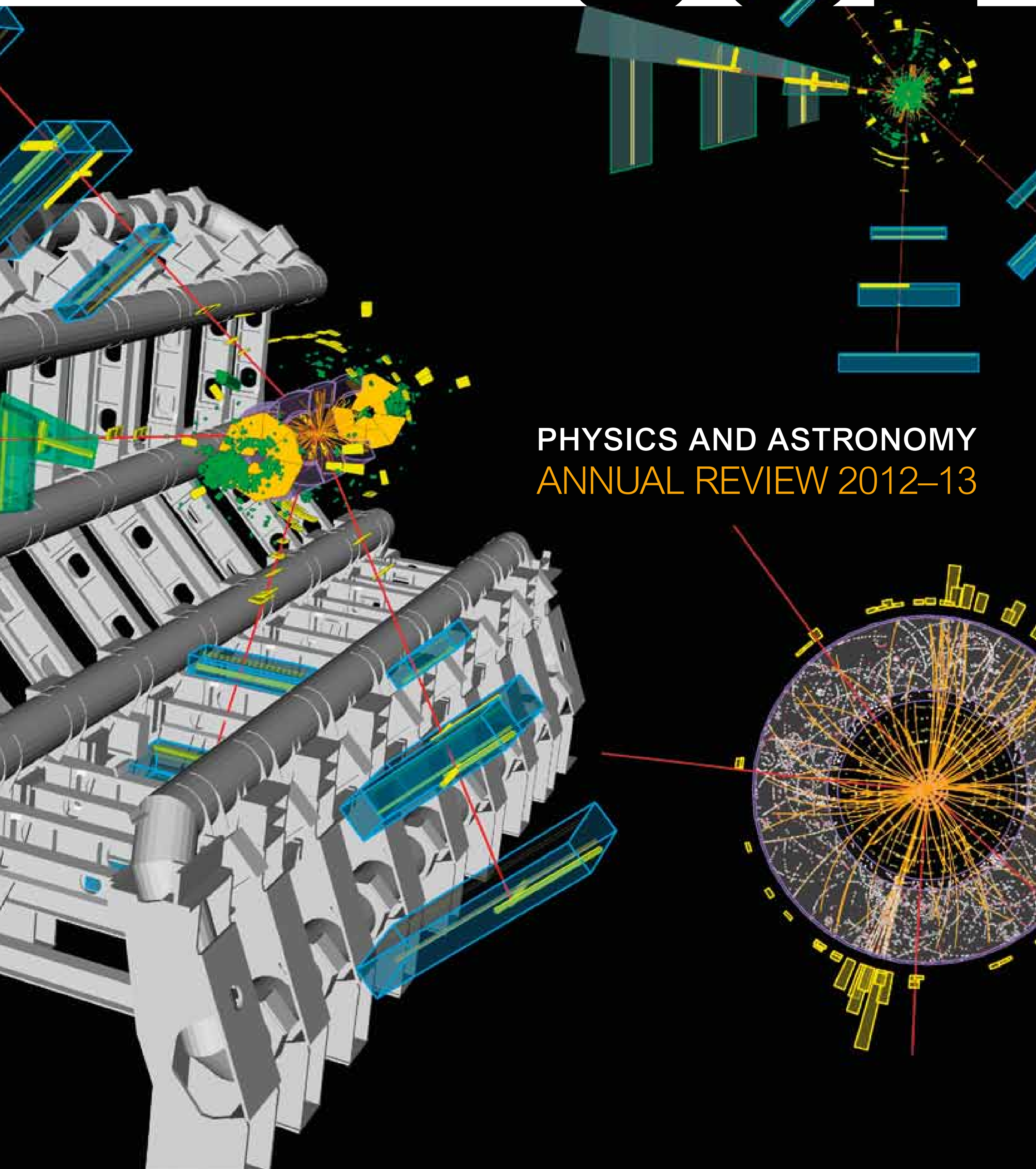
UCL DEPARTMENT OF PHYSICS AND ASTRONOMY

UCL



PHYSICS AND ASTRONOMY
ANNUAL REVIEW 2012–13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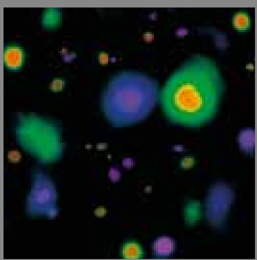
Contents






Cover image: **Display of a collision event in the ATLAS detector, where a Higgs boson candidate decays to two Z bosons, each of which decays to a muon and an anti-muon (red lines). ATLAS Experiment © 2012 CERN**

Inside cover image:
Components in the undergraduate teaching laboratory used to explore practical thermodynamics.
Credit: Paul Woods (UCL). http://paulwoods.4ormat.com

Image page 3:
The newly refurbished undergraduate library. Credit: Paul Woods (UCL)

Image page 12**:**
The Physics Building. Credit: Paul Woods (UCL)

Image page 16**:**
A random collection of textures taken from high-resolution, supercomputer simulations. Red indicates a positive twist in the topological charge density and blue a negative twist. Credit: V. Travieso and N. Turok

Review edited by **Katherine Heyworth**, k.heyworth@ucl.ac.uk
Design © UCL Creative Media Services

Welcome

Welcome to another annual review of the activities of the UCL Department of Physics & Astronomy.

Inside you will find items focusing on research highlights, as well as features on selected staff, students and events over the past year. I hope these speak for themselves, giving a true impression of the lively and exciting intellectual life of one of the UK's leading Physics & Astronomy Departments.

There are also statistics, including grant income and student admissions. While ploughing through these in detail may be a challenge, they also convey an important message; that the Department continues to thrive, our activities are well recognised and people want to join us.

On a personal note, I stepped down from my role as an ATLAS Physics Group Co-ordinator at CERN at the end of September and am now able to spend much more time in UCL to deal with departmental matters. Still, I can't write this introduction without mentioning the exciting discovery announced on the 4th July, but I refer you to the article by **Nikos Konstantinidis**. See page 17 for more details.

> The Department continues to thrive, our activities are well recognised and people want to join us.

There have been several new academic appointments over the past year, and I am pleased to report that we are in the process making more. A day of presentations and interviews may not be much fun for candidates, but chairing the appointment panels has been a fantastic way for me to broaden my physics knowledge, learning from some of the brightest stars in their fields.

Professor Jon Butterworth, Head of Department and Dr Tony Harker, Deputy Head of Department

Every shortlist has been amazingly strong and each appointment bodes well for the future.

However the arrival of new staff and the continuing success of existing members of the Department, does increase pressure on our infrastructure. Laboratory, workshop, teaching and office space are all at a premium; but so are services such as power, cooling and high performance computing. UCL has a strategic programme to address these needs and we have already benefited from some refurbishments (page 4). New research laboratory refits are also underway, with more required in the near future. A major refurbishment of the Kathleen Lonsdale Building is also planned. In the longer term, the Department has a developing presence at the Harwell Science and Innovation Campus in Oxford (as well as at CERN), and is involved in discussions of possible developments at Stratford.

The underlying problem is our location in Bloomsbury; but this is also a massive advantage. Not only is it an exciting and well-connected place to be, but with major facilities such as the UCH hadron therapy unit and the Crick Institute arriving in the neighbourhood, the scientific benefits of being here are one of the things which distinguishes UCL Physics and Astronomy.

Finally, one of the fun departmental events I attended this year was the annual Cumberland Lodge meeting. I arrived on the Sunday to an excited welcome from our first-year students who had just been to the chapel and met the Queen. A lovely start to undergraduate life here and I am confident the physics & astronomy learned over the next few years will be (at least!) as exciting.

Professor Jonathan Butterworth
Head of Department

Community Focus

The Wow Factor is back!

by Professor Tony Harker

Summer 2012 saw the first phase of a complete refurbishment of the undergraduate teaching laboratories. This is an ambitious programme, aimed at bringing the laboratories from the 1950s into the 21st century. It involved thinking very carefully about how the space is currently used and how that might evolve, and gaining from the experience of others by visiting Physics departments around the country who have recently undertaken similar projects. Everything, from heating, lighting and ventilation to benching and seating, has been completely updated.

> Bringing the laboratories from the 1950s into the 21st century

Driven by a necessity to complete in time for the start of term, the refurbishment required meticulous planning and a phenomenal amount of hard work by all involved.

Many people have played a part, but special thanks are due to Paul Murphy and his architectural team, David Young and UCL Estates, **John O'Brien** and the laboratory technicians (who not only contributed to the planning, but also had to clear and store equipment and get it all deployed again in time for the start of term), and to Peak, the main contractors.

The hard work has paid off and what has been achieved is essentially a brand new laboratory. Both students and demonstrators enjoy the innovative ways in which the new facilities can be used. Inspired by the success of this project, everybody is looking forward to phase two of the refurbishment which will involve similar transformations to the remaining two teaching labs. Work is scheduled to commence in summer 2013.

In addition the seminar room, student common room and cluster room have also been redecorated and brightly furnished.

Undergraduates at work in the refurbished first year laboratory.

The newly refurbished student common room.

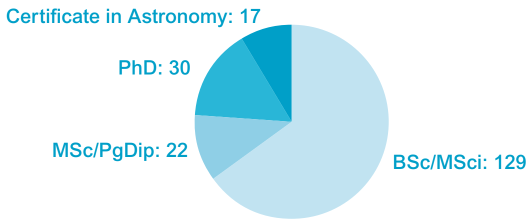
The major transformation here has been to the undergraduate library, which now enjoys natural light. The photograph on page 3 shows a section of the undergraduate library after refurbishment.

The undergraduate teaching laboratory 1, before refurbishment.

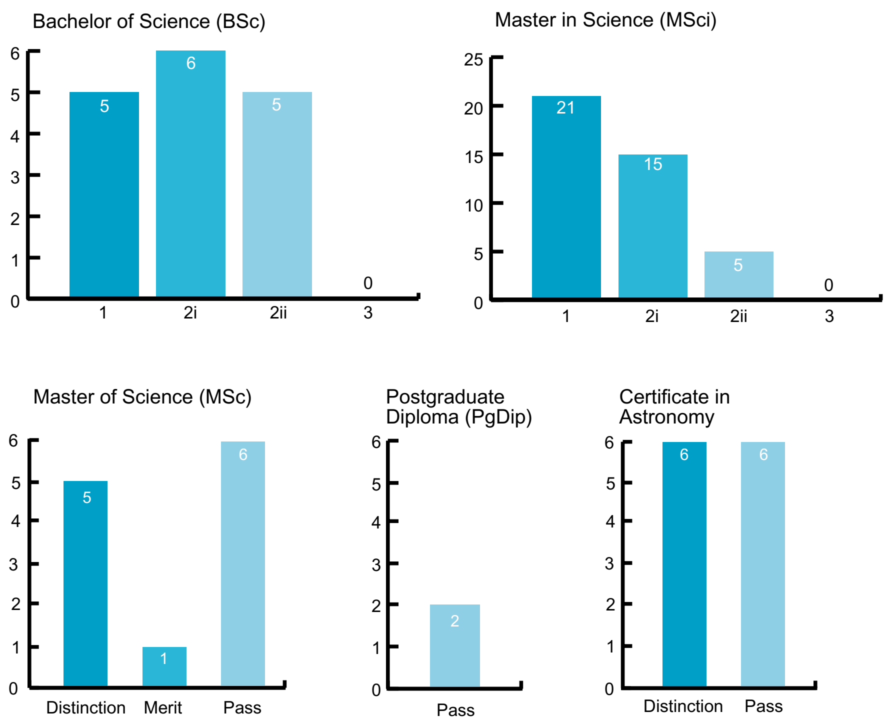
After extensive refurbishment the laboratory has now been transformed.

Teaching Lowdown

Intake



Awards



Royal Astronomical Society Keith Runcorn Prize for 2011

Awarded to **Dr David Kipping** for the best doctoral thesis in Geophysics. Entitled ‘The Transits of Extrasolar Planets with Moons’, David’s thesis has also been published by the Springer Theses series.

Headline Research

UCL team develops laser accelerator for neutral particles

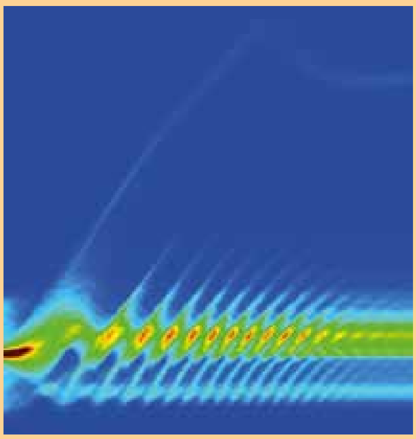
Laser-driven acceleration of neutral particles

C. Maher-McWilliams, P. Douglas, P.F. Barker, Nature Photonics, 6 (2012)

Precise control of the motion of atoms and molecules is extremely difficult, yet important for a large spectrum of scientific and industrial processes. Applications range from surface growth and deposition, to elucidating the details of chemical reactions through controlled collisions.

UCL researchers have recently developed a high-accuracy method, whereby acceleration up to velocities of hundreds of metres per second has been achieved. The method produces a beam of particles characterised by a narrow velocity spread, precisely controlled mean velocity, and sufficient flux over a wide range. This acceleration occurs over tens of billionths of a second and over micrometre length scales.

The laser accelerator enables particle velocity to be continuously tuned over a wide range, while maintaining a narrow velocity spread. Their method has the potential to be applied to a wide range of applications; allowing acceleration or deceleration of a variety of neutral atomic and molecular species, as well as nanoscale particles.



