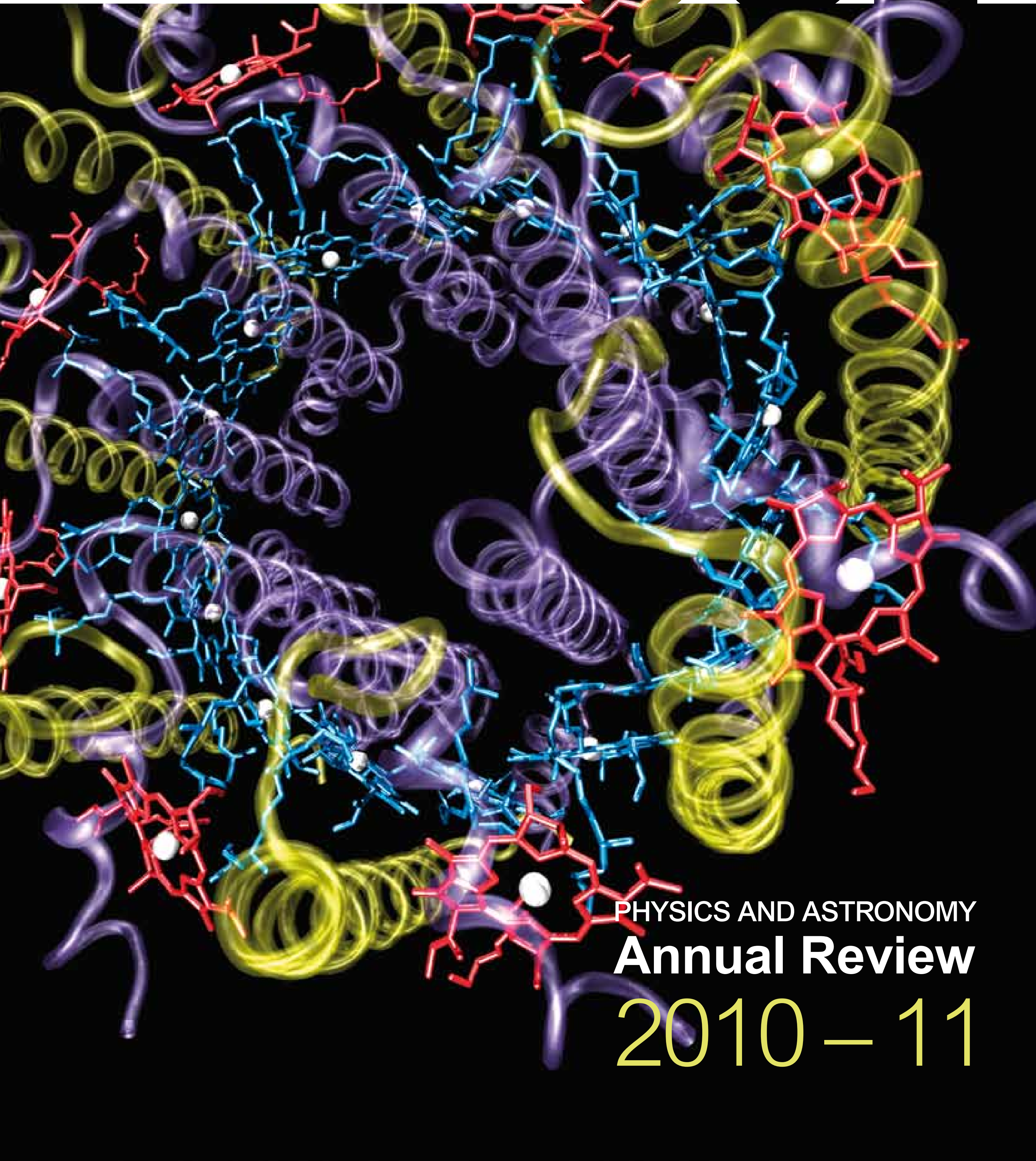
UCL DEPARTMENT OF PHYSICS AND ASTRONOMY

UCL



PHYSICS AND ASTRONOMY

Annual Review

2010 – 11

Contents

Cover image:

Structure of the light-harvesting antenna (LH2) isolated from photosynthetic purple bacteria Phaeospirillum molischianum. Pigments (in red and blue) are attached to a protein backbone (ribbons) and cooperate to absorb and transfer sunlight efficiently. Dr Alexandra Olaya-Castro and graduate student Edward O'Reilly are investigating the impact of variations in the protein composition on the energy transfer properties within and between LH2 complexes.

