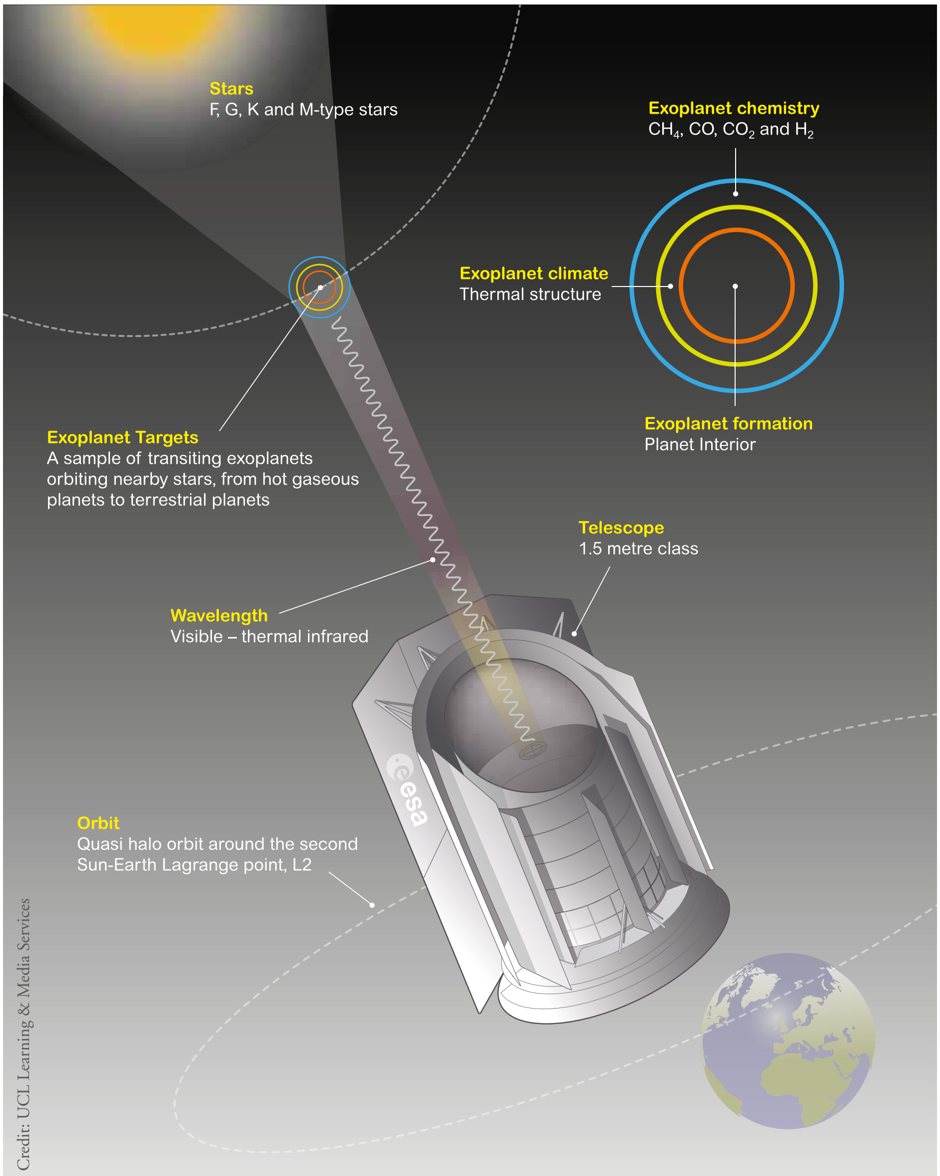


Figure 5
Artist's impression of the EChO spacecraft as designed by ESA

Biological Physics (BioP)

The BioP group is a virtual research group, forming a network between experimentalists and theorists across different research areas within the Department.

Professor Ian Robinson, an experimentalist member of the CMMP group, describes below his recent work on studying the structure of the human chromosome using X-ray imaging. Research has now started in the new labs set up at the Research Complex at Harwell (RCaH). The group is taking a fresh look at imaging, with the chromosome at its focus. The plan is to build on established imaging methods in order to guide the X-ray imaging when that goes live early next year. The RCaH is located next door to the Diamond Light Source which has been building the I-13 'Imaging and Coherence' beamline facility; this will provide the largest coherence lengths to date of any X-ray beamline in Europe. The biophysical side of the group is led by Dr Mohammed Yusuf, who is training four PhD students in cytogenetic methods and handling chromosomes. Dr Joerg Schwenke will join soon as the last member of the group and design the X-ray instrument required to orient chromosome samples at liquid nitrogen temperature in vacuum within the coherent X-ray beam at I-13.