Student Accolades

Undergraduate Awards

Departmental Awards

Oliver Lodge Prize
Best performance 1st year Physics
Mr Harapan Ong

Halley Prize
Best performance 1st year Astronomy
Mr Felix Priestley

C.A.R. Tayler Prize
Best 2nd Year Essay
Mr Tong Wang

Wood Prize
Best performance 2nd year Physics
Mr Stefan Blesneag

Huggins Prize
Best performance 2nd year Astronomy
Mr Sandor-Iozsef Kruk

David Ponter Prize
Most improved performance in Department, 2nd year
Mr Tobias Jackson

Sydney Corrigan Prize
Best performance in experimental work, 2nd year
Mr Myles Nadarajah

Sessional Prize
Best Performance 3rd Year Physics
Mr Zhi Wong

Sessional Prize
Best Performance 3rd year astrophysics
Mr Marco Rocchetto

Additional Sessional Prize for Merit
1st and 2nd year
Mr Martin Buettner

Additional Sessional Prize for Merit
3rd year
Mr James Hutson

Burhop Prize
Best performance 4th year Physics
Mr Giulio Pepe

Herschel Prize
Best performance 4th year astronomy
Miss Shaghayegh Parsa

Brian Duff Memorial Prize
Best 4th year project in the department
Mr Ryan Varley

William Bragg Prize
Best overall undergraduate
Mr Arnold Mathijssen

Tessella Prize for Software
Best use of software in final year physics/astronomy project (joint award)
Mr Stuart Vincent &
Miss Wilma Trick

Faculty Awards

(only Physics and Astronomy winners are listed here)

Faculty Medal 2012
(joint award)
Mr Arnold Mathijssen

Dean's List
Mr Kaijian Xiao
Mr Giulio Pepe
Miss Shaghayegh Parsa
Miss Jiuling Xue
Mr Asif Suleman

Faculty Undergraduate Scholarships for Excellence 2012
Best Year 2 undergraduate
Mr Stefan Blesneag

Postgraduate Awards

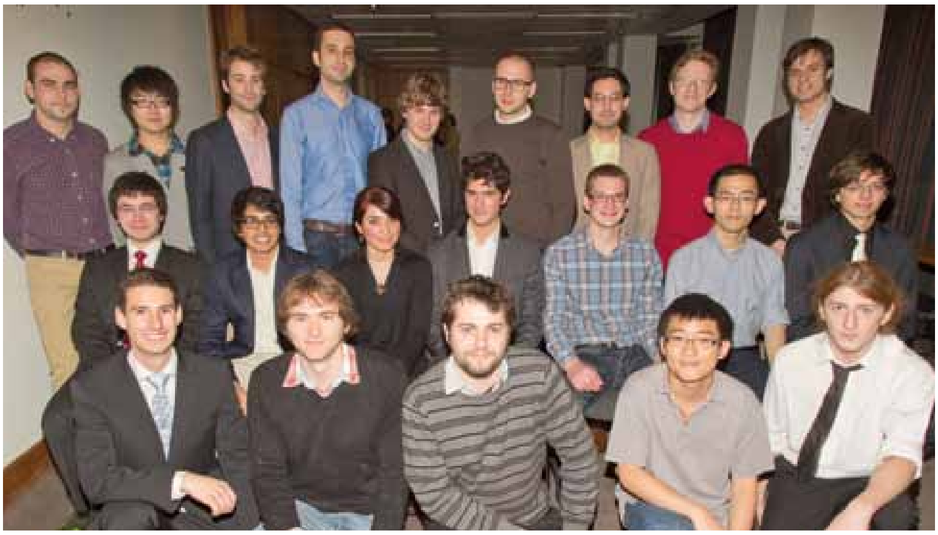
Harrie Massey Prize
Best overall MSc student
Mr Oliver Dicks

Carey Foster Prize
Outstanding postgraduate research physics, AMOPP (joint award)
Dr Matthew Hoban
Dr Bradley Augstein

HEP Prize
Outstanding postgraduate research physics, HEP
Dr James Robinson

Marshall Stoneham Prize
Outstanding postgraduate research physics, CMMP
Dr Francesco Di Stasio

Jon Darius Memorial Prize
Outstanding postgraduate research astrophysics
Dr Ingo Waldmann



Physics and Astronomy prize winners 2012

Doctor of Philosophy (PhD)

Michelle Antonik
The dark energy camera's optical corrector
(Supervisor Dr A. P. Doel)

Bradley Augstein
Orbit based studies of quantum interference effects in atomic and molecular high-order harmonic generation
(Supervisor Dr C. Figueira De Morisson Faria)

Luke Austen
Production of p-wave Feshbach molecules from an ultra-cold Fermi gas
(Supervisor Professor J. Tennyson)

Anastasia Basharina-Freshville
Search for the neutrinoless double beta decay of 100Mo with the NEMO3 detector and calorimeter R&D for the SuperNEMO experiment
(Supervisor Professor R. Saakyan)

James Chivall
Growth and characterisation of uranium nanostructures
(Supervisor Dr S. W. Zochowski)

Helen Christie
Structure and depletion in star forming clouds
(Supervisor Professor S. Viti)

Liam Cook
Feshbach resonances and the three-body problem
(Supervisor Professor T. S. Monteiro)

Francesco Di Stasio
Supramolecular architectures: Properties and applications
(Supervisor Professor F. Cacialli)

Jose Garcia Coello
Quantum information processing in mesoscopic systems
(Supervisor Professor S. Bose)

Alex Grimwood
Imaging elastographic contrast in optical coherence tomography for applications in dermatology and oncology
(Supervisor Professor Q. A. Pankhurst)

Stephen Harrison
Electron-collisions with molecules of interstellar and plasma interest via the R-Matrix method
(Supervisor Professor J. Tennyson)

Matthew Hoban
Computational perspectives on bell inequalities and many-body quantum correlations
(Supervisor Dr D. E. Browne)

Simon Hodges
A multi-wavelength study of fast winds from central stars of planetary nebulae
(Supervisor Professor R. K. Prinja)

David Houseman
A function-analytic development of field theory
(Supervisor Professor R. Thorne)

Hongyu Li
Research on manufacturing mirror segments for an extremely large telescope
(Supervisor Professor D. D. Walker)

Penglei Li
Graphene-based and low-gap semiconductors for electronic applications
(Supervisor Professor F. Cacialli)

Matthew J. Mottram
A search for ultra-high-energy neutrinos and cosmic rays with the ANITA-2 experiment
(Supervisor Dr R. Nichol)

Piyphat Phoonthong
State-insensitive traps for caesium atoms
(Supervisor Professor F. Renzoni)

Thomas Riddick
Modelling energy loss mechanisms and a determination of the electron energy scale for the CDF Run II W Mass Measurement
(Supervisor Dr D. Waters)

James Robinson
Jet physics with the ATLAS experiment at the LHC
(Supervisor Dr M. Campanelli)

Taha Sochi
Atomic and molecular aspects of astronomical spectra
(Supervisor Professor P. J. Storey)

Tommaso Tufarelli
Qubit-controlled displacements in Markovian environments
(Supervisor Professor S. Bose)

Ingo Waldmann
Of "cocktail parties" and exoplanets: data analysis in exoplanetary spectroscopy
(Supervisor Professor B. Swinyard)

Arne Wickenbrock
Cold atoms in light fields: from free space optical lattices to multimode optical cavities
(Supervisor Professor F. Renzoni)

Sai-Yun Ye
Coherent effects in dispersive quantum dynamics
(Supervisor Dr A. Serafini)

Headline Research

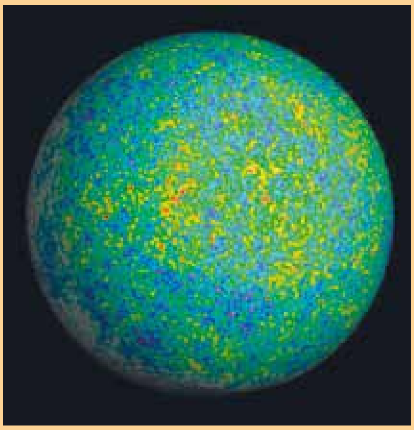
Robust constraint on cosmic textures from the cosmic microwave background

S. M. Feeney, M. C. Johnson, D. J. Mortlock, **H. V. Peiris**, Phys. Rev. Lett. 108, 241301 (2012)

Theories of the primordial Universe predict the existence of knots in the fabric of space. It is hypothesised that as the Universe cooled, a series of phase transitions occurred, analogous to water freezing into ice, known as cosmic textures.

Such textures would interact with light from the cosmic microwave background (CMB), relic radiation left over from the Big Bang, to leave a set of characteristic hot and cold spots. These signatures would yield invaluable insight into the types of phase transitions that occurred when the Universe was a fraction of a second old.

Using data from NASA's Wilkinson Microwave Anisotropy Probe (WMAP) satellite, researchers performed the first search for textures on the full sky. However they found no evidence to support this theory and are able to rule out at 95% confidence, theories that produce more than six detectable textures on our sky.

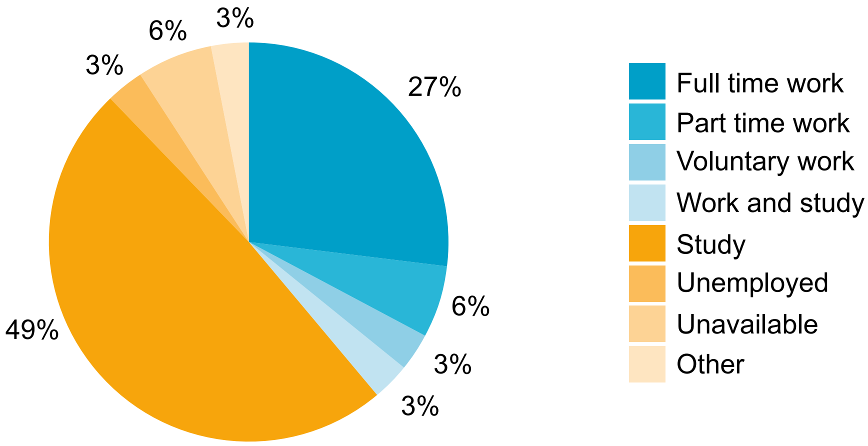


© Max Tegmark (MIT)

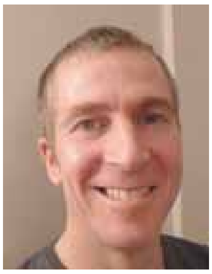
Career Profiles

Graduate Destinations for 2011

Total Number of Graduates: 90
Response Rate: 82.2%
Median Salary: £25,000



Chris Howarth
IT Infrastructure Architect
(BSc Physics 1986, PhD High Energy Physics 1990)



Ifor Evans Hall was my home for the first year and introduced me to many life-long friends

My days at UCL began in 1983 as a geeky physics undergraduate. Ifor Evans Hall was my home for the first year and introduced me to many life-long friends, as well as being the only place I've ever seen fried eggs cooked by completely submerging them in fat. Still, a solid breakfast was needed for 9 a.m. lectures with **Tegid Jones** on electromagnetism, or Leonardo Castillejo on Relativistic Quantum Mechanics (actually even a full english wasn't sufficient preparation for that one).

After 3 fantastic years in a department which came with the added bonus of being just yards from the Student Union, the prospect of going out to the horrible real world seemed too grim so I went on to do a PhD in the High Energy Physics group...oh and then a couple of years as a Research Assistant. Finally, breakfast discussions in the CERN canteen involving quarks and gluons proved too much, when I really wanted to talk about the latest episode of 'Home and Away' and so I was lucky enough to get a job at the Bloomsbury Theatre as a technician. The huge turnover of productions, both professional and student (very much not professional, but a good laugh), made for a really great atmosphere, with moments such as Lilly Savage hurling abuse at me whilst having to hand crank out the fire curtain during the interval when the motor broke!

Since leaving UCL, I trained hard to gain a place in the GB Fencing Team and was fortunate enough to pick up a couple of medals at the Commonwealth Games in Kuala Lumpar for England. I now work as an IT infrastructure architect at Citibank and am married (to another fencer - Liz). We have two spirited daughters who we try to keep away from the swords.

Pierre Deludet
Banking Analyst
(BSc Theoretical Physics 2011)

In September 2008, I started my degree in Theoretical Physics at UCL. A week later, Lehman Brothers filed for bankruptcy. This was followed by the greatest financial crisis in the world since 1929. Many students would have been apprehensive about joining the financial industry at such a time, but I was not – great risks come with great rewards, my dad used to say. Fast-forward to today, I am working at a burgeoning investment banking advisory boutique in London, whose success has come as a direct beneficiary of this recent financial crisis.

The firm focuses on financial restructuring and merger and acquisitions (M&A) advisory assignments. This means that whatever the state of the economy, we are always busy! My day-to-day responsibilities include financial modelling of various corporates, and creating pitch materials and management / bank presentations. So far, I have had the chance to work on multiple transactions in Europe, the Middle East and East Africa.

I am grateful for my experience at UCL as physics not only prepared me for a career in academia, it shaped the way I think

I am grateful for my experience at UCL as physics not only prepared me for a career in academia, it shaped the way I think and gave me the right skills to succeed in a job that requires a significant amount of analytical thinking. The training I received at university now makes it very easy for me to navigate through spreadsheets and financial models. When I was at UCL, I spent a lot of time running around campus organising society events or, as General Secretary of the Student Union, chairing various meetings. This gave me incredible leadership experience, which is becoming increasingly important as I progress in my career.

Headline Research

First visualisation of the DNA double helix in water

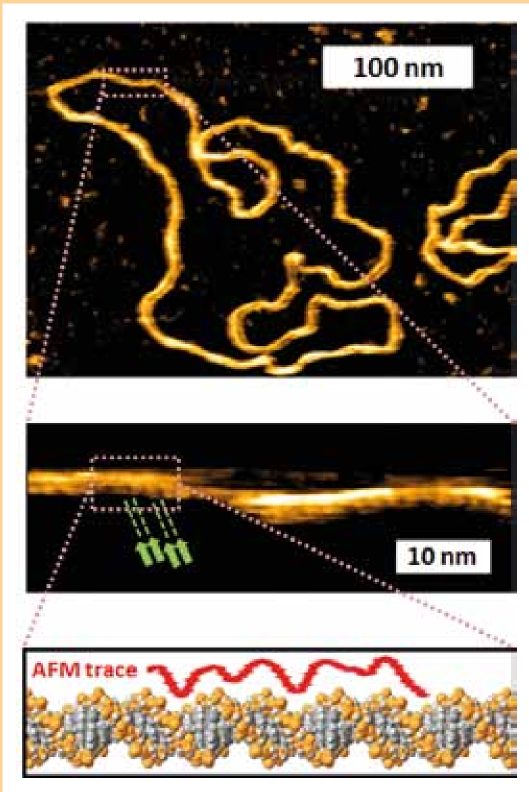
Atomic force microscopy with nanoscale cantilevers resolves different structural conformations of the DNA double helix

A. Bestembayeva, J. Stinson, B. W. Hoogenboom and co-authors, Nano Letters, 12, 7, 3846–3850 (2012)

Though the double-helix structure of the DNA has become iconic for our understanding of life, no-one had ever observed this structure on a single molecule in its natural environment, in aqueous solution. This has now been achieved by atomic force microscopy (AFM).