Introduction

2010 has been an exciting year for the Department of Physics and Astronomy due to a number of long-term, high-profile experiments beginning to harvest data. In some cases, members of the Department have been involved in the projects for many years: from the initial proposals to their current fruition.

Among these include the HEP involvement in the ATLAS experiment on the Large Hadron Collider (LHC) at CERN; the Astro group's participation in the Planck and Herschel satellites, jointly launched in 2009; and the discovery of 'magnetricity' by members of the CMMP group in late 2009. These projects are explained in detail in the research section of this review (starting page 18) and are indicative of the scientific excitement which has been maintained across the disciplines. This flow of results is set to continue with first light on the Dark Energy Survey (DES), in which the Astro group are playing pivotal roles in both the science and the instrumentation. These results are due late 2011, along with a number of other major developments in the pipeline.

Every year I seem to report that our student recruitment remains buoyant; we received a record number of undergraduate applicants last year which resulted in our largest ever first year cohort. This is further swollen both by the significant fraction of Natural Science students choosing majors from within the Department and students from outside the Department taking our courses, particularly those studying Physics with Medical Physics, now admitted by Engineering. While it is very pleasing to welcome so many able and enthusiastic physics students, it undoubtedly puts a strain on our resources. UCL has very few large lecture theatres and those it has are heavily used; furthermore our undergraduate laboratories are now catering for numbers significantly larger than they were designed for. Similarly extra students also places more demands on staff time.

The number of PhD students we recruited during 2010 was also, by some distance, a record. This was, in part, helped by the College's Impact Studentship scheme mentioned in last year's Annual Review-alumni may recall our appeal for co-funding of supplementary PhD places, which is still in place. It is pleasing that we have been able to offer places to more of the well-qualified applicants who approach us each year, PhD training is an activity in which we would like to grow further.

I am delighted to congratulate Prof Gabriel Aeppli, Quain Professor of Physics in the Department and Director of the London Centre of Nanotechnology (LCN), on his election as a Fellow of the Royal Society (see page 9). It is gratifying that after a gap of twenty years, two members of the Department have been elected FRS in successive years. I am optimistic that our research successes will lead to further elections in the not too distant future.

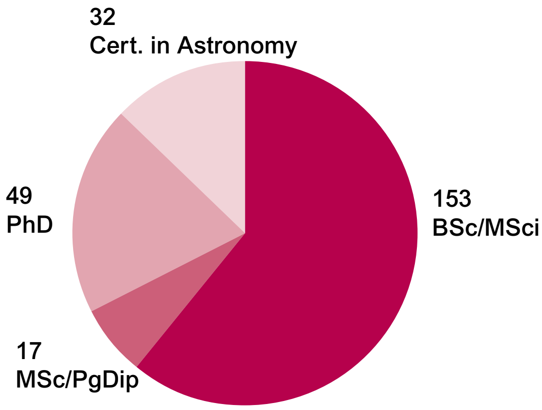
On a personal level, I have been fortunate enough to be awarded a European Research Council Advance Investigator Grant to run a project entitled 'ExoMol: molecular linelists for exoplanets and other atmospheres'. This is due to start in 2011 for 5 years. If you are interested, a flavour of the project can be obtained from www.exomol.com. This is a major opportunity for me and I have therefore decided to stand down as Head of the Department of Physics and Astronomy at the end of the 2010/11 academic year. As I write, the process of appointing a new Head of Department is well underway. I wish my successor the best of luck with what can be a very exciting job.

Professor Jonathan Tennyson FRS
Head of Department

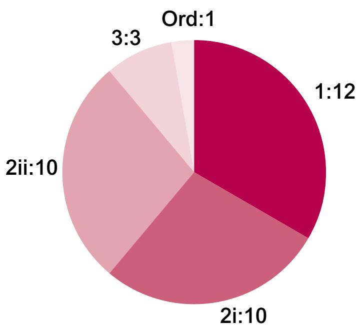
Student Highlights and News

Student Entry and Pass Figures for 2010

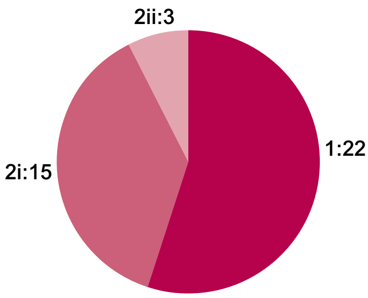
Intake



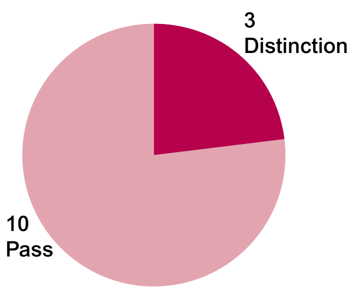
Awards



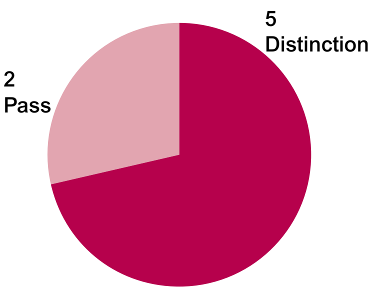
Bachelor of Science (BSc)