Chromosome Imaging

So far the work has concentrated on chromosome sample preparation and fluorescent labelling experiments, using a newly acquired Zeiss fluorescence microscope for imaging. The philosophy is that while much chromosome imaging has been reported before, going back well over 100 years, the chromosome is a living organelle whose structure evolves dramatically during the cell cycle. Therefore there is no such thing as a single 'chromosome structure'. The group has therefore decided to concentrate on metaphase chromosomes, but even those are expected to undergo major morphological changes from one copy to another. This situation is complicated further for defective chromosomes, often related to human disease and genetic abnormalities, where major insertions, inversions or deletions may have taken place. Metaphase chromosomes will be investigated because they are the most compact compared with other stages of the cell cycle and thus will be easier to image with X-rays. The metaphase is also likely to be the most ordered state of the chromosome.

> "There is no such thing as a single chromosome structure"

The chromosome is an unusual structure in the sense that we have full knowledge at the two ends of the range of resolution, but not in the middle. The structures of the DNA, the simplest histones and the first level of integration, the nucleosome, are all known perfectly at atomic resolution. The shape of the whole assembly is known at the micron-level resolution from optical (fluorescence) microscopy. What is unknown is the structure between the 11nm nucleosome and the 400nm wavelength limit of visible light. The chromosome's function is extremely well known and this indicates a high level of intermediate structure, at the level of 10^5 to 10^6 base pairs, which will be the main focus of the study. It is assumed, moreover, that only three-dimensional images, as will be provided with X-rays, will be meaningfully interpretable. The interpretation of the folded chromosome will be helped by collaboration with topology experts from the Danish Technical University (DTU).

The group's approach to chromosome structure is therefore to undertake investigations with existing scanning electron microscopy (SEM) methods, in order to understand the issues of sample preparation. Due to the resolution scale being targeted, it is planned to use samples that are chemically fixed, with the DNA Platinum stained, and histone proteins labelled with specific antibodies. It is planned to investigate critical-point and solvent-based drying methods, in preparation. This goes against conventional wisdom that 'frozen hydrated' samples are the only ones that would be biologically relevant, the decision is defendable because of the special situation concerning the considerable amount of prior knowledge of the chromosome. This 'correlative microscopy' may allow synthesis of multiple resolution scale information. X-ray imaging, under development at the Diamond Light Source, will allow additional levels of 3D structural information about the chromosome, perhaps sufficient for a complete picture.

Project Development

At the current stage of the project development, working protocols and risk assessments for all methods such as cell culture, preparation of metaphase chromosomes, Fluorescent in situ

Project in Focus

Chromosome Imaging

Aim

High resolution three dimensional images of the structure of chromosomes in the metaphase stage of the cell cycle.

Results to Date

Sample preparation is under way using fluorescence microscopy to understand how to preserve the low resolution structure.

UCL Involvement

UCL has a resident group based in the Research Complex at Harwell, which is next door to the X-ray beamline where the X-ray imaging measurements will be made.