AFM detects molecules by ‘feeling’ them with a sharp tip on a microfabricated cantilever, in a process similar to that of a blind person reading Braille. For imaging biological samples, its main challenge lies in detecting molecules with forces that are sufficiently small not to perturb the molecular structure. Here, this has been achieved by miniaturising cantilevers to nanoscale dimensions and detecting the proximity of the DNA via changes in the resonance frequency of the cantilever.

The resulting images show the two strands of the double helix twisting clockwise around the central axis of the molecule, setting these images apart from two decades of previous AFM measurements on DNA.



Science in Action

by Dr Ryan Nichol

'Bright Club is the thinking person's variety night, blending comedy, music, art, new writing, science, performance, and anything else that can happen on a stage'

Bright Club was the brain child (think Frankenstein's experiment) of Dr Steve Cross, Head of UCL Public Engagement. He asked "What would happen if we got a bunch of interesting comedians and musicians, and combined them with all of the fascinating people who work for one of the UK's best Universities?"

The idea sounds simple enough; take some sociable, but awkward researchers and place them on a stage in front of a paying audience expecting to have a good time. Remarkably, this blending of researchers and comedy seems to work, with Bright Clubs now appearing all over the country.

Over the past few years several members of the Department have taken to the Bright Club stage to try their hand at stand-up comedy. The list of performers covers all research groups and includes PhD students, researchers and academics.

> Take some sociable, but awkward researchers and place them on a stage in front of a paying audience expecting to have a good time.

London Bright Club events take place monthly, usually in the cosy environment of an Islington comedy club. Each event attempts to draw researchers from across UCL to discuss their research on themes such as 'Life', 'Lust', 'Presents', or 'Big'. However the theme is somewhat open to interpretation, for example during the 'Big' theme night, **Professor Jon Butterworth** spoke about the Large Hadron Collider (the largest particle physics experiment ever built), whilst **Dr Ryan Nichol** spoke about the neutrino ("the most tiny quantity of reality ever imagined by a human being").

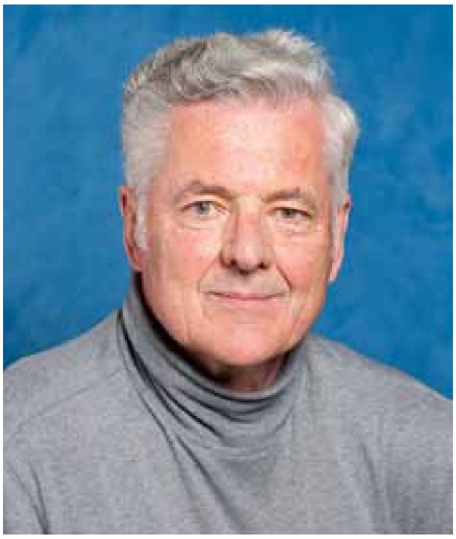
So why are physicists so keen on performing on the Bright Club stage? The top three reasons given were:

- It is a great opportunity to explain exciting research to a new audience in an unusual setting.
- It is fascinating to find some of the other excellent research that is taking place at UCL, outside of the Physics and Astronomy department.
- It is a unique opportunity to freely express views on a subject, such as the utility (or lack thereof) of string theory and string theorists.

Further information about Bright Club can be found at www.brightclub.org

Alumni Matters

by Professor Tegid Wyn Jones



On Friday 25 October 2013, the Department will host its first Gala Dinner...

During the past five years I have organised six alumni dinners and it is a pleasure to report that the last one was held on 4 May 2012 and attended by 38 alumni, the highest attendance to date.

We were addressed by the distinguished physicist, Prof. Cyril Hilsum CBE, FRS, FREng, Hon FinsP who graduated from UCL in 1945, some three years before Mr Frank Warren, who has faithfully attended the Alumni dinner every year. In an enthralling speech, Cyril began his UCL degree in Bangor, North Wales where the UCL Physics Department had been evacuated to during the Second World War. He described how intensive physics studies in the dark days of war were enlivened by interaction with the local Welsh lasses and star roles in various theatrical experiences!

As I outlined at last year's event, the arrangement for the alumni dinner has now changed; on Friday 25 October 2013, the Department will host its first Gala Dinner. The event will start with a drinks reception and student prize giving ceremony, followed by a three course meal. Students, parents, staff and alumni are all invited and I hope that many of you will be able to join me in what I am sure will prove to be an enjoyable evening.

The Gala Dinner will conclude with an after dinner speech by UCL alumnus Charlotte Nichol (née Waterhouse). Charlotte graduated from the Department with an MSci Physics degree in 2000. She has had a distinguished career as a physics teacher in an inner London school and is now Deputy Head of St Augustine's School in Kilburn. Charlotte still teaches A-level Physics and is married to **Dr Ryan Nichol**, a fellow alumnus who graduated in the same year as Charlotte, and is now a Reader in the UCL High Energy Physics Group.

Further details about the dinner are given in the enclosed invitation letter.

In Memoriam

Professor Tom Duke (1964 – 2012)

It is with deep regret that Physics and Astronomy announces the death of Professor Tom Duke. Tom had been Deputy Director for Biomedicine at UCL in the London Centre for Nanotechnology since October 2007, and was one of the outstanding biological physicists of his generation. He provided distinguished leadership to the LCN's research in biomedicine and continued his own research at a high level, winning the Franklin Medal and Prize of the Institute of Physics in 2010, as well as being a successful and popular teacher in UCL Physics and Astronomy.

As recently as April 2012, he and UCL colleagues published an important breakthrough in Nature, modelling the competition between different processes in the formation of stable cell layers (epithelia). He was universally admired for his penetrating and creative intellect, coupled with a deep knowledge of physics and mathematics; for his ability to get to the heart of the complex physics underlying a biological process, and solve a simple model to explain it; and for his generous and selfless devotion to his junior colleagues. He will be very deeply missed.

The Biological Physics section of this Review focusses on Tom's research in further detail (page 27).

by **Professor Andrew Fisher**

Academic Showcase

Staff Accolades

Europhysics Prize

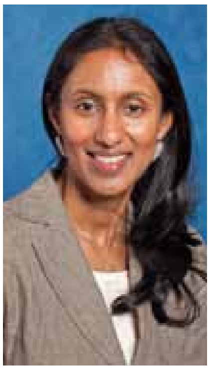
Professor Steven Bramwell

"[F]or the prediction and experimental observation of magnetic monopoles in spin ice."

Institute of Physics (IOP): Maxwell Medal and Prize

Dr Meera Parish

"For her pioneering work in the theory of cold fermionic matter and magnetotransport in highly disordered media."



Royal Astronomical Society (RAS): Fowler Prize for Early Achievement in Astronomy

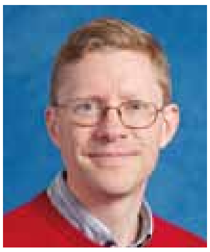
Dr Hiranya Peiris

"[I]n recognition of her particularly noteworthy contribution to astronomy at an early stage of her research career." &

Co-recipient of the Gruber Cosmology Prize

Awarded to Charles L. Bennett and the Wilkinson Microwave Anisotropy Probe Science Team, including Dr Hiranya Peiris

"[F]or their exquisite measurements of anisotropies in the relic radiation from the Big Bang---the Cosmic Microwave Background. These measurements have helped to secure rigorous constraints on the origin, content, age, and geometry of the Universe, transforming our current paradigm of structure formation from appealing scenario into precise science."



UCL Departmental Teaching Award

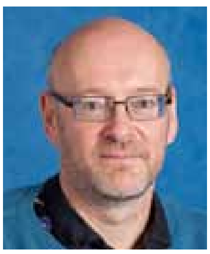
Dr David Bowler

Determined by student nominations, the Departmental Teaching Prize is awarded annually to a member of staff for their outstanding teaching.

UCL Provost's Teaching Award

Dr Paul Bartlett

The Provost's Teaching Awards were set up to celebrate the best of pedagogic prowess at UCL and to reward staff who are making outstanding contributions to the learning experience and success of our students.



UCL Business Award 'One to Watch'

Professor Neal Skipper and Dr Chris Howard

"Their process could help unlock the huge commercial potential of carbon nanotubes by providing a means to separate semiconducting tubes from metallic."

Headline Research

Ground-breaking EMMA results could revolutionise cancer therapy

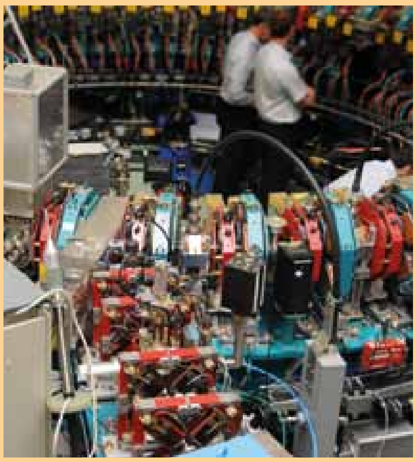
Acceleration in the linear non-scaling fixed-field alternating-gradient accelerator EMMA

R. D'Arcy and co-workers,
Nature Physics, 8, 243–247 (2012)

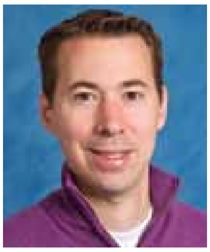
The Electron Model for Many Applications (EMMA) is a prototype for a new particle accelerator which has the potential to revolutionise the use of such accelerators. This paper reports the first experimental results from EMMA, confirming the principle underlying its technology.

Particle accelerators have already had a profound beneficial impact upon society and boast a wide range of applications in industry, medicine and basic science, such as the development of the MRI and X-rays. However they currently operate on principles developed over 50 years ago and their potential is limited by their size, complexity and cost.

EMMA is based on innovative concepts, resulting in a compact, cost effective and operationally simpler accelerator. It is hoped that in this new technology will allow hospitals to implement more effective forms of beam therapy to help cure some of the most difficult cancers such as radiation-resistant, or awkwardly sited tumours.

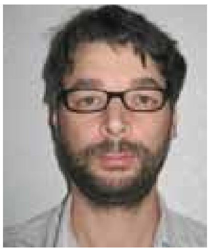


Academic Appointments



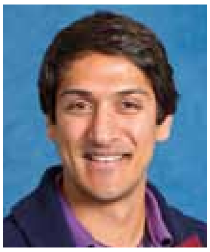
Dr Mark Buitelaar

Lecturer joining the CMMP group, previously based at the University of Cambridge



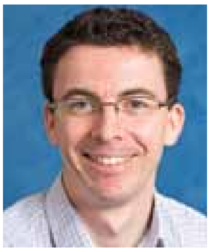
Dr David Cassidy

Lecturer joining the AMOPP group, previously based at the University of California



Dr Chamkaur Ghag

Lecturer joining the HEP group, previously based at the University of California



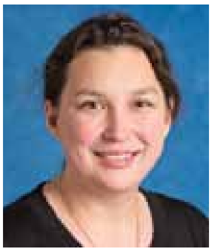
Dr Stephen Hogan

Lecturer joining the AMOPP group, previously based at ETH Zurich

Dr Steven Schofield

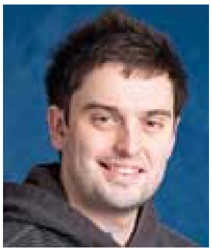
Lecturer joining the CMMP group, previously the holder of an EPSRC Career Acceleration Fellowship based at UCL

Long term Fellowships



Dr Anna Holin

Royal Society Dorothy Hodgkin Fellowship



Dr Andrew Pilkington

Royal Society University Research Fellowship

Promotions

Professorships

Professor Jonathan Oppenheim

Professor Serena Viti

Readerships

Dr Hiranya Peiris

Dr Peter Sushko

Resignations

Dr Sarah Bridle,

to take up a Professorship position at Manchester University

Fellowships of Learned Societies

American Academy of Arts & Sciences

Professor Gabriel Aeppli

European Astronomical Society

Professor Serena Viti

Royal Astronomical Society

Dr Frederick Poidevin

Portrait of…

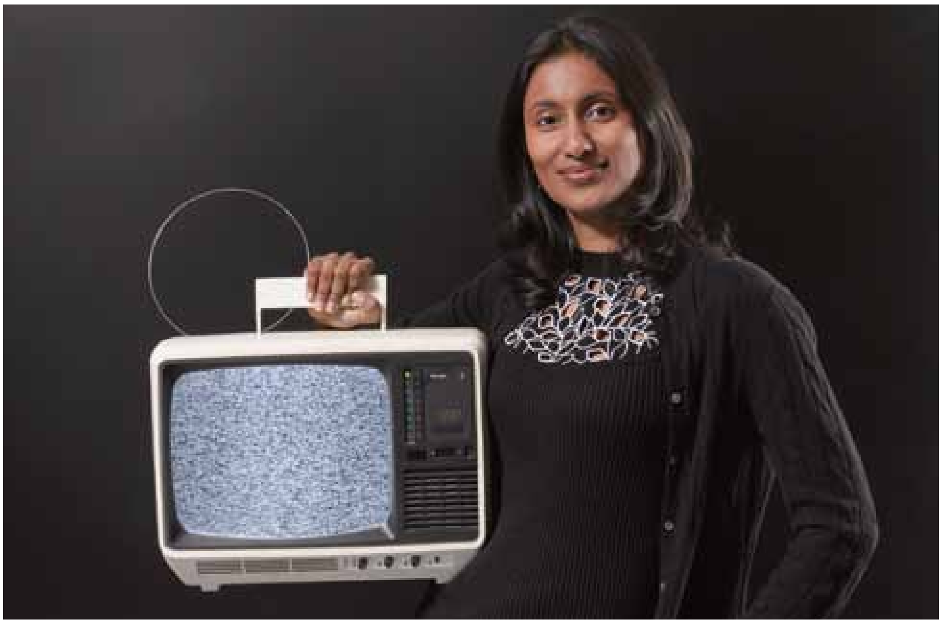
Dr Hiranya Peiris

"The first principle is that you must not fool yourself – and you are the easiest person to fool..." (Richard Feynman); avoiding this pitfall is one of the fundamental problems that will be encountered by the CosmicDawn project, due to start in January 2013. Led by **Dr Hiranya Peiris**, the CosmicDawn project is supported by the European Research Council (ERC) and will focus on studying the physics of the early universe, aiming to uncover the origin of the structure we see in the universe today.