Master in Science (MSci)



Master of Science (MSc)



Certificate of Higher
Education in Astronomy

Student Prizes 2010

UNDERGRADUATE PRIZES

Oliver Lodge Prize
(Best performance 1st year Physics)
Kaijian Xiao

Halley Prize
(Best performance 1st year Astronomy)
Marco Rocchetto

C.A.R. Tayler Prize
(Best 2nd Year Essay)
Pierre Deludet

Wood Prize
(Best performance 2nd year Physics)
Arnold Mathijssen

Huggins Prize
(Best performance 2nd year Astronomy)
Shaghayegh Parsa

David Ponter Prize
(Most improved performance in Department, 2nd year)
Carmen Thompson

Corrigan Prize
(Best performance in experimental work, 2nd year – joint winners)
Jonathan Pilcher & Giulio Pepe

Best Performance 3rd Year Physics
Maximilian Genske

Best Performance 3rd Year Astronomy
Carl Salji

Additional Sessional Prize for Merit (3rd Year) (Most improved 3rd Year)
Alexander Glen

Burhop Prize
(Best performance 4th year Physics)
Solimon Edris

Herschel Prize
(Best performance 4th year Astronomy
Luke Peck

Brian Duff Memorial Prize
(Best 4th Year project in the Department
Alexander Dunning

William Bragg Prize
(Best overall undergraduate)
Sidney Tanoto

Tessella Prize for Software
(Best use of software in final year Physics/Astronomy projects)
Jake Stinson

POSTGRADUATE PRIZES

Harrie Massey Prize
(Best overall MSc student)
Sadi Ahmed

Jon Darius Prize
(Outstanding Postgraduate Research, Astronomy)
Shaun Thomas

Carey Foster Prize
(Postgraduate research, physics AMOPP)
Hannu Wichterich

HEP Group
(Postgraduate research, physics HEP)
Adam Davison

Marshall Stoneham Prize
(Outstanding postgraduate research, physics CMMP)
Tom Headen
Christiane Losert-Valiente Kroon

DEPARTMENTAL TEACHING PRIZE

Professor Ian Ford

PhD'S AWARDED

Sabina J A Abate
Measuring Cosmology from Dark Universe
(Supervisor Dr S Bridle)

Robert Aldus
Neutron Scattering Studies of Frustrated Magnets
(Supervisor: Prof. S Bramwell)

Lilly Asquith
Using ATLAS to Investigate the Associated Production of a Higgs Boson with a Pair of Top Quarks
(Supervisor: Dr N Konstantinidis)

Carolyn Atkins
Active X-ray Optics for the Next Generation of X-ray Space Telescopes
(Supervisor: Dr A P Doel)

Zainab Awad
The Chemistry of Warm Cores in Low Mass Star Forming Regions
(Supervisor: Dr S Viti)

Mandakranta Banerji
Galaxies in the Distant Universe: Colours, Redshifts & Star Formation
(Supervisor: Prof. O Lahav)

Catrin Bernius
Investigation of the Discovery Potential of a Higgs boson in the $t\bar{t}H$, $H\rightarrow b\bar{b}$ Channel with the ATLAS experiment
(Supervisor: Dr N Konstantinidis)

Wisdom Beyhum
Investigation of the Role of Magnetic Materials in Neurodegenerative Diseases
(Supervisor: Prof. Q Pankhurst)

Sarah Boutle
Beauty in Photoproduction at HERA II with the ZEUS Detector
(Supervisor: Prof. M Wing)

Benjamin Bryant
Scanning Tunnelling Microscopy of Bilayer Manganites
(Supervisor: Dr C Renner)

David Cooke
Positron Impact Ionization of Atoms and Molecules
(Supervisor: Prof. G Laricchia)

Daniel Credgington
Nano-scale Lithography and Microscopy of Organic Semiconductors
(Supervisor: Prof. F Cacialli)

Thomas Forrest
Ordering and Dynamics of Strongly Correlated Transition Metal Oxides
(Supervisor: Prof. D McMorrow)