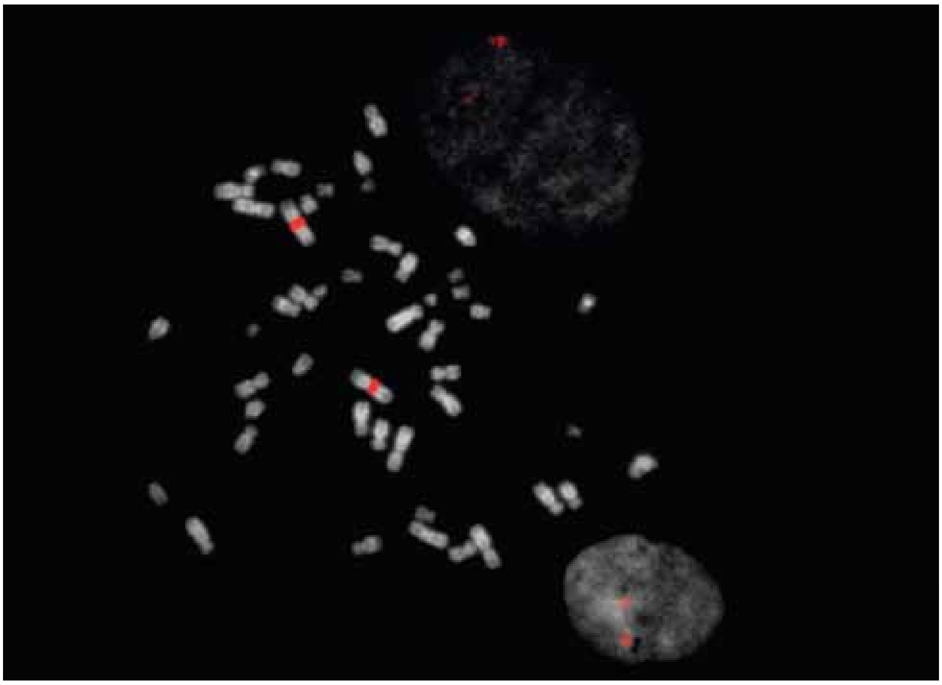


Figure 1
Fluorescence microscopy image of the chromosomes extracted from a single cell of a human liver cell line. Centromeres of chromosome 1 are labelled with a specific red fluorescent dye. The two red signals label the two copies of that chromosome which are present in metaphase.

hydridisation (FISH), storage of cells in liquid nitrogen, SEM sample preparation have been established and the lab work has begun. The group has managed to prepare chromosome samples from a chosen human cell line (obtained from the health protection agency) now growing in the RCaH cell culture facility and following the basic methods for preparing chromosomes mentioned above, spreading them on microscope slides for examination by fluorescence microscopy.

One of the first results to come from the fluorescence microscope is shown in Figure 1. The full complement of 46 chromosomes can be counted. The AT-rich regions of the DNA of the structures are stained with DAPI, 4’,6-diamidino-2-phenylindole stain, highlighting all the chromosomes in blue, while the centromere of both copies of chromosome 1 is hybridised to a probe containing its specific DNA sequence and carrying a red fluorescent dye. This probe allows identification of the chromosomes chosen for further study and will allow the development of separation methods for them to be isolated. It is planned to take samples from the fluorescence microscope to the SEM microscope to compare the structures.

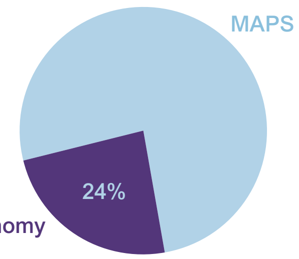
Research Statistics

Publication Summary

Research Group	Number of publications in refereed journals
Astro	132
AMOPP	60
CMMP	111
HEP	171

Active Grants and Contracts

In the last financial year (Aug 2010 – July 2011), Physics and Astronomy generated 24% of the total research income for the MAPS faculty. The MAPS faculty as a whole yielded £34,716,000, with Physics and Astronomy contributing £8,436,000.



Astrophysics

University Research Fellowship (URF) (Royal Society) £482,594 PI: Dr Filipe Abdalla

EUCLID Definition Phase (STFC) PI: Dr Filipe Abdalla £53,758

Phase B1 Funding for the UK EUCLID Programme, to Selection of the Mission in October 2011 (STFC) PI: Dr Filipe Abdalla £10,986

Modelling and Observations of Planetary Atmospheres: the Solar System and Beyond (STFC) PI: Prof Alan Aylward £700,632

ATMOP: Advanced Thermosphere Modelling for Orbit Prediction (European Commission FP7) PI: Prof Alan Aylward £194,152

Clusters, Starbursts and Feedback into the Environments of Galaxies (STFC) PI: Prof Michael Barlow £495,913

The Dust Enrichment of Galaxies (STFC) PI: Prof Michael Barlow £326,268

Quantifying the Dark Universe using Cosmic Gravitational Lensing (Royal Society) PI: Dr Sarah Bridle £273,240

COGS - Capitalising on Gravitational Shear (European Commission FP7) PI: Dr Sarah Bridle £1,050,000

Small Award: Universe Today: Cosmology, Astrophysics and Technology in Your Classroom (STFC) PI: Dr Francisco Diego £7,500

Large Aperture Telescope Technology (ESA) PI: Dr Peter Doel £26,766

PATT Linked Grant (STFC) PI: Prof Ian Howarth £13,294

Leverhulme Early Career Fellowship (Leverhulme Trust) PI: Dr Caitriona Jackman £48,688

RAS Fellowship: Energy Release from Magnetospheres (Royal Astronomical Society) PI: Dr Caitriona Jackman £50,895

Experimental Particle Physics at UCL (STFC) PI: Prof Nikolaos Konstantinidis £3,249,880

A Wide-Field Corrector for the Dark Energy Survey (STFC) PI: Prof Ofer Lahav £1,762,661

Cosmology: from Galaxy Surveys to Dark Matter and Dark Energy (STFC) PI: Prof Ofer Lahav £829,994

Observing Dark Energy (Royal Society) PI: Prof Ofer Lahav £101,260

Dark Energy Survey Collaboration (University of Nottingham) PI: Prof Ofer Lahav £300,000

Artist in Residence: Ms K Paterson (Leverhulme Trust) PI: Prof Ofer Lahav £12,500

Cosmology from Surveys (STFC) PI: Prof Ofer Lahav £468,087

Leverhulme Trust Senior Research Fellowship - The Dark Energy Survey and Beyond (Royal Society) PI: Prof Ofer Lahav £48,014

Grant Highlight

Professor Jonathan Tennyson FRS has been awarded £1,854,000.24 by the European Research Council (ERC) for 'EXOMOL – Molecular Line Lists for Exoplanet Atmospheres'.