2012 has been an eventful year for Hiranya; in addition to being awarded over £1million to head the CosmicDawn project, Hiranya has also been promoted to a Readership position at UCL and honoured with a Royal Astronomical Society (RAS) award. She was also a co-recipient of the 2012 Gruber Cosmology Prize (page 13).

> Innovative methodology will be used to analyse enormous volumes of data and isolate important physical signals from the latest CMB and LSS datasets.

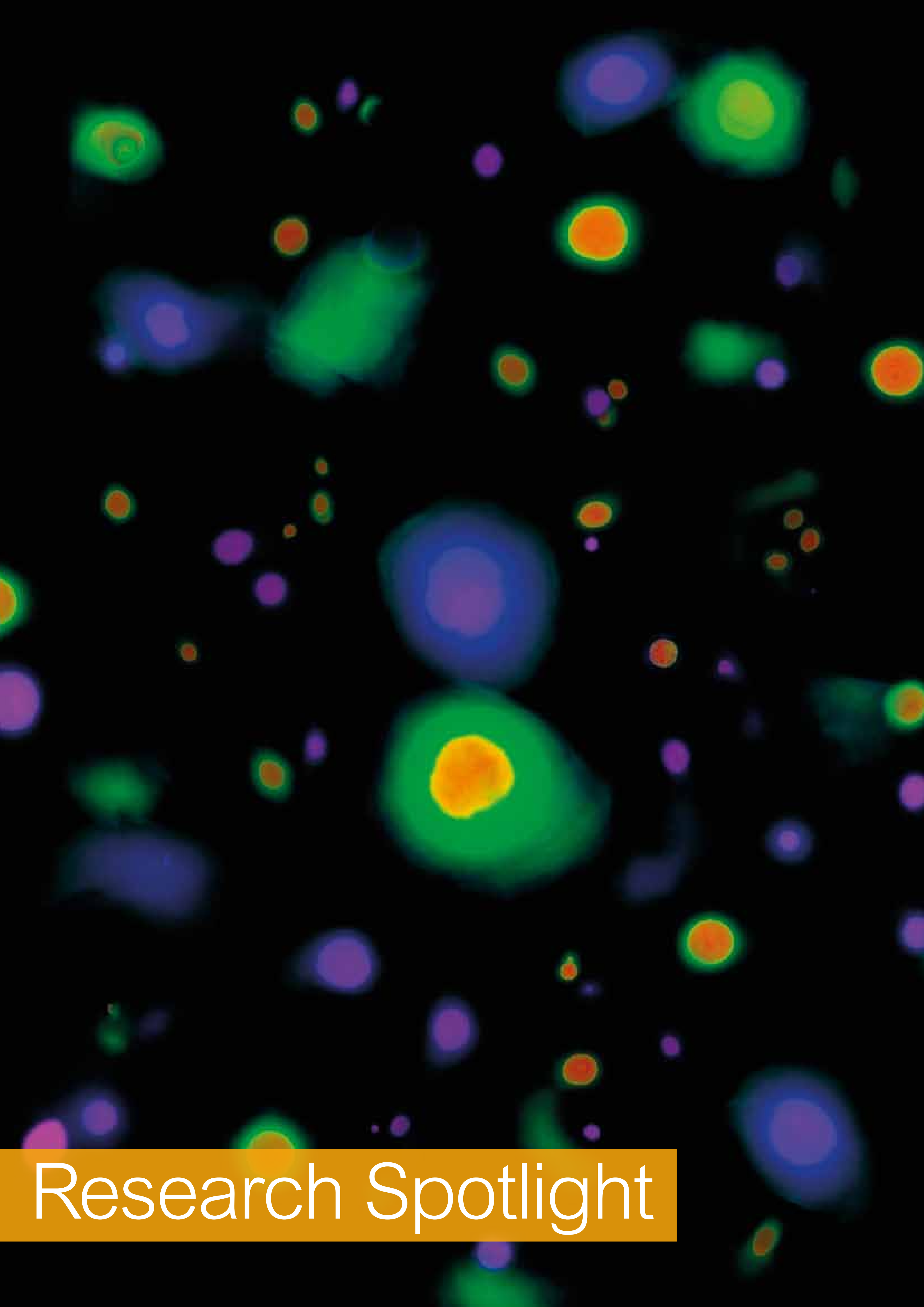
So where did it all begin? As an undergraduate at the University of Cambridge, it was Hiranya's summer work experience at the Jet Propulsion Laboratory which played a pivotal role in her chosen career path. Using the Galileo satellite to observe Jupiter, "studying things that no human eye had ever seen before" captured Hiranya's imagination and helped steer her towards a career in Astrophysics. Hiranya's PhD research was undertaken at Princeton University and helped to focus her specialisation in



the very early universe. Using data from the Wilkinson Microwave Anisotropy Probe (WMAP) spacecraft, Hiranya studied the cosmic microwave background radiation (CMB) and describes the first release of results as a pivotal event in cosmology and an "amazing time" which so far, has been the highlight of her career.

The CMB is a picture of the universe when it was less than 0.01% of its present age. It carries the almost unblemished signature of primordial fluctuations in the very early universe which, under the action of gravitational instability, grew into the variety of structures which fill the universe today. In addition to CMB data, the next generation of galaxy surveys such as the Dark Energy Survey (DES) (page 19), will enhance our understanding of the early universe. Galaxy surveys reveal the large scale structure (LSS) of the universe, by sampling different physical scales, at different epochs in the history of the universe.

CosmicDawn will study the physics of the early universe and how its structure originated. Central to its success will be the innovative methodology used to analyse enormous volumes of data, and isolate important physical signals from the latest CMB and LSS datasets. Theoretical modelling will be combined with advanced Bayesian and wavelet methods to extract reliable information from the data. The project will aim to rigorously test the theory of inflation; an integral part of the Standard Cosmological Model, and the dominant paradigm for the origin of cosmic structure – as well as seeking signatures of new physics that are likely to exist at these unexplored energies. As technology progresses, there is an urgent need to develop algorithms which can cope with the vast and diverse amounts of data to isolate interesting signals. Looking beyond the CosmicDawn project, Hiranya hopes to be able to apply this data analysis methodology further afield, in areas such as high performance computing and signal processing. In the meantime, the next five years should prove to be an exciting time, not just for astrophysics but for science as whole.



Research Spotlight

High Energy Physics (HEP)

Project in Focus

The ATLAS experiment at the Large Hadron Collider

Aim

To investigate some of the most fundamental questions in nature and to shed light into the first moments in the lifetime of our universe, right after the Big Bang.

Results

The discovery of a Higgs boson, nearly half a century after the Higgs particle was postulated theoretically! In addition, over 200 publications with measurements of Standard Model processes and searches for new physics, at the highest energies ever achieved by mankind.

UCL Involvement

Leading role in the detector operation, online event selection and offline reconstruction and simulation software; key involvement in the ongoing data analyses to determine the properties of the newly discovered Higgs particle, as well as leading the studies of several important Standard Model processes.

High energy particle physics is about looking at extremely small sizes or, equivalently, at extremely high energies. It is concerned with the underlying nature and foundations of the entire physical universe, as well as the forces and laws that govern its development.

The search for the Higgs boson has been the flagship research topic for CERN's Large Hadron Collider (LHC), and the discovery of a Higgs particle in 2012, by the ATLAS and CMS experiments represents a triumph of human intellect; both in terms of the theoretical ingenuity to postulate the existence of the Higgs boson nearly half a century ago, and in terms of the experimental challenges that had to be overcome to make the discovery. **Professor Nikos Konstantinidis** has been a member of the ATLAS collaboration since 2000 and played a major role in the development and optimisation of the ATLAS Trigger system. He describes below, the significance of the Higgs discovery, as well as future plans for the LHC.

The cornerstone of the Standard Model (SM)

Imagine a universe where all fundamental particles have absolutely zero mass. Electrons, like all massless particles, move with the speed of light, hence they cannot easily stick around protons to form atoms. Then, in a moment, everything changes. A symmetry is broken (hidden, in fact) and most particles slow down, they suddenly acquire mass because they 'feel the drag' of something, a field. Different types of particles acquire diverse masses because they experience a varying strength of the drag from this field. Electrons start to orbit around protons and nuclei, forming atoms and molecules, allowing chemistry and, ultimately biology to happen.

This oversimplified description in a few lines shows the profound implications that the Higgs field and its quantum, the Higgs boson, have for the evolution of our universe and the creation of structure and life itself, as we see it today. It is therefore no surprise that the Higgs boson has been named the cornerstone of the Standard Model (SM) (the theory that describes all the fundamental particles and their interactions), the Holy Grail of Particle Physics and even (slightly unfortunately!) the God particle.

> During the 2012 LHC operation, nearly half a billion proton-proton collisions were taking place every second.

The Standard Model predicts all properties of the Higgs boson, except for its mass, mH. However, for a given mH assumption, the SM predicts in detail how the Higgs would be produced (and with what frequency) in the proton-proton collisions at the LHC and how it decays. Figure 1 shows the so-called branching ratios, i.e. what fraction of the time the Higgs decays to a given set of particles, as a function of mH. Despite 'knowing what to look for', the search for the Higgs at the LHC was extremely challenging, because the chances of producing it in a given collision are tiny. During the 2012 LHC operation, nearly half a billion proton-proton collisions were taking place every second in the centre of the ATLAS detector, but only a handful of collisions per day would lead to the production of the Higgs particle that appeared in the ATLAS Higgs discovery plots! In fact, one of the greatest challenges for ATLAS was to be able to select in real time (online) the most interesting handful of collision events in every million, as it is technically impossible to record everything. The system that performs this online event selection is called the Trigger, and the UCL-ATLAS group has been playing a leading role in optimizing the ATLAS Trigger in order to select online the most interesting events and amongst them, hopefully, those where the Higgs particle was produced. The recorded events are then processed offline by dedicated analysis software looking to identify the Higgs decay products in the various parts of the ATLAS detector and to combine them to reproduce the original particle.

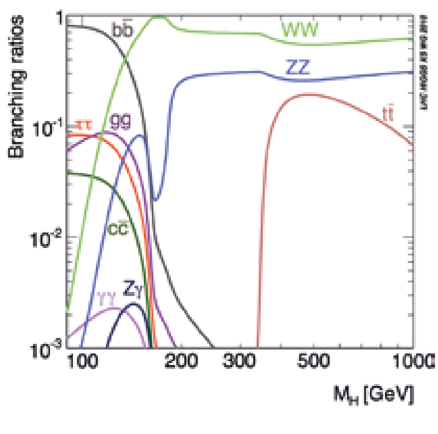


Figure 1. The branching ratios (probabilities) for the various Higgs decay modes as a function of the Higgs mass.

Figure 2 shows the results of the analysis searching for the Higgs decays to two photons. There is a huge number of events containing two isolated, energetic photons coming from various SM processes, but when combined they give a smoothly falling mass distribution. The small bump visible around 125GeV in the di-photon mass spectrum is due to the newly discovered particle.

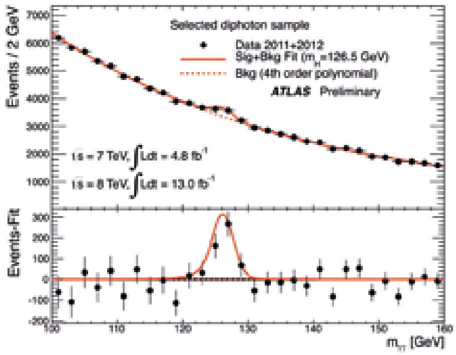


Figure 2. The two-photon invariant mass distribution in the search for H→γγ, showing the bump around 125GeV over the expected smooth background shape. The bottom histogram shows the difference between the data distribution and the background-only expectation (as indicated by the dashed red line in the upper histogram).

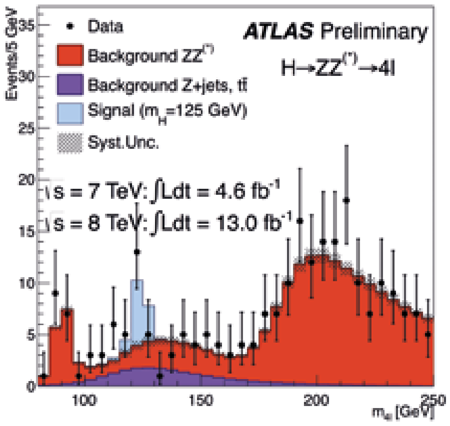


Figure 3. The four-lepton invariant mass in the H→ZZ→4e leptons search, showing the excess of events around 125GeV over the expected background. The light blue histogram shows the expected Higgs contribution in the simulation.

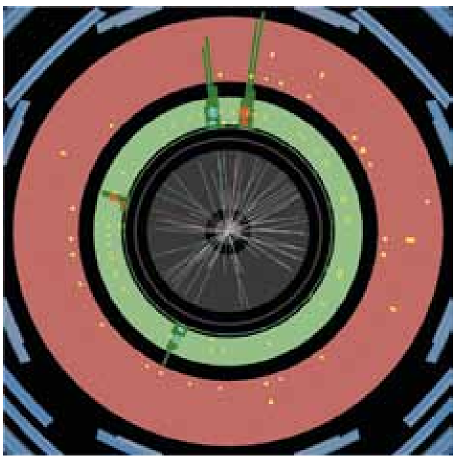


Figure 4. An ATLAS collision event containing a H→ZZ→4e candidate.

A similar bump, consistent with figure 2, is seen again around 125GeV in figure 3. This shows the invariant mass distribution of four leptons in events selected by the analysis looking for the decays of the Higgs into two Z bosons, each of which subsequently decays to a pair of leptons (electrons or muons). One such event is displayed in figure 4. Putting together these observations and the results from analyses looking for the other Higgs decay channels, the chances that the observed bumps are just random fluctuations are smaller than one-in-a-million, signifying therefore the unequivocal discovery of a new particle!

Despite the certainty for the discovery of a new boson, and all the indications that it has many similarities with what we had been looking for in the searches for the Higgs boson, the jury is still out as to whether the properties of the newly discovered boson are consistent with all the properties predicted by the SM for the Higgs boson. A very intense and exciting programme of work is now underway in ATLAS to maximise the sensitivity of the analyses and extract as much information as possible from the collisions collected so far about the properties of the newly discovered boson, before calling it definitively the Higgs boson. In particular, with the data analysed so far there is not enough sensitivity to observe and study the boson's decays to fermions (specifically to a pair of b-quarks or tau leptons), which is a very important check of the SM prediction for the Higgs. UCL-ATLAS is heavily involved in the work to observe and study in detail the decays to b-quarks and the projections indicate that by the end of 2013, after optimising and analysing the full 2012 dataset, this will be possible.