Filimon Gournaris
A Study of the Top Quark Production Threshold at a Future Electron-Positron Linear Collider
(Supervisor: Prof. M Wing)

Thomas Headen
Asphaltene Aggregation on the Nanoscale **(Supervisor: Prof. N Skipper)**

Anna Holin
Electron Neutrino Appearance in the MINOS Experiment
(Supervisor: Prof. J Thomas)

Bethan James
An Optical and Infrared Analysis of Blue Compact Dwarf Galaxies
(Supervisor: Prof. M Barlow)

Matthew Kauer
Search for Double Beta Decay of Zr-96 with NEMO-3 and Calorimeter Development for the SuperNEMO Experiment
(Supervisor: Dr R Saakyan)

David Koskinen
MINOS Sterile Neutrino Search
(Supervisor: Prof. J Thomas)

Jennifer Lardge
Investigation of the Interaction of Water with the Calcite $\{10\bar{1}4\}$ Surface Using Ab-Initio Simulation
(Supervisor: Dr D Duffy)

Stephen Leake
Coherent X-ray Diffraction Imaging of Zinc Oxide Crystals
(Supervisor: Prof. I Robinson)

Vyacheslav Lebedev
AC Driven Ratchets for Cold Atoms: Beyond 1D Rocking Ratchets
(Supervisor Prof. F Renzoni)

2010 prize winners

Christiane Losart-Valiente
Stochastic Population Dynamics in Astrochemistry and Aerosol Science
(Supervisor: Prof. I Ford)

Sarah Malik
Precision Measurement of the Mass and Width of the W Boson
(Supervisor: Prof. M Lancaster)

Dara McCutcheon
Open Quantum Systems in Spatially Correlated Regimes
(Supervisor: Prof. A Fisher)

Simon Purcell
Laser Induced Molecular Motion in Strong Nonresonant Laser Fields
(Supervisor: Prof. P Barker)

Alessandro Sena
Density Functional Theory Studies of Surface Interactions and Electron Transfer in Porphyrins and Other Molecules
(Supervisor: Dr. D Bowler)

Rajeevan Sivasubramanian
Chemomagnetism: The Influence of Applied Magnetic Fields on Solid State Combustion Reactions
(Supervisor: Prof. Q Pankhurst)

Shaun Thomas
Probing Gravity and the Neutrinos with Cosmology
(Supervisor: Prof. O Lahav)

Hemal Varambhia
R-Matrix Calculations on Molecules of Astrophysical Interest Using Quantemol-N
(Supervisor: Prof. J Tennyson)

Magda Vasta
Modelling Ionised and Photodissociated Regions
(Supervisor: Dr S Viti)

Hannu Wichterich
Entanglement Between Noncomplementary Parts of Many-body Systems
(Supervisor: Prof. S Bose)

Lars G Winroth
Physical Characterisation of Interfaces in Organic Devices
(Supervisor: Prof. F Cacialli)

Rui Zhang
R-matrix Calculations of Polarisation Effects in Low-energy Positron-molecule Collisions
(Supervisor: Prof. J Tennyson)

External Research Awards

Dr Justin Evans, was awarded The Alvin Tollestrup Award for Outstanding Postdoctoral Research, conferred by Fermilab.

"For his work on the measurement of the muon neutrino and antineutrino oscillation parameters with the MINOS experiment. Dr Evans made significant contributions to the measurement of the muon neutrino mass-squared splitting at the atmospheric scale, and to the first direct measurements of the muon antineutrino oscillations parameters. Dr. Evans is recognized as an expert and a leader in the experimental analysis and comparison of the neutrino and antineutrino oscillation parameters."

Dr Matthew Kauer, was the recipient of the Institute of Physics (IOP) Astroparticle Physics Thesis Prize.

Matthew's work contained two major results; the world's most accurate measurement of the two-neutrino double beta decay of the Zirconium 96 isotope, and the development and characterisation of a plastic scintillator calorimeter with unprecented energy resolution for low energy electrons, required for the SuperNEMO experiment.

Both of the award recipients were members of the High Energy Physics (HEP) group

Research Highlight

Observation of Ultrahigh-Energy Cosmic Rays with the ANITA Balloon-Borne Radio Interferometer

A. Connolly, R.J. Nichol & co-workers
Physical Review Letters 105, 151101 (2010)

The Antarctic Impulsive Transient Antenna (ANITA) is a long-duration balloon experiment that has spent over two months circling 37 km above Antarctica searching for ultrahigh energy neutrinos interacting in the ice below.