The discovery of extrasolar planets was one of the major scientific advances of the last two decades. Many hundreds of planets have now been detected and astronomers are beginning to characterise their composition and physical properties. To do this requires huge quantities of spectroscopic data, most of which is not available from laboratory studies.

The interdisciplinary ExoMol project will provide a comprehensive solution to this problem by providing spectroscopic data on all the molecular transitions of importance in the atmospheres of exoplanets. This data will be widely applicable to other problems and will be used for studies on cool stars, brown dwarfs and circumstellar environments. ExoMol will also be used by scientists who study spectra of hot molecules in other situations such as combustion.

ExoMol

Early Career Fellowship - Probing Cosmological Structure through Novel Signal Processing Methods (Leverhulme Trust) PI: Dr Jason McEwen £46,000

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 Acceleration - Understanding Cosmic Acceleration: Connecting Theory and Observation (European Commission FP7) PI: Dr Hiranya Peiris £37,500

Cosmic Acceleration: Connecting Theory and Observation (STFC) PI: Dr Hiranya Peiris £304,205

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

Detecting Signatures of Eternal Inflation using WMAP and Planck Data (FQXi) PI: Dr Hiranya Peiris £64,189

The E-Merlin Legacy CYG OB2 Radio Survey: Massive Star Feedback and Evolution (STFC) PI: Prof Raman Prinja £400,466

UCL Astrophysics Short-Term Visitor Programme 2010-2012 (STFC) PI: Dr Giorgio Savini £44,489

Modular Wide Field of View RF Configurations (ESA) PI: Dr Giorgio Savini £54,706

A Study of Galactic Polarized Dust with Blast Pol (Leverhulme Trust) PI: Dr Giorgio Savini £80,621

Impact Studentship: Silvia Martinavarro – for Infrared and Sub-Millimetre Study of Evolved Stars (STFC) PI: Prof Bruce Swinyard £30,288

URF - Exploring Extrasolar Words: from Terrestrial Planets to Gas Giants (Royal Society) PI: Dr Giovanna Tinetti £421,241

Molecules in Extrasolar Planet Atmospheres (Royal Society) PI: Dr Giovanna Tinetti £12,000

Chemistry in Galaxies at Low and High Redshifts (STFC) PI: Dr Serena Viti £302,053

LASSIE - Laboratory Astrochemical Surface Science in Europe (European Commission FP7) PI: Dr Serena Viti £145,179

Investigating the Formation of Glycolaldehyde in Space (Leverhulme Trust) PI: Dr Serena Viti £117,898

3D Radiative Transfer Studies of HII/PDR Complexes in Star-Forming Galaxies (STFC) PI: Dr Serena Viti £381,854

Impact Studentship: Camilla Danielski - Probing the Atmospheres of Extrasolar Worlds Around M Dwarfs (Associacao Solidariedade E Esperanca) PI: Dr Serena Viti £25,000

Integrated Knowledge Centre in Ultra Precision and Structured Surfaces (EPSRC) PI: Dr David Walker £391,853

Ultra Precision Surfaces - Translation Grant (EPSRC) PI: Dr David Walker £670,810

KTP with Zeeko Ltd (Zeeko Ltd) PI: Dr David Walker £82,261

KTP with Zeeko Ltd (AEA Technology PLC) PI: Dr David Walker £126,409

Impact Studentship: Willhelmus Messelink - Advanced Optical Fabrication Techniques (Zeeko Ltd) PI: Dr David Walker £29,811

AMOPP

Dynamics of Information in Quantum Many-Body Systems (Royal Society) PI: Dr Janet Anders £382,692

Creating Ultra-Cold Molecules by Sympathetic Cooling (EPSRC) PI: Prof Peter Barker £1,252,039

Cavity Optomechanics: Towards Sensing at the Quantum Limit (EPSRC) PI: Prof Peter Barker £814,269

Dr S Bose: Spin Chain Connectors, Entanglement by Measurements and Mesoscopic Quantum Coherence (EPSRC) PI: Prof Sougato Bose £776,411