In 2013–14, the LHC equipment will undergo technical upgrades that will allow it to go to nearly double the beam energies (to 6.5-7TeV from 4TeV in 2012) and increase further the rate of collisions when it restarts operations in 2015. Beyond that, there is a long-term plan for upgrades that will see the LHC delivering 100 times more collisions than to date, with a rate exceeding five billion proton-proton collisions per second! This is a programme that will last for at least another two decades and will allow the thorough exploration of the high-energy frontier in the multi-TeV region, as well as the observation of rare processes involving the Higgs boson, such as the process where the Higgs boson interacts with itself. These studies will help scientists achieve an unprecedented level of understanding of nature at the most fundamental level. In order for ATLAS to maintain its sensitivity and exploit optimally the data delivered by the LHC upgrades, it also requires major upgrades to its sub-systems. UCL-ATLAS has been playing a key role in the ATLAS upgrades programme, leading the work to define the optimal Trigger strategy for the future, which is expected to be one of the most major challenges for achieving the optimal performance.

The chances that the observed bumps are just random fluctuations are smaller than one-in-a-million, signifying therefore the unequivocal discovery of a new particle!

Major breakthrough in the neutrino sector – the θ_{13} angle

Although the LHC and the Higgs discovery dominated the particle physics headlines, 2012 saw another major discovery, this time in the neutrino sector. The angle θ_{13}, a key parameter in describing the mixing between the flavour and mass states of the three neutrino families, was measured for the first time to be non-zero, 9 degrees to be precise. This is a major breakthrough, because a non-zero value of this parameter opens up the way for significant CP-violation in the neutrino section, which in turn may contribute in explaining the huge matter-antimatter asymmetry in our universe. This result has given a major boost in the neutrino sector, for experiments that will pin down more of the neutrino properties. UCL is at the forefront of this research, leading the SuperNEMO and MINOS+ experiments, and playing a major role in defining the international research programme in neutrino physics.

Astrophysics (Astro)

The UCL Astrophysics Group is one of the largest in the UK, consisting of 67 academic, research and support staff, along with 37 PhD students. The work carried out is diverse; ranging from instrumentation to data acquisition and analysis, as well as theoretical modeling, in the fields of massive stars, star formation, interstellar and circumstellar processes, astrochemistry, cosmology, galaxy formation and evolution, extra-solar planets, and atmospheric physics.

> DES will conduct the largest galaxy survey ever undertaken, producing detailed colour images of one-eighth of the sky.

Group members play leadership roles in a number of high-profile international projects such as the Dark Energy Survey (DES) and e-MERLIN, the Herschel and Planck space missions, and proposed/forthcoming missions such as the Euclid cosmology mission, the Jupiter Icy Moon Explorer (JUICE) and Exoplanet Characterisation Observatory (EChO). 2012 has been a particularly exciting year for the DES team, with the camera now operational and detecting its 'first light' in September, **Professor Ofer Lahav** explains the significance of this.

The Dark Energy Survey (DES)

The Nobel Prize in Physics 2011 was awarded to three astronomers "for the discovery of the accelerating expansion of the Universe through observations of distant supernovae". More generally, observations over the past decade strongly favour a 'concordance' model in which the Universe is flat and contains approximately 4% ordinary atomic matter, 21% Cold Dark Matter and 75% Dark Energy. The Dark Energy paradigm and its extensions pose fundamental questions about the origins of the Universe: is Dark Energy an actual ingredient, or should Einstein's gravity theory be modified?

The Dark Energy Survey (DES) is a photometric survey of the Southern sky that aims to answer key questions about the nature of Dark Energy and the structure of the Universe. The recently installed, wide-field Dark Energy Camera will be used to conduct the survey from the Blanco Telescope in Chile.

Over the next five years, DES will conduct the largest galaxy survey ever undertaken, producing detailed colour images of one-eighth of the sky, or 5,000 square degrees. DES scientists aim to discover and measure 300 million galaxies, 100,000 galaxy clusters, and 4,000 supernovae. The data will then be used to study four probes of Dark Energy: galaxy clusters, supernovae, the large-scale clumping of galaxies, and weak gravitational lensing. This will be the first time all four of these methods will be possible in a single experiment.

DES has brought together cosmologists and instrumentation experts from five countries: the US, UK, Spain, Brazil, Germany and Switzerland. The DES:UK Consortium includes UCL, Portsmouth, Cambridge, Nottingham, Sussex and Edinburgh, with UCL astronomers playing leading roles in the project; **Professor Ofer Lahav** is chair of the DES Science Committee and the DES:UK consortium, Dr Sarah Bridle is Co-Coordinator of the DES Weak Lensing Working Group and **Dr Filipe Abdalla** is Co-Lead of the DES Spectroscopic Task Force. In addition, over a dozen UCL post-doctoral researchers and PhD students are working on the project.

DES instrumentation

The UCL Astrophysics Instrumentation group has made a significant contribution to the Dark Energy Survey project through the construction of the optical corrector for the survey camera. The Dark Energy Camera (DECam) is a 570-megapixel wide field camera, mounted on the 4-m Blanco telescope at the Cerro Tololo Inter-American Observatory (CTIO) in Chile.

Dr Peter Doel, **Dr David Brooks** and their associates at UCL have led the effort on designing and constructing the optical corrector, a major component of the camera which took several years to complete. The corrector consists of an array of five large lenses which sit at the primary focus of the camera, with the principle lens measuring one metre across. To ensure a high degree of accuracy, the lenses are aligned to within 50 microns-this is equivalent to half the thickness of a sheet of paper and enables the camera to produce high resolution images over an extremely wide field.

> The assembly of the five lenses for DECam and its installation on the telescope was a major technological achievement, producing one of the largest cameras on the globe.

DECam is roughly the size of a phone booth and is the most powerful survey instrument of its kind, able to see light from over 100,000 galaxies up to 8 billion light years away in each snapshot. The camera has an array of 62 charge-coupled devices which provides an unprecedented sensitivity to very red light. When coupled with the Blanco telescope's large light-gathering mirror (spanning 13 feet across),

Project in Focus

The Dark Energy Survey (DES)

Aim
To observe and characterise the nature of dark energy.

Results to Date
DES achieved 'first light' on 12 September 2012, followed by verification of observations. Two supernovae have already been discovered.

UCL Involvement
The optics systems for the Dark Energy Camera were assembled at UCL before being installed on the Blanco 4-m telescope in Chile. UCL cosmologists are leading the analysis of data from the telescope and simulations.

Figure 1. Dr David Brooks and PhD student Michelle Antonik, with the DECam corrector lens.

Figure 2. DES Optical Corrector in the lab, overseen by (foreground, l-r) lead instrument scientist, Dr Peter Doel,; UCL President and Provost, Professor Malcolm Grant and DES:UK chair, Professor Ofer Lahav.

DECam allows scientists from around the world to pursue investigations ranging from studies of asteroids in our own solar system to the understanding of the origins and the fate of the Universe.

The assembly of the five lenses for DECam and its installation on the telescope was a major technological achievement, producing one of the largest cameras on the globe. It was shipped from London to the telescope in Chile in December 2011 and installation on the telescope was completed in August 2012.

First light and dedication ceremony

On 12 September 2012, 8 years of preparation culminated in the DES camera detecting its 'first light'. The first pictures taken were of the Southern sky and included the barred spiral galaxy NGC 1365 in the Fornax cluster of galaxies (figure 3).

This important milestone was celebrated on the 9 November 2012 with a ceremony at the summit of Cerro Tololo, Chile.

The event marked the dedication of the Dark Energy Camera and the beginning of the 50th anniversary celebration of the CTIO, a division of the National Optical Astronomy Observatory (NOAO). Speakers included Professor David Silva (NOAO Director), Professor Joshua Frieman (Director of the Dark Energy Survey) and **Professor Ofer Lahav** (UCL). Professor Lahav's talk focused upon the international perspective of DES, on behalf of the non-US partners: the UK, Spain, Brazil, Germany and Switzerland.

Once the camera has been fully tested and data verified, the Dark Energy Survey is expected to begin in 2013. It will take advantage of the excellent atmospheric conditions in the Chilean Andes and deliver pictures with the sharpest resolution ever seen in such a wide-field astronomy survey. Two supernovae have already been discovered.

In addition to funding from the Science and Technology Facilities Council (STFC) Consolidated Grant, the DES work at UCL is also supported by grants held by Dr Sarah Bridle (ERC Starting Grant, awarded April 2010), **Professor Ofer Lahav** (ERC Advanced Grant, awarded May 2012) and **Dr Hiranya Peiris** (ERC Starting Grant, awarded January 2013). DES also receives funding from the U.S. Department of Energy; the National Science Foundation; and funding agencies in Spain, Brazil, Germany, and Switzerland; and the participating DES institutions.

Figure 3. Zoomed-in 'First Light' image from the Dark Energy Camera of the barred spiral galaxy NGC 1365. This galaxy lies in the Fornax cluster of galaxies, about 60 million light years from Earth.

Figure 4. Dark Energy Camera Dedication at the Cerro Tololo Inter-American Observatory with DES members (9 November 2012).

Condensed Matter and Materials Physics (CMMP)

Research within the CMMP group spans a wide spectrum of subjects, ranging from the theoretical and experimental components of imaging at the atomic scale, to understanding the extreme environment of the Earth's deep interior. Currently the group is comprised of roughly 90 members, making it one of the largest condensed matter groups in the UK.

Qubits have the intriguing ability of existing in a superposition of states, this has profound implications if we consider quantum systems of more than one qubit.

One particular area of interest is the creation of nano- and atomic-scale structures that can be used as buildings blocks for novel quantum devices. A notable example is the quantum computer, which is able to perform computational tasks that are unattainable in a classical context. The elementary unit of information in a quantum computer is the quantum bit or qubit which, like the classical bit, is a two-level system but with the intriguing ability to exist in a superposition of states. This means it can be in the on and off state at the same time which has profound implications if we consider quantum systems of more than one qubit. Instead of each qubit carrying any well-defined information of its own, the information is encoded in their joint properties. In quantum mechanics, the qubits are described as being entangled. **Dr Mark Buitelaar** and **Dr Steven Schofield** describe below the challenges in finding ways to harness quantum phenomena such as superposition and entanglement and the creation and understanding of nano- and atomic-scale quantum devices.

Reading out spin qubits in carbon nanotubes

A very natural qubit is the electron spin. The energy difference between spin states of an electron can be precisely controlled by magnetic fields and, using the electron's charge, it is also possible to isolate and manipulate individual spins electrically. **Dr Mark Buitelaar**'s research focusses on electrons trapped in carbon nanotube quantum dots. These consist of small sections of carbon nanotube in which the electrons are confined in all three dimensions, see figure 1. Compared to other materials, carbon nanotubes have the advantage of a very clean spin environment, due to the absence of unpaired nuclear spins in the dominant carbon-12 isotope. As a result, the important quantum superposition states are expected to survive much longer, making it possible to perform more computing operations on entangled spin qubits.

The current challenge lies in reading out a single electron spin due to the minuscule magnetic moment. For example, conventional electron-spin-resonance (ESR) spectroscopy requires about 10^{10} spins to move in sync to obtain measurable signal-to-noise ratios. As readout of the state of a single spin is required, it is necessary to improve on this by ten orders of magnitude! A solution is found by coupling two quantum dots in series and probing the ability of the electrons to move between the quantum dots. This spin-to-charge conversion process is illustrated in figure 1b. Two electrons, each on a separate quantum dot, can readily form a spin singlet or triplet. However, two electrons on a single quantum dot, occupying the same

Project in Focus

Physics at the nanoscale

Aim
To create and measure novel quantum systems and functional devices that exploit quantum effects.

Results
Manipulation of individual atoms and molecules and the creation of atomic-scale quantum systems. Spin to charge conversion and readout in quantum dots.

UCL Involvement
UCL has extensive facilities for researching nanoscale physics. These include a dilution refrigerator for mK transport experiments and three low-temperature ultrahigh-vacuum scanning tunnelling microscopes.

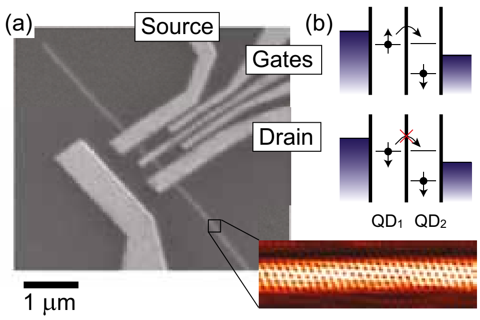


Figure 1. (a) Scanning electron micrograph of an individual carbon nanotube coupled to several metallic electrodes. The two sections in between the source and drain electrodes form a double quantum dot. The inset shows an atomically resolved scanning tunnelling image of a chiral carbon nanotube. The diameter is approximately 1.5 nm. (b) Schematic diagram of the double quantum dot. Tunnelling between the dots is allowed for electrons in a singlet state but forbidden for the triplets.

spatial orbital, have to form a spin singlet by virtue of the Pauli exclusion principle (electrons are fermions). Therefore, electron transport between the quantum dots is only allowed for the spin singlets.

Carbon nanotubes have the advantage of a very clean spin environment, making it possible to perform more computing operations on entangled spin qubits.

To detect the movement of individual electrons between the quantum dots, the device is coupled to an electrical resonator as illustrated in figure 2. The phase of a radio-frequency signal reflected off the device is a sensitive probe of the ability of the electrons to move in response to the oscillating potential and thus of the singlet and triplet states. Due to the resonator having a large bandwidth, measurement can also be very fast. This provides the tools to determine exactly how long spin coherence can be maintained in carbon nanotube quantum dots, and address fundamental questions about the coupling of electron spins to their environment.

Using spin-orbit interaction, which is relatively strong in carbon nanotubes, it should also be possible to manipulate spin states electrically and thus control individual qubits. Future work will explore routes to entangle multiple spin qubits, either by direct coupling or using a measurement-based approach.