The international team of scientists had a surprise when they analysed data from the first 35 day flight. Instead of measuring radio pulses from neutrinos, the team found 16 signals that came from very energetic cosmic rays interacting in the atmosphere. Most of these radio signals were detected after they had reflected off the ice, so in some sense ANITA can be thought of as a gigantic radio telescope with the ice as the mirror.

The origin of the energetic cosmic rays that continuously bombard the Earth is one of the great questions. The third ANITA flight is planned for 2013 and will be capable of detecting some of the highest energy particles ever measured. One hundred years after cosmic rays were discovered, ANITA is keeping scientific ballooning at the cutting edge and may help solve the question of where the cosmic rays come from.

Exclusive tours of the world's largest laboratory for UCL staff and students

UCL's President and Provost, Professor Malcolm Grant (second from left) in the CERN control room

Exploiting their research connections with the Large Hadron Collider (LHC) at CERN (Geneva), the HEP group organised two separate tours of the CERN laboratories. UCL's President and Provost, Professor Malcolm Grant was the guest of honour for one tour, whilst 50 Physics and Astronomy undergraduates were the lucky recipients of the second tour.

The CERN laboratory is the largest laboratory in the world and the tours allowed participants to experience the exciting period of the LHC startup. Ordinarily waiting lists of more than one year are common, especially for large groups such as the 50 undergraduates attending the second tour. However we are fortunate enough to have two qualified CERN guides within the HEP group and they were able to arrange the tours.

Although visits to underground installations are no longer possible due to the first beams being circulated in the machine, the visitors were able to see the ATLAS visitor centre (including the control room, some illustrative videos and some prototypes of the detector). As well as the Microcosm exhibition and some other parts of the laboratory not usually seen by the visitors.

More detail about CERN and the LHC is given in the HEP research pages.

Research Highlight

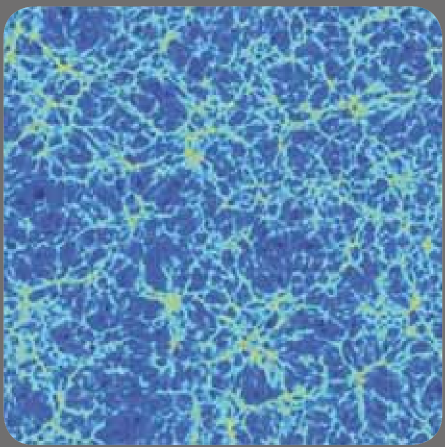
Upper Bound of 0.28 eV on Neutrino Masses from the Largest Photometric Redshift Survey

S.A. Thomas, F.B. Abdalla, O. Lahav
Physical Review Letters,
105, 031301 (2010)

Evidence has been found that the mass of the neutrino particle is less than 0.28 electron volts- a billionth of a hydrogen atom. These findings are arguably the lowest and most robust upper bound estimated to date.

Neutrinos tend to smooth out the clumpy and clustered nature of matter in the Universe, with the effect being stronger, the larger their mass. Therefore, to place the above mentioned upper bound, the researchers constructed a map of the distribution of 700,000 luminous red galaxies, which trace the underlying distribution of matter, using data from the Sloan Digital Sky Survey.

The distances to these galaxies were derived from their colours using a technique developed by UCL's cosmologists. The team expects projects such as the international Dark Energy Survey (DES), in which the UCL Astrophysics Group plays a major role, to improve the results. As shown in another study by the team (Lahav et al., MNRAS, 405, 168, 2010) DES combined with Cosmic Microwave Background Planck data may detect the total neutrino mass if its value is significantly larger than 0.1 eV.



Alumni Matters

By Professor Tegid Wyn Jones

I find it hard to imagine that I shall have a more memorable year as the departmental Alumni Co-ordinator than the year gone by.

The UCL Honorary Degree Ceremony, attendees included (from left to right, seated) Peter Higgs, Roger Penrose and Dimitri Vassiliev (standing) Mark Lancaster, Frank Warren, Ceiri Griffiths, Tegid Jones, Jonathan Butterworth and Dave Miller.

The Annual Alumni Dinner was held on the 7 May and was attended by 29 guests. This was a welcome increase compared to last year and may reflect our efforts to reduce the cost of the dinner.

We were particularly fortunate to be addressed by Prof. Roger Davies, the Philip Welton Professor of Astrophysics (Oxford). He graduated from UCL Physics in 1975 and recounted his international career since then, where he seemed to encounter UCL Physics and Astronomy graduates at every turn. Once again the dinner turned out to be a thoroughly enjoyable experience.