Quantum Information Uses of Complex Systems and Limits of the Quantum World (Royal Society) PI: Prof Sougato Bose £76,260

Developing Coherent States as a Resource in Quantum Technology (EPSRC) PI: Prof Sougato Bose £79,725

Leverhulme Trust Senior Fellowship - Bell Inequalities and Quantum Computation (Leverhulme Trust) PI: Dr Dan Browne £36,525

Abstract Quantum Probability (FQXi) PI: Dr Matt Leifer £14,296

Career Acceleration Fellowship (CAF) - Ionisation of Multi-Electron Atomic and Molecular Systems Driven by Intense and Ultrashort Laser Pulses (EPSRC) PI: Dr Agapi Emmanouilidou £808,016

Thecosint - Theory of Quantum Computation and Many-Body Simulation with Novel Quantum Technologies (European Commission FP7) PI: Dr Alessandro Ferraro £124,156

Alternative S-Matrix Approaches for Matter in Strong Laser Fields (EPSRC) PI: Dr Carla Figueira De Morisson Faria £310,014

Electron Correlation in Strong Laser Fields: a Time-Dependent Density Functional Treatment (Daresbury Labs) PI: Dr Carla Figueira De Morisson Faria £17,937

Nanofibre Optical Interfaces for Ions, Atoms and Molecules (EPSRC) PI: Dr Philip Jones £197,819

Photonic Force Microscopy with Nanostructures (Royal Society) PI: Dr Philip Jones £12,000

Impact Studentship: Agata Pawlikowska - Bubbles: Sensors for the Micro-World (NPL Management LTD) PI: Dr Philip Jones £54,359

Positron Reaction Microscopy (EPSRC) PI: Prof Gaetana Laricchia £604,471

Positronium - Matter Interactions (EPSRC) PI: Prof Gaetana Laricchia £468,305

Renewal of Collaborative Computational Project 2 (EPSRC) PI: Prof Tania Monteiro £64,858

Quantum Dynamics in Atomic Molecular and Optical Physics (EPSRC) PI: Prof Tania Monteiro £167,723

Bridging the Gaps across Sustainable Urban Spaces (EPSRC) PI: Dr Alexandra Olaya-Castro £14,902

CAF - Exploiting Quantum Coherent Energy Transfer in Light-Harvesting Systems (EPSRC) PI: Dr Alexandra Olaya-Castro £721,930

Brownian Motors, Disorder and Synchronization in an Optical Lattice (Leverhulme Trust) PI: Prof Ferruccio Renzoni £21,600

Modelling Condensed Matter Systems with Quantum Gases in Optical Cavities (EPSRC) PI: Prof Ferruccio Renzoni £806,753

Many-Body Dark States: from Quantum Dot Arrays to Interacting Quantum Gases (Royal Society) PI: Prof Ferruccio Renzoni £12,000

Atomic Magnetometry via Quantum Interference (Royal Society) PI: Prof Ferruccio Renzoni £12,000

Quantum Networks Dynamics (Royal Society) PI: Dr Simone Severini £86,750

CAVIAR - Continuum Absorption at Visible and Infrared Wavelengths and its Atmospheric Relevance (NERC) PI: Prof Jonathan Tennyson £396,342

Pairing and Molecule Formation in Ultracold Atomic Gases (Royal Society) PI: Prof Jonathan Tennyson £273,240

Understanding the Spectrum of Ammonia (Royal Society) PI: Prof Jonathan Tennyson £12,000

VAMDC - Virtual Atomic and Molecular Centre (European Commission FP7) PI: Prof Jonathan Tennyson £337,022

UK R-Matrix Atomic and Molecular Physics HPC Code Development Project (UK-Ramp) (EPSRC) PI: Prof Jonathan Tennyson £300,012

Phys4Entry - Planetary Entry Integrated Models (European Commission FP7) PI: Prof Jonathan Tennyson £139,200

ESip - Efficient Silicon Multi-Chip System-in-Package Integration - Reliability Failure Analysis and Test (Technology Strategy Board) PI: Prof Jonathan Tennyson £283,488

A Calculated Methane Line List for Characterising Exoplanets and Brown Dwarfs (STFC) PI: Prof Jonathan Tennyson £380,702

EXOMOL - Molecular Line Lists for Exoplanet Atmospheres (European Commission FP7) PI: Prof Jonathan Tennyson £1,854,024

Wolfson Research Merit Award - Molecular Line Lists for Extra Solar Planet and Other Hot Bodies (Royal Society) PI: Prof Jonathan Tennyson £72,000