Atomic-scale quantum structures on silicon

The atomic-scale modification of semiconductors is an important area of physics research. It holds the potential to produce devices that exploit quantum effects in ways that are not possible with current technology. This may, for example, lead to the construction of a quantum computer through the atomically precise positioning of individual impurity atoms in silicon. Another sought-after goal is the incorporation of molecular functionality with semiconductor devices. It is anticipated that this may enhance existing technologies or lead to novel devices with single molecules as the active elements.

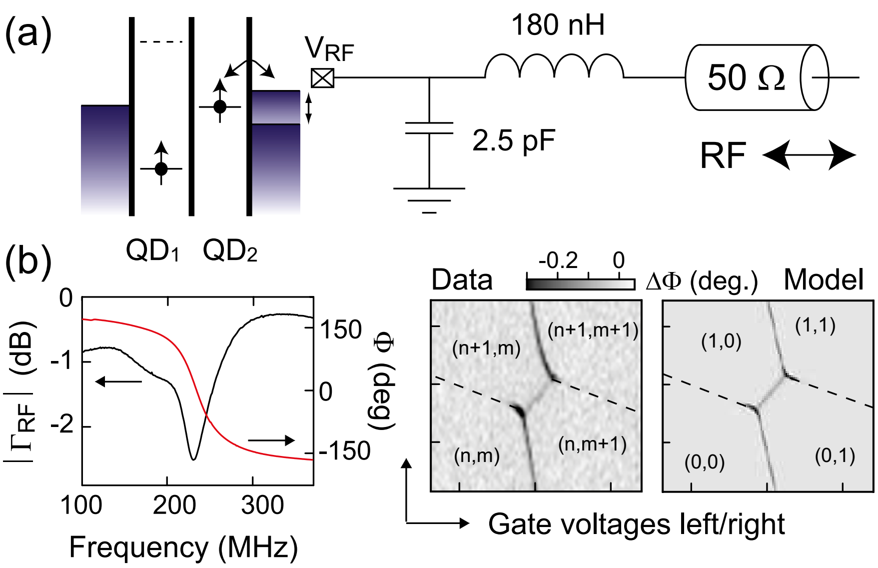


Figure 2. (a) Schematic diagram of the measurement set-up in which a double quantum dot is coupled to an electrical resonator (b) The phase and amplitude response of a reflected radio-frequency (RF) signal provide detailed information about the ability of electrons to move between the leads and quantum dots or from one quantum dot to the other. The device is measured at a temperature of ~50mK.

The scanning tunnelling microscope (STM) is a powerful tool for the investigation of physics at the nanoscale. It can be used to not only image surfaces with atomic-resolution, but also to directly manipulate individual atoms and molecules. An STM generates an image

The scanning tunnelling microscope (STM) can be used to not only image surfaces with atomic-resolution, but also to directly manipulate individual atoms and molecules.

by measuring a quantum mechanical tunnelling current between the surface and a metal probe tip, as the tip is raster scanned over the surface (figure 3a). An STM image of crystalline silicon is shown in figure 3b; each of the protrusions in this image are due to individual silicon atoms. It is also possible to measure the density of electronic states of a surface using STM by recording the tunnelling current as a function of the applied bias, as shown for a clean silicon surface in figure 3c.

At the STM laboratory in the London Centre for Nanotechnology (LCN), **Dr Steven Schofield** and co-workers are investigating the modification of semiconductor surfaces at the atomic scale. One avenue of research is to investigate the fundamental properties of the organic/semiconductor interface. Some recent STM data showing the adsorption of benzonitrile and acetophenone to the (001) surface of silicon are highlighted in figures 3d and 3e. The corresponding structural schematics (figures 3g and 3f) were determined in collaboration with density functional theory (DFT) calculations performed at the University of Sydney and the University of Newcastle, Australia. Significantly, it was found that the benzonitrile adsorbates could be repositioned by STM manipulation, and the dangling bonds (DBs) they produced in the surface were found to nucleate the growth of atomic indium chains (figures 3d and 3g).Such guided self-assembly of metal atoms by organic molecules presents a path toward the creation of single-atom wires and interconnects for future single-molecule devices (figures 3d and 3g).

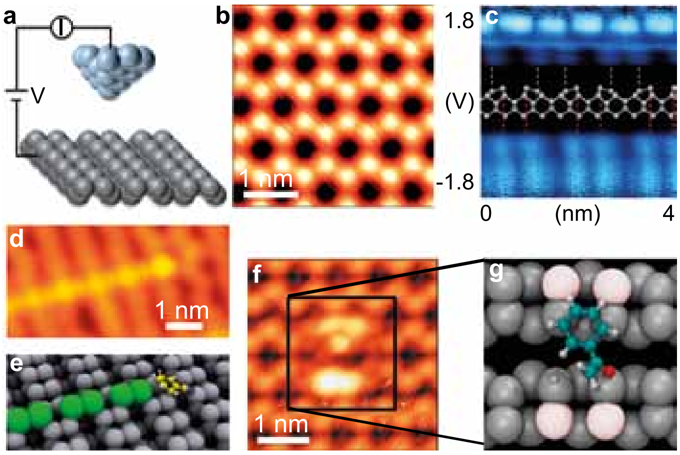


Figure 3. Organic molecular functionalisation of silicon (a) Schematic of a scanning tunnelling microscope. (b) Silicon (001) surface imaged at 77 K, and (c) measured with tunnelling spectroscopy. (d and e) Guided self-assembly of indium atom chains nucleated by benzonitrile molecules. (f and g) Acetophenone on silicon (001); the location of dangling bonds induced by the molecular adsorption are indicated by lightly coloured silicon atoms.

The creation of atomic-scale quantum states on silicon has been achieved using deterministically created point defects. Figure 4 highlights recent work where individual hydrogen atoms were removed one atom at a time from the surface of hydrogen-passivated silicon to create interacting quantum defects. Figures 4b and 4c show STM images of a pair of DBs spaced on next nearest neighbour lattice sites (figure 4a). By using the STM tip as an electrostatic gate to control which states contribute to the STM image, it was shown that the ground state wavefunctions of the individual DBs are non-interacting (figure 4b), but their first excited states overlap to form an artificial molecular orbital (figure 4c). This behaviour is similar to a recent theoretical proposal by UCL physicists to use the excited state molecular orbitals of systems of hydrogenic impurities in silicon to couple their non-interacting ground states for a silicon-based quantum computer. Figures 4d and 4f demonstrate the flexibility of the technique by extending the chain to six DBs

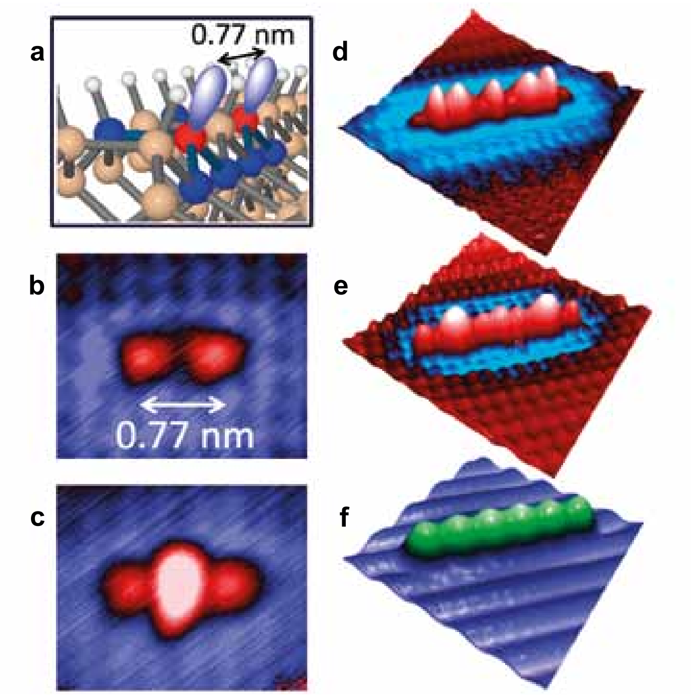


Figure 4. Atomic-scale quantum states fabricated on silicon. (a-c) A pair of dangling bonds (DBs) that have been created on hydrogen terminated silicon (001) by STM atomic manipulation. The DBs are on next-nearest neighbour lattice sites, separated by 0.77 nm. The tip bias and separation can be used as gates to control which states contribute to the image. Panel (b), +2 V, 95 pA, shows the ground state configuration of the DB pair, while panel (c) +2 V, 5 pA, shows an excited state molecular orbital of the DB pair. (d and f) Six DBs in a row spaced at next-nearest neighbour site (+1.8, +1.4, and -1.4 V, respectively; 15 pA).

Atomic, Molecular, Optical and Positron Physics (AMOPP)

The AMOPP group perform high precision measurements coupled with theoretical work, which are aimed at understanding and improving fundamental processes. The applications of this improved understanding can be applied to diverse areas such as the development and structure of the Universe, environmental change, and the behaviour of biological systems.

> Particles ranging in size from single atoms to a few microns are optically trapped and boast a range of applications including sensing and quantum information processing.

The trapping of particles is a major focus for a number of experimental research groups within the AMOPP group. Particles that range in size from single atoms to a few microns are trapped using optical, electric, magnetic or acoustic fields, for both fundamental science and applications in, for example, sensing and quantum information processing.

Magneto-optical trapping of atoms

The Laser Cooling Group, led by **Professor Ferruccio Renzoni**, uses cold atoms in optical traps to investigate different physical phenomena. The first area of interest is precision measurements, and in particular magnetometry. Using optical traps at the so-called 'magic wavelength', enables atoms to be trapped without altering their optical properties. In this way, trapped atoms may be used for extreme magnetometry, with a wide range of applications. In particular the Laser Cooling Group is investigating applications in the medical area, with a view to use atomic sensors for biomagnetism. A second area of interest is related to the investigation of fundamental processes in statistical mechanics. **Professor Renzoni**'s group has been successful in using cold atoms in optical lattices to investigate systems in which the dynamics are dominated by rare and large events and cannot be described in the framework of the standard Boltzmann-Gibbs statistical mechanics. The third area of research involves atoms confined within an optical cavity (figure 1). The cavity modifies the spectrum of the electromagnetic vacuum, thus changing the optical properties of the atoms ('cavity QED'). The Laser Cooling Group is currently investigating the case of multi-mode cavities and is expected to lead to interesting applications in quantum information.

Electric traps for atoms and molecules in highly excited states

For many applications of cold atoms and molecules it is desirable to trap samples, not only when they are prepared in their ground electronic states, but also when they are in highly excited states known as Rydberg states. Cold, trapped samples in Rydberg states are of importance in hybrid approaches to quantum

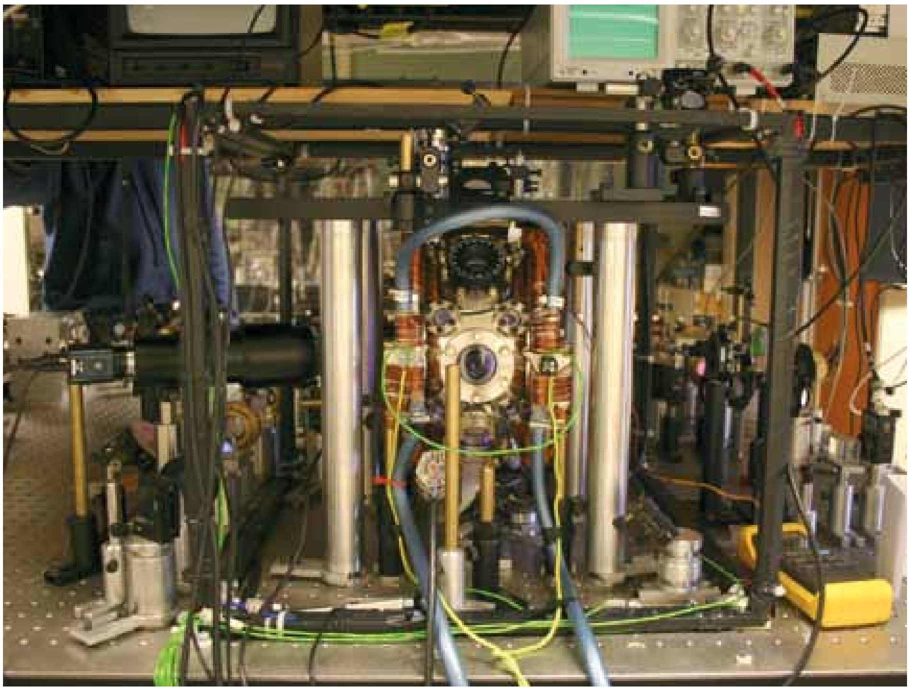


Figure 1. The cavity cooling experiment in the laboratory of the Laser Cooling Group

information processing, studies of low energy molecular collisions and interactions, and experiments with antihydrogen.

To trap atoms and molecules that are excited to Rydberg states, **Dr Stephen Hogan**'s group exploits their sensitivity to electric fields. This sensitivity is a consequence of the spatial separation of the negatively-charged, excited electron from the positively-charged ion to which it is bound, leading to the existence of a large electric dipole moment.

Dr Hogan uses chip-based electric traps composed of arrays of metallic wires integrated into surfaces as depicted in figure 2 (lower panel). By applying alternate positive and negative electric potentials to adjacent wires in the array the electric field distribution depicted in figure 2 (upper panel) can be generated. In this electric field distribution the electric field minima, indicated by the dark points ~0.8 mm above the surface represent electric traps for the excited atoms or molecules. If the potentials applied to each wire do not change with time, the traps will remain at the positions indicated. However, when the potentials oscillate in time, the traps will travel along the surface in the z-dimension, bringing with them the confined atoms or molecules. The speed at which the traps, and hence the trapped particles, travel can be varied by adjusting the frequency of oscillation of the electric potentials. This device can therefore not only be used to trap atoms and molecules in Rydberg states, but it can also be used as a conveyer belt to accelerate, decelerate and transport the trapped samples.

By combining electric traps of this kind with superconducting microwave circuits **Dr Hogan** plans to exploit trapped Rydberg atoms as quantum memories in a hybrid approach to quantum information processing.