On September 6 the prestigious UCL Honorary Degree Ceremony took place, one of the Honorary Doctorates was Prof. Tim Killeen who graduated in Physics in 1972. In 1975 he was awarded a PhD for work he did in the positron group under Prof. Ceiri Griffiths, who also attended the ceremony.

Tim Killeen is now the Assistant Director for Geoscience at the US National Science Foundation and is one of President Obama's advisors on Climate Change. Other notable Physics and Astronomy Alumni attendees included Jose-Marie Griffiths (BSc Physics 1972), now a Vice President at Bryant University; Tim Penman (BSc Physics 1972, PhD 1976) who is currently 'Head of Evidence' at the Department of Energy and Climate Change and Frank Warren (BSc Physics 1949), a regular attendee at our Annual Alumni Dinners.

An Honorary Doctorate was also conferred on Prof. Peter Higgs who had been a temporary lecturer in the UCL Maths Department 1959/60. He is famous for proposing, with several other researchers, that spontaneous symmetry breaking may be the mechanism by which the W and Z bosons of the weak interaction acquire mass. He predicted that this mechanism should be associated with a particle now being the subject of an extraordinary search at the LHC, and called the Higgs Boson (see the HEP research section).

I hope that many of you will come to our next alumni dinner on Friday 6 May 2011, the after dinner speaker will be Prof. Mike Charlton (BSc Physics 1978, PhD 1980). He left UCL in 1999 to become the Head of the Physics Department at Swansea University.

Professor Marshall Stoneham FRS (1940-2011)

After a short illness, Professor Marshal Stoneham sadly passed away on 18 February 2011.

He joined UCL in 1995 as the first Massey Professor of Physics and Director of the Centre for Materials Research. Though nominally retired from UCL, he remained highly active both within the Department and the LCN. He was also President of the Institute of Physics from October 2010.

Professor Richard Catlow, a longstanding colleague and Dean of Mathematical and Physical Sciences said "Marshall Stoneham was one of the outstanding physicists of his generation, who made a huge contribution to condensed matter physics. He will be greatly missed by the UK and indeed the international physics community". A full obituary will follow in the 2011–12 Annual Review.

In memoriam

Professor Gerald Vann Groves
(1928–2010)

We are sad to report the death of an ex-colleague, Prof. Gerald (Gerry) Vann Groves.

Gerry was one of the post-war generation of scientists who ‘invented’ space science as the new ‘sounding rockets’ reached previously unobtainable altitudes. In parallel with the work of Harrie Massey and others, Gerry’s atmospheric physics group in the UCL Physics Department (now Physics and Astronomy), began launching grenades into the upper atmosphere, measuring the sound waves that came back to the ground and from that deducing the density structure of the upper atmosphere. Later he moved to working on models of the upper atmosphere and contributed to the early CIRA model (COSPAR International Reference Atmosphere), particularly trying to characterise the dynamics, tides and planetary waves of the middle and upper atmospheres.

Gerry grew up in Northampton, and received a Scholarship to the Northampton Town and County Boys School. From there he gained entry aged 17, to Peterhouse, Cambridge (1945–48), where he graduated with an MA in the Maths Tripos. He worked in the scientific civil service for a while, then came to UCL where he received his PhD in 1957 and joined the staff soon after. There are several senior people in the field today who will have been introduced to Space Science by doing his Diploma in Space Science, or hearing him lecture on space topics. A quiet, undemonstrative man, his enthusiasm for the subject nevertheless shone through.

Gerry retired from UCL in 1984, but continued working with the British Interplanetary Society as a space advocate, becoming its President for a number of years. At the age of 78 he undertook the task of managing the construction of a new house on the plot next to where he lived, he moved into it in spring 2010, just a few months before he died. His wife Joyce died in 2002, he is survived by his son Jonathan.

by Professor Alan Aylward

Research Highlight

BLAST-pol has Landed!

BLAST-pol (Balloon-borne Large-Aperture Sub-millimeter Telescope) was successfully launched on 27 Dec 2010 from the McMurdo base in Antarctica, on the coast opposite New Zealand. The telescope landed on 5 Jan 2011, 500km away on the Ross ice shelf, after almost circumnavigating the South Pole thanks to high altitude wind currents.

The original experiment, launched in 2006 was featured in the movie documentary ‘BLAST!’. BLAST-pol is the second generation experiment. Flown from a Long Duration Balloon platform, the telescope and its instruments have been pointed at a number of star forming regions and molecular cloud targets in the galaxy to measure the infrared polarised emission from cold dust in the presence of magnetic fields.