CAF - Star Formation and the Ism Evolution of Galaxies across Cosmic Time (STFC) PI: Dr Thomas Greve £471,898

CMMP

URF: Computer Simulation of Redox and Hydrolysis Reactions in Enzymatic Systems (Royal Society) PI: Dr Jochen Blumberger £202,106

Impact studentship: Modelling Electron Transport in Multi-Heme Proteins (PNNL) PI: Dr Jochen Blumberger £21,587

Impact Studentship: a Computational Investigation of Charge Transfer in Organic Semiconducting Materials (PNNL) PI: Dr Jochen Blumberger £10,295

URF Extension - Understanding Gas Transport in Hydrogenases Through Novel Computer Simulations (Royal Society) PI: Dr Jochen Blumberger £332,813

Impact Studentship: Bio-Inspired Materials for Sustainable Energy (University of Cambridge) PI: Dr David Bowler £119,580

ONE-P - Organic Nanomaterials for Electronics and Photonics: Design, Synthesis, Characterization, Processing, Fabrication and Applications (European Commission FP7) PI: Prof Franco Cacialli £312,741

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 £7,880

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 £23,845

URF Extension - Nanomaterials for Biomolecular Sciences and Nanotechnology (Royal Society) PI: Dr Thanh Nguyen £146,806

URF - Nanomaterials for Biomolecular and Biomedical Sciences and Nanotechnology (Royal Society) PI: Dr Thanh Nguyen £325,058

Bio-Functional Magnetic Nanoparticles: Novel High-Efficiency Targeting Agents for Localised Treatment of Metastatic Cancers (EPSRC) PI: Prof Quentin Pankhurst £12,824

Magnetic Targeting of Stem Cells (EPSRC) PI: Prof Quentin Pankhurst £8,346

Support for the UK Car-Parrinello Consortium (EPSRC) PI: Prof Chris Pickard £5,716

Ex Nihilo Crystal Structure Discovery (EPSRC) PI: Prof Chris Pickard £1,338,601

Laser Materials Interaction: Ashley Garvin (PNNL) PI: Prof Alexander Shluger £42,400

EngD - Advanced Gate Stack and Dielectric in Resistive Memory Material (International Sematech) PI: Prof Alexander Shluger £48,047

Impact Studentship: David Gao - Using Computation In Component Development (Chevron Oronite Company LLC) PI: Prof Alexander Shluger £86,670

MORDRED- Modelling of the Reliability and Degradation of Next Generation Nanoelectronic Devices (European Commission FP7) PI: Prof Alexander Shluger £382,186

Impact Studentship: Laser-Materials Interactions: Theory and Experiment (PNNL) PI: Prof Alexander Shluger £11,400

DIAMOND: Decommissioning, Immobilisation and Management of Nuclear Wastes for Disposal (EPSRC) PI: Prof Neal Skipper £72,233

Electron Gas in Reduced Ionic Insulators and Semiconductors (Royal Society) PI: Dr Peter Sushko £478,269

Learning to Control Structure and Properties of Nano-Scale Ferroelectrics Using Defects (EPSRC) PI: Dr Peter Sushko £264,337

Heavy Metal Ions in Multi-Component Glasses: The Local Atomic Structure and Mechanisms of the Charge Compensation (IHI Corporation) PI: Dr Peter Sushko £7,500

Modelling Correlated Electron-Ion Diffusion in Nano-Scal Tio2: Beyond Periodic Model and Density Functional Theory (EPSRC) PI: Dr Peter Sushko £101,530

Theoretical Modelling of Amorphous Electrides, Electride Surfaces, and Quasi-Two-Dimensional Active Materials (Tokyo Institute of Technology) PI: Dr Peter Sushko £257,273

Multiscale Modelling of Metal-Semiconductor Contacts for the Next Generation of Nanoscale Transistors (EPSRC) PI: Dr Peter Sushko £292,850

HEP

Development and Maintenance of Atlas Run Time Tester (STFC) PI: Prof Jonathan Butterworth £182,207

Electroweak Symmetry Breaking and Jet Physics with Atlas at the LHC (Royal Society) PI: Prof Jonathan Butterworth £86,247

Terauniverse ~ Exploring the Terauniverse with the LHC, Astrophysics and Cosmology (European Commission FP7) PI: Prof Jonathan Butterworth £356,475

IPPP Associateships 2010-2011 - Dr Mario Campanelli (University of Durham) PI: Dr Mario Campanelli £4,000

Experimental Particle Physics at UCL (STFC) PI: Prof Nikolaos Konstantinidis £1,403,342