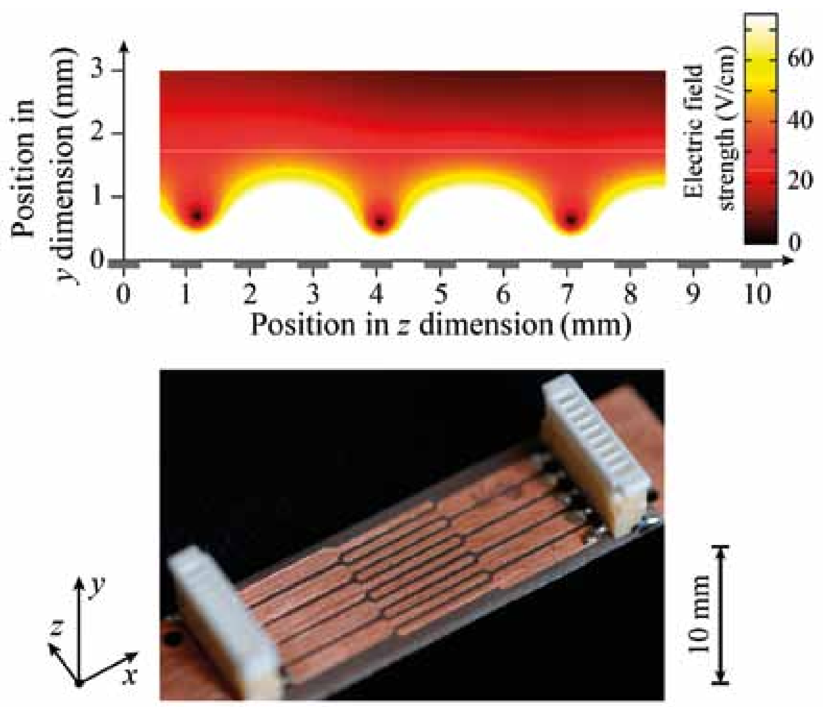


Figure 2. Photograph of a chip-based array of metallic wires (lower panel) which can be used to generate electric field distributions (upper panel) appropriate for electric trapping of samples in Rydberg states.

Project in Focus

Particle trapping

Aim
Trapping and manipulation of particles ranging from single atoms to microscopic material for fundamental science and applications.

Results
Significant results include models of non-equilibrium statistical mechanics, cavity cooling of 100nm size particles and optical trapping of graphene.

UCL Involvement
UCL has a number of research groups using optical, electrostatic, magnetic and acoustic fields for particle manipulation.

Optical and acoustic trapping of microscopic particles

The Optical Tweezers group led by **Dr Phil Jones** uses the force exerted by a single laser beam to trap micro and nanoscopic particles, including carbon nanotubes and graphene. In collaboration with the National Physical Laboratory, the group is presently developing an experiment to combine optical trapping with acoustic manipulation. The target objects for these experiments are microscopic gas bubbles, stabilised by a lipid or polymer coating and suspended in liquid, which are presently used as an agent for enhancing contrast in ultrasound scans. The method by which a coated bubble scatters ultrasound, in particular the frequency content of the scattered field depends on both the mechanical properties of the coating and the properties of the surrounding medium. The purpose of the project is to use optical forces to measure and characterise the coating in order to then use changes in the measured scattered ultrasound field to detect changes in the local environment. Calibrated in this way, the microbubble can be used as

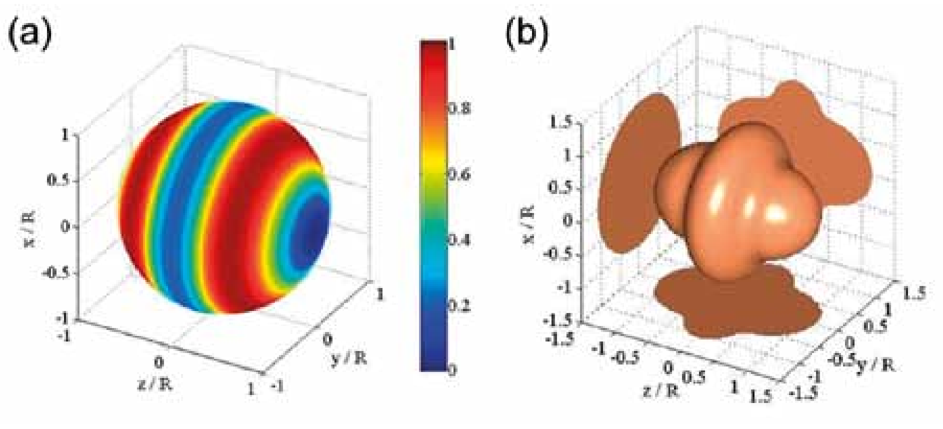


Figure 3. Calculated stress distribution on the surface of a microbubble in an optical trap and the resulting deformation.

a highly sensitive sensor for changes in its surroundings, for example the small change in density that might be indicative of a contaminant in biofuels. This year the group has modelled the way in which a microbubble may be deformed in an optical trap (figure 3) from which the stiffness of the coating material can be deduced. They are presently integrating the optical trap into a microfluidic device which will also have the facility for long-range manipulation and interrogation of microbubbles using ultrasound.

Optical and electrodynamic trapping in cavity optomechanics.

Professor Peter Barker's group seeks to determine whether nanoscopic and microscopic objects, which typically follow classical laws of physics, can be engineered to behave as quantum mechanical objects. By doing this they aim to explore the boundary between classical and quantum behaviour at this scale, and determine if such relatively large objects can be used as sensors of force, mass or length at their ultimate limit determined by quantum mechanics. An important step towards reaching the quantum regime is to cool these objects to very low temperatures in the microKelvin range. However this is difficult as they are in direct contact with the relatively hot environment of a vacuum chamber. Trapping with electromagnetic fields in vacuum offers a means to isolate particles allowing them to be cooled while minimising contact from with the environment. To do this the group are using both optical and ion traps to levitate silica (glass) particles, which range in size from 50 nm to 10 microns (figure 4). An important step towards reaching the quantum regime is the development of methods to cool the trapped particles. One method the group has developed uses an optical cavity to damp the motion of trapped particles in the 100 nm size range. However larger microspheres in excess of a few microns cannot be cooled by an external cavity.

> An important step towards reaching the quantum regime is the development of methods to cool the trapped particles.

For these particles, they have developed and are implementing a a type of Doppler cooling. This process is analogous to laser cooling of atoms and utilises the whispering gallery modes of the sphere.

Figure 4. A silica glass sphere held in an ion trap.

Biological Physics (BioP)

Project in Focus

The physics of hearing

In honour of the late Professor Tom Duke, this section describes one of his key contributions to the area of biological physics.

The BioP group is a virtual research group which aims to address critical biological questions using physical science research. The group forms a network between experimental and theoretical physicists from the different research groups in the Department, for whom biological problems are either the main focus and/or a significant application of their research activities.

> The physics of hearing was greatly enriched by the contribution of Professor Tom Duke (1964 – 2012)

Based in part on Professor Tom Duke's 'The power of hearing', Physics World (2002) and his lecture notes for the European School On Nanosciences & Nanotechnologies, Grenoble, **Dr Bart Hoogenboom** describes Professor Duke's work on the physics of hearing.

A choir for hearing

It is rumoured that, sometime in the early years of their curriculum, UCL physics students are exposed to the shrill sounds of a violin for an illustration of vibrations and waves. Interestingly, a violin is not only useful for mastering the concept of waves, but also for our understanding about how we hear them. For example, the 18th-century violinist Giuseppe Tartini remarked that the difference frequency $2 f_1–f_2$ can be heard when two notes with frequencies f_1 and f_2 are played simultaneously, even though that combination of frequencies is absent in the sound waves. The physics of hearing was greatly enriched by the contribution of Tom Duke (1964 – 2012), Professor at the London Centre for Nanotechnology and the Department of Physics and Astronomy at UCL.

Hearing is the most remarkable of our senses. It covers a frequency range from 20 Hz to an age-dependent upper limit of about 20 kHz. It can detect sounds that impart no more energy than thermal noise (4 zepto-Joule), and, most impressively, it responds and adapts over 12 orders of magnitude of intensity: the loudest noise our ears can meaningfully interpret is 1012 times the intensity of the softest noise to which it can respond.

Omitting the gory biological detail, the ear can be considered as a set of oscillators that each respond to a distinct frequency, not dissimilar to a harp in which strings of different lengths can be made to vibrate at different frequencies. Nature's main problem was how to design a harp that could deal equally well with very gentle (thermal vibrations) and with very rough handling, equivalent to blowing the harp to pieces.

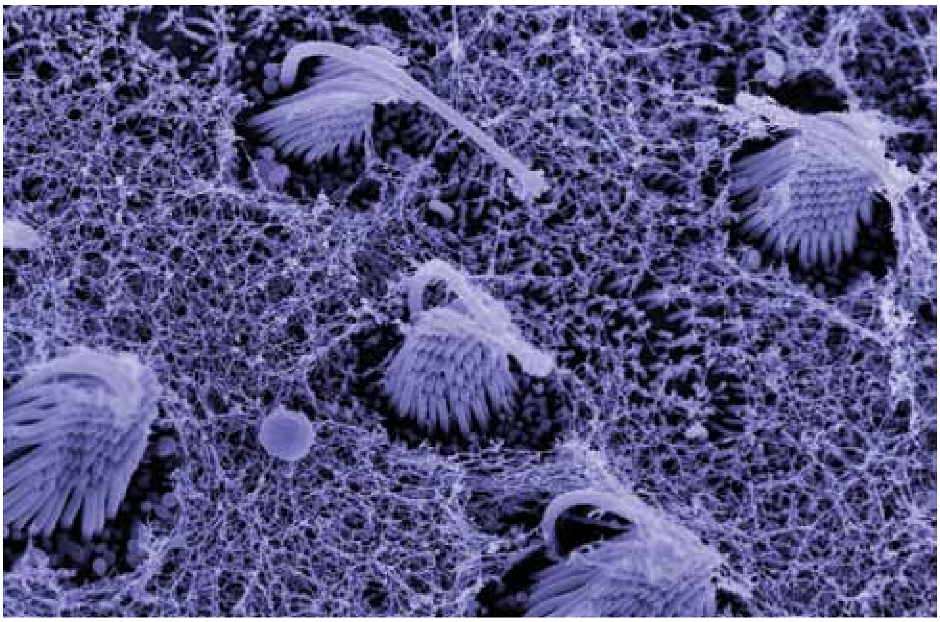
In the creation of such a design, Nature may well have wished to have some radio-engineers at her disposal. In 1948, Thomas Gold proposed that the ear operates as a regenerative radio receiver, in which an active feedback adds energy at the very frequency that the receiver is trying to detect. A choir of differently toned voices would thus be a better analogy for the ear than a harp.

This idea was worked out 50 years later by Tom and others in (then) Cambridge, Paris, and Rockefeller. Starting from what is probably the most common equation in physics, that of the driven harmonic oscillator, they demonstrated how the characteristics of our hearing can be modelled as self-tuned oscillators that are continuously kept at the verge of oscillation.

The therefore required internal active process has the pleasant side-effect of overcoming viscous damping, which would prevent any resonating responses otherwise. It provides a significant boost to the oscillatory response for weak stimuli (sound), but only moderate gain for strong stimuli, which is exactly the behaviour required to achieve the many orders-of-magnitude dynamic range.

Tom and collaborators also showed the intricacies of such oscillators when responding to multi-frequency stimuli, such as Tartini's two-tone response alluded to above. They went on to suggest that, although the idea originated from experimental data in the frog ear this may well determine the appreciation of music by the human ear.

While Tom will of course remain known for these and other scientific contributions, for all who knew him, he will be remembered as a fine and immensely kind colleague.



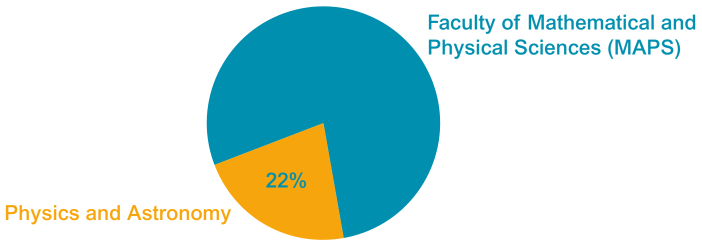
Scanning electron microscope view of the bundle of hairs in the vertebrate ear where Tom Duke placed the active process in his model. The bundle is a collection of stiff rods about 800nm in diameter which are rocked by sound. Credit: Andy Forge (UCL Ear Institute).

Research Statistics

Publication Summary

Research Group	Number of publications in refereed journals
Astro	128
AMOPP	118
CMMP	102
HEP	204

Active Grants and Contracts



In the last financial year (Aug 2011 – July 2012), Physics and Astronomy generated 22% of the total research income for the MAPS faculty. The MAPS faculty as a whole yielded £36,297,000 with Physics and Astronomy contributing £7,899,000

Astrophysics

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

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

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

Impact Studentship: David Johnson – Improving the Representation of the Thermosphere and Ionosphere for Space Weather (UK Met Office) PI: Dr Anasuya Aruliah £31,627

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

ESPAS: Near-Earth Space Data Infrastructures for E-Science (European Commission FP7) PI: Prof. Alan Aylward £197,306

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

Large Scale Structure Insights into the Origins of Cosmic Acceleration (Royal Society) PI: Dr Sarah Bridle £11,920

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

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

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

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

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

DESPEC: Spectroscopic Upgrade of the Dark Energy Survey (STFC) PI: Prof. Ofer Lahav £141,585

UCL Astrophysics Consolidated Grant (STFC) PI: Prof. Ofer Lahav £1,883,126

TESTDE: Testing the Dark Energy Paradigm and Measuring Neutrino Mass with the Dark Energy Survey (European Commission FP7) PI: Prof. Ofer Lahav £1,812,291

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

Newton Fellowship: Probing Cosmological Structure through Novel Signal Processing Methods (Royal Society) PI: Dr Jason McEwen £102,000

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: 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

Cosmological Constraints on the Very Early Universe (Royal Society) PI: Dr Hiranya Peiris £12,000

Travel for Collaboration on Exoplanets (FQXi) PI: Dr Hiranya Peiris £3,047

The E-Merlin Legacy CYG OB2 Radio Survey: Massive Star Feedback and Evolution (STFC) PI: Prof. Raman Prinja £215,102

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: Paul Moseley - Novel QF Quasi-Optical Components for the THZ Astronomy (ESA) PI: Dr Giorgio Savini £29,813

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

EcHO Study Support (UKSA) PI: Prof. Bruce Swinyard £85,919

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

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

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

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

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

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

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

Impact Studentship: Antonios Makrymallis – Time Senses Analysis of Chemical Models of Star Forming Regions (Columba Systems Ltd.) PI: Prof. Serena Viti £31,627