The data will be analysed in the coming year and will help us to understand the role of magnetic fields in the star formation process. The international consortium of universities working on the experiment includes **Dr G. Savini**.

Careers with Physics and Astronomy Degrees

Parveen Akther

Managing Director of TUV Rheinland, Australia

(BSc Physics 1992)

I joined UCL in 1989 to study for a BSc in Physics with Medical Physics but after two years I decided to change to a straight Physics degree. I have never been a keen writer and looking back, I think it was the thought of having to write essays that put me off doing one more year of medical physics! For me, Physics was always my first love, inspired by a great teacher who challenged us to think out of the box.

Upon graduation, I embarked on a PhD in atomic and molecular physics. However by the time I had finished my research, I was already living and working in Japan, and somehow writing up my thesis fell to the wayside.

Many things have happened in my life since leaving UCL; I have been married (also to a UCL student), divorced, and had two children along the way, Sophie (10) and Marc (4). After spending 13 years in Japan, I moved to Melbourne in 2009.

After my PhD research I taught English for a while, but after a year and half found I was missing science. So in 1999 I began working for a German engineering company, TUV Rheinland doing Electromagnetic Compatibility testing (EMC). This brought back memories of Prof Corrigan's lessons on electromagnetic waves and those squiggly little worms (those of you who were fortunate to have been in his lectures will remember the worms!).

Hence my career started as an engineer inspecting, reporting and showing products from hairdryers to large scale industrial machines are in compliance with EU regulations. For me, EMC testing was wonderful and I loved the variety of products we had to test. In particular I enjoyed it when products failed and then you had to apply your technical background to identify and resolve the problems; although not so much fun for the manufacturers who had to go back to the drawing board to eliminate the issues!

From testing, I went on to manage the EMC Group in Japan, and in 2004 became the Branch Manager for the regions Kyushu, Hiroshima and Okinawa. This meant developing business from inspection services in food to safety testing, as well as EMC. I then moved to Melbourne to take up my current position as Managing Director of TUV Rheinland Australia.

I don't know if this is our final destination, my daughter would love to return to Japan but who knows. All I learned at UCL, including my PhD research has helped me become the person I am today. In my spare time I work out and my future goal is to run a marathon and raise money for charity along the way.

Jon Gingell

Co-founder and CTO of IT consultancy firm OpenSymmetry

(BSc Physics with Space Science 1994, PhD Physics 1998)

I graduated from UCL with a degree in Physics with Space Science. This was the first year that UCL had run this course and although meeting the challenges presented by it was thoroughly rewarding, it was indeed a pioneering experience at times; as I'm sure my colleagues would also testify! During the final two years of my degree I was given the opportunity to work closely with the AMOPP group where, under the expert guidance of Nigel Mason, I developed a love for experimental physics and chemistry which led me to take a PhD studentship in the group.

My PhD studies at UCL provided me with huge opportunities to travel and learn from the best minds in the field. I often look back at my time studying with great fondness and am acutely aware of the benefits that such an education has given me in my subsequent career. The nature of PhD studies is a great foundation for future life, providing problem solving skills and, as is certainly the case for experimentalists, the ability to make swift decisions in the heat of the moment. Anyone who has experienced handling explosive gases in a system of glassware that is rapidly disintegrating in front of their eyes will find such skills tested and honed to the full!

After completing my PhD I worked as a post-doc in the Chemistry Department. In conjunction with Physics and Astronomy, I designed and built the equipment for a major experiment to study the formation of molecular hydrogen in simulated interstellar conditions. The PhD student that was entrusted to my day-to-day management and care was James Perry. James went on to complete his PhD using this equipment and he took on my old post doc position after I left UCL, as you will read later on.

After 10 years at UCL, I decided that the time had come for me to broaden my horizons beyond scientific research. I was offered a job as an IT consultant during the tail end of the .com boom, athough with no proven track record of experience in the field, I had to start near the bottom of the ladder.

Over the next 4 years I found myself working for FTSE 100 and Fortune 500 sized companies around the world, and finally decided to form my own IT company (OpenSymmetry) with a colleague in the USA. Shortly afterwards, we expanded to Europe and set up OpenSymmetry in the UK. We hired James Perry and Philip Holtom as our first two employees, and have never looked back since. Despite the failing global economy, the business has grown and we are now proud to have opened further offices in Sydney, Australia and Johannesburg, South Africa. The business has recently been restructured to allow us to pursue business opportunities in Asia, and as Chief Technology Officer (CTO) I will remain actively involved in all technical operations of a global company that I helped to grow from scratch.