Higgs-Zap - Understanding the Origin of Mass with the Atlas Experiment at the Large Hadron Collider. Dr Ilekra Christidi (European Commission FP7) PI: Prof Nikolaos Konstantinidis £33,750

Atlantis Event Display (STFC) PI: Prof Nikolaos Konstantinidis £143,166

Atlas Upgrade Project (STFC) PI: Prof Nikolaos Konstantinidis £183,598

URF - Higgs Physics and the Mystery of Particle Masses (Royal Society) PI: Dr Gavin Hesketh £525,834

URF - Investigating Neutrino Oscillations with Minos and Neutrino Astronomy with Anita (Royal Society) PI: Dr Ryan Nichol £452,369

URF Extension - Neutrino and Cosmic Ray Studies with Minos, Anita and Cream Tea (Royal Society) PI: Dr Ryan Nichol £298,804

URF - Search for a Vector Boson Fusion Produced Higgs Boson at Atlas (Royal Society) PI: Dr Emily Nurse £399,633

Studentship for Supernemo Design Study (STFC) PI: Prof Ruben Saakyan £15,808

Supernemo Demonstrator Module Construction (STFC) PI: Prof Ruben Saakyan £297,427

New Frontiers in Neutrino Physics - Wolfson Research Merit Award (Royal Society) PI: Prof Jennifer Thomas £75,000

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

Construction, Calibration and Exploitation of the Minos Experiment (STFC) PI: Prof Jennifer Thomas £15,075

Royal Society Leverhulme Trust Senior Fellowship (Royal Society) PI: Prof Jennifer Thomas £42,010

IPPP Associateships 2009-10 (University of Durham) PI: Prof Robert Thorne £12,000

Theoretical Particle Physics Rolling Grant (STFC) PI: Prof Robert Thorne £191,476

Particle Physics Phenomenology (STFC) PI: Prof Robert Thorne £343,107

GridPP Tier-2 Support (STFC) PI: Dr Ben Waugh £128,480

GridPP Tier-2 Support (STFC) PI: Dr Ben Waugh £35,700

GridPP3 Tranche 2 Londongrid UCL Grant (STFC) PI: Dr Ben Waugh £8,100

European XFEL Clock and Control System (European X-Ray Free-Electron Laser Facility GmbH) PI: Prof Matthew Wing £645,926

Impact Studentship Scott Mandry: Diagnostics for a Proton-Driven Plasma Wakefield Experiment (Max Planck Institute For Physics) PI: Prof Matthew Wing £31,627

Headline Research

Classical vs Quantum = Addition vs Multiplication

M. J. Hoban, D. E. Browne, Stronger Quantum Correlations with Loophole-Free Postselection, *Phys. Rev. Lett.* 107, 120402 (2011)

John Bell's famous 'Bell inequality' is one of the cornerstones of our understanding of quantum mechanics – demonstrating that with quantum systems, one can achieve things impossible in a purely classical world. Although first derived in 1964, it remains a subject of intense debate and research, and was an important motivation for the development of quantum computation and quantum cryptography.

Recent work published by PhD student **Matty Hoban** and **Dr Dan Browne** sheds a new light upon this important work. By exposing a link between the Bell inequality and simple arithmetic calculations: Classical vs Quantum = Addition vs Multiplication, they derive generalisations of the classic Bell inequality experiment with a number of surprising features. Their work strengthens the link between the foundations of quantum physics and its potential future applications.

Staff Snapshot

Head of Department

Professor J M Butterworth

Astrophysics

**Head of Group:
Professor M J Barlow**

Professors:
A D Aylward, M J Barlow, I D Howarth, O Lahav, S Miller, R K Prinja, J M C Rawlings, B M Swinyard

Professorial Research Fellow:
D D Walker

Readers and Senior Lecturers:
A L Aruliah, S L Bridle, A P Doel, I Furniss, G Tinetti, S Viti

Lecturers:
F Abdalla, N Achilleos, H Peiris, G Savini

Royal Society Fellowship:
J McEwen (Newton)

Senior Research Associates:
F Deigo, J Yates (Honorary)

Research Associates:
R Aladro, R J Barber, T Bisbas, P Guio, M Hirsch, O Host, C Jackman, S Jouvel, D Kirk, M Matsuura, W Nicholson, F Poidevin, B Rowe, C Sabiu, T Spain, S Thomas, S J Thompson, L Voigt, P Woods, J Zuntz

Support Staff:
M Bibby, D Brooks, J R Deacon, J Fabbri, R Heward, D Witherick

Atomic, Molecular, Optical and Positron Physics

**Head of Group:
Professor G Laricchia**

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

Reader and Senior Lecturers:
A J Bain, P H Jones

Lecturers:
D Browne, C Figueira de Morisson Faria, A Olaya-Castro, J Oppenheim, A Serafini, J Underwood