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

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

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

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

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

AMOPP

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

Low Power Sub-wavelength Resolution Fluorescence Imaging (BBSRC) PI: Dr Angus Bain £118,922

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

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

Hybrid Superconductor-Semiconductor Devices for Majorana Fermion Detection (EPSRC) PI: Prof. Sougato Bose £36,831

Nonclassicalities and Quantum Control at the Nanoscale (EPSRC) PI: Prof. Sougato Bose £1,166,350

Nanoelectronic based Quantum Physics – Technology and Applications (EPSRC) PI: Prof. Sougato Bose £441,672

PACOMANEDIA: Partially Coherent Many-Body Non-Equilibrium Dynamics for Information Applications (European Commission FP7) PI: Prof. Sougato Bose £933,809

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

Career Acceleration Fellowship (CAF) - Ionisation of Multi-Electron Atomic and Molecular Systems Driven by Intense and Ultrashort Laser Pulses (EPSRC) PI: Dr Agapi Emmanouilidou £994,556

Control and Imaging of Processes Triggered by X-Ray Pulses in Multi-Centre Molecules (EPSRC) PI: Dr Agapi Emmanouilidou £309,665

Orbit-Based Methods for Multi-electron Systems in Strong Fields (EPSRC) PI: Dr Carla Figueira De Morisson Faria £313,960

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

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

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

Impact Studentship: Chris Fury – Sono-acoustical Trapping of Microbubbles (NPL Management) PI: Dr Philip Jones £35,430

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

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

CAF - Exploiting Quantum Coherent Energy Transfer in Light-Harvesting Systems (EPSRC) PI: Dr Alexandra Olaya-Castro £973,877

URF – Quantum Information, Entanglement and Cryptography (Royal Society) PI: Prof. Jonathan Oppenheim £203,957

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

COSMA – Coherent Optics Sensors for Medical Applications (European Commission FP7) PI: Prof. Ferruccio Renzoni £23,550

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

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

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

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

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

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

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

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

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

Impact Studentship: Dan Underwood – Sulphur Trioxide/Oxide High-Temperature Spectroscopic Databases (Technical University of Denmark) PI: Prof. Jonathan Tennyson FRS £32,126

High Accuracy Line Intensities for Carbon Dioxide (NERC) PI: Prof. Jonathan Tennyson FRS £219,065

CMMP

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

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 £335,813

Development of Microscopic Gas Diffusion-Reaction Model for a H2 Producing Biocatalyst (EPSRC) PI: Dr Jochen Blumberger £171,252

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

SUPERIOR - Supramolecular Functional Nanoscale Architectures for Organic Electronics: a Host-Driven Network (European Commission FP7) PI: Prof. Franco Cacialli £314,284

CONTEST: Collaborative Network for Training in Electronic Skin Technology (European Commission FP7) PI: Prof. Franco Cacialli £480,418

Impact Studentship: Giuseppe Maria Paterno – Nanoscale Characterisation and Radiation Damage Testing of Organic Solar Cells Using Neutron Scattering Techniques (STFC) PI: Prof Franco Cacialli £42,676

Global Engagement for Global Impact: Strategic Interaction with China, India, Germany and USA (EPSRC) PI: Prof Franco Cacialli £2,046

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 £320,558

BIS Secondment (EPSRC) PI: Dr Thanh Nguyen £10,032

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

TOUCAN: Towards an Understanding of Catalysts and Nanoalloys (EPSRC) PI: Prof. Chris Pickard £269,504

Impact Studentship: Ashley Garvin - Laser Materials Interaction (PNNL) PI: Prof. Alexander Shluger £22,800

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

ENGD Studentship: Jonathan Cottom – AB-Initio Simulations in Bulk and Interface Defects (Infineon Technologies Austria AG) PI: Prof. Alexander Shluger £30,000

Impact Studentship: Laser-Materials Interactions: Theory and Experiment (PNNL) PI: Prof. Alexander Shluger £22,800

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

Case Studentship: Radhika Patel – In Situ Studies of Clay Hydration for Sustainable Oil and Gas Exploration (M-I Drilling Fluids UK Ltd.) PI: Prof. Neal Skipper £27,000

URF - 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

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

ENGD Studentship: Oliver Dicks – Tuning Electronic Properties of Thin Films and Interfaces Using Defects (Argonne National Laboratory) PI: Dr Peter Sushko £20,375

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

Small Items of Research Equipment (EPSRC) PI: Prof. Jonathan Butterworth £23,068

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

Dorothy Hodgkin Fellowship – Investigating the Neutrino with MINOS and Liquid Argon Detector Technology (Royal Society) PI: Dr Anna Holin £459,226

Front End Test Stand Continuation (STFC) PI: Dr Simon Jolly £45,046

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

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

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

Experimental Particle Physics at UCL (STFC) PI: Prof. Nikolaos Konstantinidis £2,314,756

Atlas Upgrades Continuation (STFC) PI: Prof. Nikolaos Konstantinidis £117, 469

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

URF Extension - Neutrino and Cosmic Ray Studies with Minos, Anita and Cream Tea (Royal Society) PI: Dr Ryan Nichol £306,804

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 CBE £75,000

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

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

MINOS Spokesperson Travel (STFC) PI: Prof. Jennifer Thomas CBE £8,000

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

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

Terauniverse - Exploring the Terauniverse with the LHC, Astrophysics and Cosmology (European Commission FP7) PI: Prof. Robert Thorne £356,475

Impact Studentship: Guillaume Eurin – Low Background Physics and the Search for Neutrinoless Double-Beta Decay (Centre National de la Recherché Scientifique) PI: Dr David Waters £31,627

Experimental Particle Physics Consolidated Grant 2012 – 2016 (STFC) PI: Dr David Waters £4,340,016

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

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 Funding

Professor Sougato Bose

European Research Council (ERC)

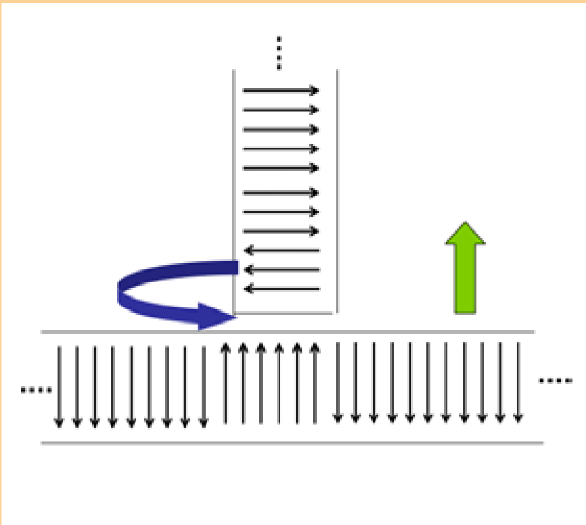
PACOMANEDIA

€1,245,078

This project focuses on utilising the full potential of quantum mechanics for future electronic technology. The project will examine automata which is produced from multiple quantum units such as nanomagnets for transporting bits and performing classical (Boolean) reversible logic. The figure below is a schematic for a reversible Boolean gate between bits, encoded in magnetic domains.

Such automata could potentially lead to significant increases in computational speed and energy-efficiency. The performance of the machine would be determined by the couplings of the quantum many-body system, with calculations set in a regime where dissipation (decay of energy) becomes irrelevant. However dephasing (loss of quantum coherence) may be substantial.

An alternative methodology for quantum information processing will also be investigated, addressing questions such as whether a network of interacting spins can serve as an automata for running an entire quantum algorithm, and the viability of using magnon wavepackets can be used for computations.



Staff Snapshot

Head of Department

Professor J M Butterworth

Astrophysics

Head of Group:
Professor M J Barlow

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

Professorial Research Fellow:
D D Walker

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

Lecturers:
F Abdalla, N Achilleos, G Savini

Royal Society Fellowship:
J McEwen (Newton)

STFC Advanced Fellowship:
T. Greve

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

Research Associates:
R. Aladro, M. Banerji, A. Benoit-Levy, T. Bisbas, S. Feeney, D. Fenech, J. Frazer, P. Guio, M. Hirsch, O. Host, C. Jackman, D. Kirk, A. Merson, W. Nicholson, F. Poidevin, B. Rowe, C. Sabiu, T. Spain, S. Thaithara Balan, S. Thompson, L. Voigt, I. Waldmann, P. Woods, J. Zuntz

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Atomic, Molecular, Optical and Positron Physics

Head of Group:
Professor G Laricchia

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D. Browne, D. Cassidy, C. Figueira de Morisson Faria, S. Hogan, A. Olaya-Castro, 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, D. Ballester, R. Barber, S. Brawley, C. Coppola, F. Fassioli-Olsen, A. Ferraro, C. Hill, S. Hutchinson, A. Kolli, V. Laporta, C. Lazarou, L. Lodi, S. Lopez Lopez, M. Marciante, R. Marsh, S. Midgley, J. Millen, D. Monahan, N. Nicolaou, O. Polyansky, A. Wallis, A. Werpachowska, A. Wickenbrock, A. Williams

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F. Lopez Gejo, S. Hepplestone, A. Kimmel, A. Kubas, N. Kuganathan, S. Ling, M. Martinez Canales, A. Morris, D. Ortega, M. Watkins

Most research staff are employed through the LCN

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C. Jordan, J. Rooke

High Energy Physics

Head of Group:
Professor M A Lancaster

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

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A. Holin (Dorothy Hodgkin)

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A. Basharina-Freshville, P. Bernat, I. Christidi, B. Cooper, T. Coughlin, R. D'arcy, A. Davison, A. Desai, E. Dobson, J. Evans, E. Jansen, J. Monk, P. Motylinski, R. Prabhu, S. Torre, D. Wardrope, L. Whitehead

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Director of Postgraduate Studies:
T. S. Monteiro

Director of Laboratories:
F. Renzoni

Senior Teaching Fellow:
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Laboratory Superintendent:
J. O'Brien

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

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

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

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Manager:
P. K. Thomas

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T. Schlichter

Technical Support:
M. Pearson

Maps Workshop

Superintendent:
R. Gollay

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J. Benbow, J. F. Percival

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K. Heyworth

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D. Buck

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N. Waller

Grants Officer:
J. Barrett

Group Administrator Astro:
K Nakum

Group Administrator AMOPP & HEP:
C. Johnston

Group Administrator CMMP:
C. Jordan

Science Centre Organiser:
S. Kadifachi

Undergraduate Administrator:
S. Lo

Visiting Professors and Emeritus Staff:

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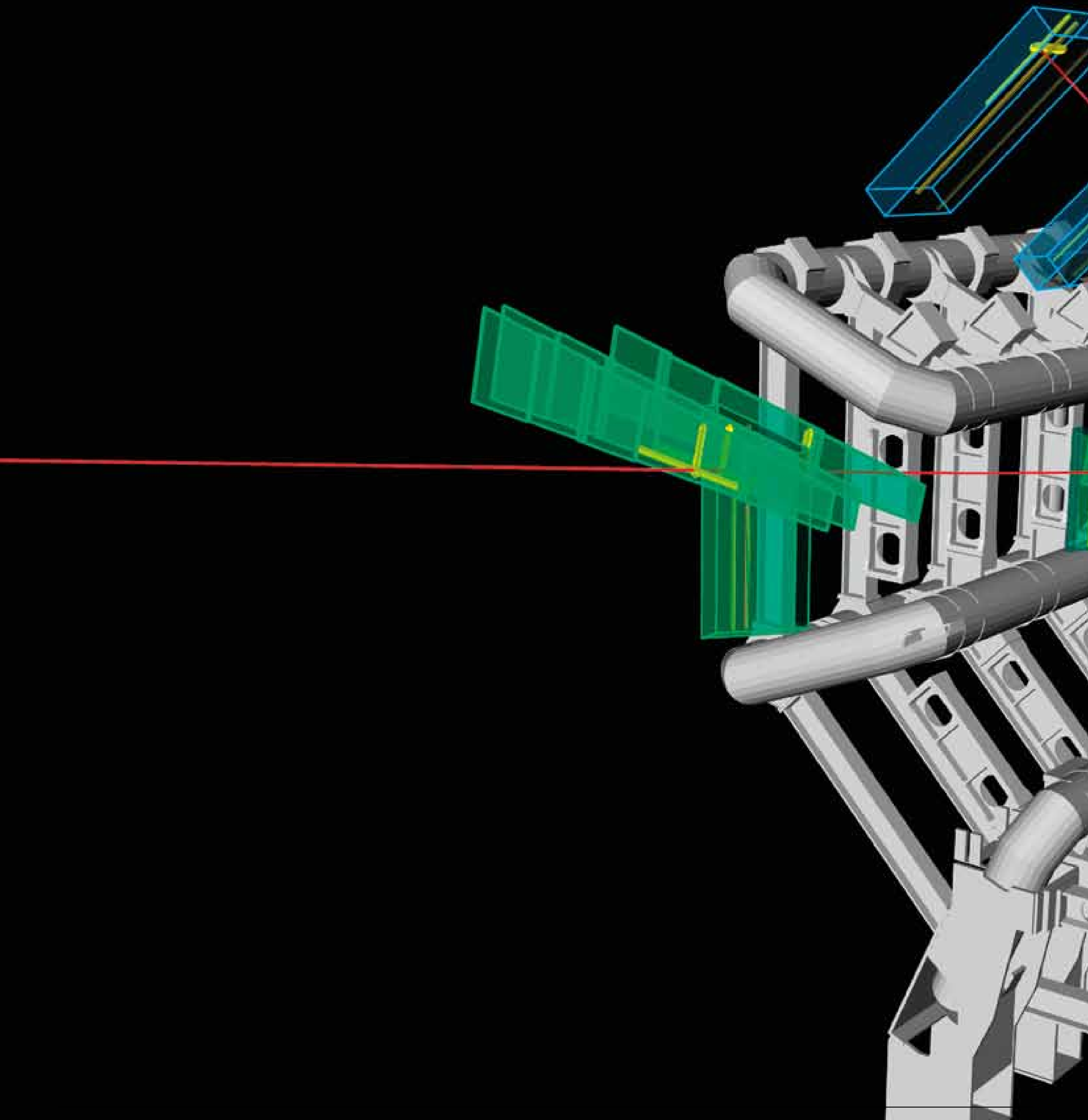

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