EPSRC Career Acceleration Research Fellow:
A Emmanouilidou

Royal Society Fellowship:
J Anders (Dorothy Hodgkin)

Senior Research Associate:
S Yurchenko

Research Associates:
B Augstein, C Cassidy, C Coppola, A Davison, A Ferraro, C Hill, S Hutchinson, A Kolli, V Laporta, C Lazarou, L Lodi, S Lopez Lopez, R Marsh, S Midgley, J Millen, N Nicolaou, B Walker, A Wickenbrock

Support Staff:
J Dumper, R Jawad

Condensed Matter and Materials Physics

**Head of Group:
Professor A Shluger**

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

Readers and Senior Lecturers:
D R Bowler, D Duffy, T T K Nguyen, S W Zochowski

Lecturers:
J Blumberger, M Ellerby, C Hirjibehedin, B W Hoogenboom, M Parish, P Sushko

EPSRC Career Acceleration Research Fellow:
S Schofield

Research Associates:
O Fenwick, F Lopez Gejo, S Hepplestone, A Kimmel, N Kuganathan, S Ling, M Martinez Canales, A Morris, D Ortega

Most Research staff are employed through the LCN

High Energy Physics

**Head of Group:
Professor M Lancaster**

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

Readers:
M Campanelli, R Nichol, D S Waters

Lecturers:
F Deppisch, S Jolly

Royal Society University Research Fellows:
G Hesketh, E Nurse

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

Research Associates:
P Bernat, I Christidi, B Cooper, T Coughlin, E Dobson, J Evans, A Holin, E Jansen, J W Monk, R Prabhu, S Torre, D Wardrope

Support Staff:
D J Attree, G Crone, J Grozier, T J Hoare, E Motuk, M Postranecky, B M Simmons, M R Warren

Teaching

Director of Postgraduate Studies:
T S Monteiro

Director of Undergraduate Teaching:
R Prinja

Director of Laboratories:
F Renzoni

Principal Teaching Fellow:
M Coupland

Teaching Fellows:
D Armoogum, P Donovan

Co-ordinator 1st year Laboratory:
P Bartlett

Laboratory Superintendent:
J O'Brien

Laboratory Technicians:
B T Bristoll, M J Palmer, M A Sterling, D Thomas

Admissions Tutors:
A Aylwood (Undergraduate), F Cacialli (MSc), R S Thorne (Postgraduate research), M M Dworetsky (Astronomy Certificate)

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

University of London Observatory

Director:
I D Howarth

Manager:
P K Thomas

Demonstrators:
S J Boyle, S J Fossey

Computing and Experimental Officer:
T Schlichter

Technical Support:
M Pearson

Maps Workshop

Superintendent:
R Gollay

Technicians:
J Benbow, J F Percival

Administrative Staff

Departmental Manager:
H Wigmore

Grants Officer:
M Young

Examinations Co-ordinator and IT Support:
K Heyworth

Finance Officer:
D Buck

Finance and Postgraduate Administrator:
N Waller

Undergraduate Administrator:
S Cross

Group Administrator Astro:
K Nakum

Group Administrator AMOPP & HEP:
C Johnston

Group Administrator CMMP:
C Jordan

Science Centre Organiser:
S Kadifachi

Visiting Professors and Emeritus Staff:

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 R Newell, G Peach, P G Radaelli, A C Smith, P J Storey, D N Tovee, C Wilkin, D A Williams, A J Willis

Headline Research

Hubble Space Telescope View of Galaxy Clusters

The international CLASH project is using the Hubble Space Telescope to obtain deep imaging (in 16 colour bands) of 25 galaxy clusters. This is one of the largest ever Hubble programmes.

Through the phenomenon of gravitational lensing, these images are used to study the distribution of dark matter within the clusters, and to detect extremely distant, magnified galaxies in the early Universe. The data also enables detailed studies of cluster member galaxies and makes it possible to search for high-redshift supernovae which can help to understand the puzzle of dark energy.

The image shows Abell 383, the first CLASH cluster to be observed. The imaging revealed 13 new images, of five different sources. These provide tight constraints on the cluster mass distribution.

Using photometric redshifts and modeling systematic uncertainties in the lensing analysis, **Professor Ofer Lahav**, **Dr Ole Host** and **Dr Stephanie Jouvel** work on measuring the distances to the sources detected in the CLASH data using photometric redshifts, and on modeling systematic uncertainties in the lensing analysis.

Notes

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