It is without doubt that I owe my ability to have done this, to my training and education at UCL. I can also say that, without doubt, the best and most versatile employees I have ever hired have had an education in a physics based subject; both James and Phil are testament to this. The problem solving abilities and transferrable skills instilled by such a course are second to none, far outstripping those of any computer-science graduate that I have ever encountered. So, if you are reading this as an undergraduate or graduate of the Physics and Astronomy Department then well done – you've chosen the best course possible… want a job?!

James Perry

Principle Consultant for OpenSymmetry

(MSci Physics 1998, PhD Chemistry 2001)

After finishing my PhD I worked at UCL for two years as a post-doc. I left UCL in 2003 to work for Vodafone, where I spent the majority of my time in the Radio Network Design team. In 2006 Jon Gingell, who I'd worked with at UCL, contacted me about working for his new IT consultancy and it seemed an exciting opportunity.

Since joining OpenSymmetry I have worked on projects for clients across a wide range of industries, in 10 countries and across 4 continents. The job is never routine and poses many technical challenges. The skills a physics degree provides, especially in complex problem solving, and the self-sufficiency learned doing a PhD are extremely beneficial in our industry.

Philip Holtom

Principle Consultant for OpenSymmetry

(MSci Physics 1998, PhD Chemistry 2001)

Since finishing my PhD at UCL I have worked in IT, my first job was at EDS working on the London Underground Oystercard ticketing system. After working there for 12 months, I moved into IT Consulting at OpenSymmetry.

My consulting role at OpenSymmetry has led me to work all over the world with a number of large clients and has provided almost as many technical challenges and opportunities for travel as my PhD at UCL did. The experiences I gained at UCL have given me a huge boost working at OpenSymmetry.

Calling all Alumni

We would love to hear about your career and life since leaving UCL, with a view to possibly including your story in the next Annual Review.

If you would be willing to write a piece for the next Annual Review, please contact **Kate Heyworth** via email **k.heyworth@ucl.ac.uk**

Research Highlight

Fellowship of the Royal Society (FRS)

Professor Gabriel Aeppli was elected to a Fellow of the Royal Society (FRS). Gabriel is Director of the LCN and Quain Professor of Physics.

Election for this fellowship is one of the highest honours a scientist working in the UK can attain. "Aeppli is one of the world's leading condensed matter physicists, a winner of the American Physical Society's major Oliver Buckley Prize. He identified magnets with tunable quantum fluctuations using them to study the cross-over between the classical and quantum behaviour. His work demonstrated that magnetic quantum fluctuations could not be described by otherwise successful 20th century theory. His team showed such fluctuations as particularly strong in exotic superconductors, such as high transition temperature copper oxides, providing key evidence that quantum spin fluctuations, rather than the atomic vibrations of standard theory, are at the root of exotic superconductivity."

Physics and Astronomy Outreach

Science for the Public

The Department runs a number of school and public science events annually, the full list of lectures and events can be found in the 'Science for the Public' section of our website.

One event of particular interest this year was the Royal Society Summer Exhibition 2010. The exhibition ran for two weeks at the Royal Festival Hall and proved to be a great success, inspiring children and adults alike.

Physics and Astronomy was involved in two stalls, with the 'Nanoscale Science: A Giant Leap for Mankind' stand selected by New Scientist as one of the three best stalls at the event!

Nanoscale Science: A Giant Leap for Mankind

Organised and run by members of UCL as part of The Davy Faraday Research Laboratory from The Royal Institution, the team consisted of chemists, doctors, physicists and engineers exhibiting their work on nanoparticles in the advancement of healthcare diagnostics and therapeutics.

Nanotechnology is the science of the very small, working on a scale one-billionth of a metre. The Davy Faraday researchers are exploring how nanoparticles can be used in healthcare, from disease diagnosis to cancer treatment. Their research focuses on two specific particles; gold nanoparticles, and magnetic colloids. Gold nanoparticles can be used in pregnancy tests, blood sugar monitoring and anti-cancer therapy, and magnetic colloids are used as MRI contrast agents. These have great potential for anti-cancer therapy and drug delivery.

Visitors to the exhibit saw nanoparticles in action and took part in making them using cooking ingredients such as lemon juice, salt and eggs. The team demonstrated colour changes in nanoparticles, and how heating magnetic nanoparticles on human tissue can provide powerful localised therapy for cancer.

Dr Nguyen TK Thanh demonstrating how to change the colour of gold nanoparticles by adding salty water and how to stabilise them using egg white.

An interactive display demonstrating the targeted delivery of magnetic nanoparticles to certain part of the body using a hand held magnet.

A Molecule's Eye View of Water

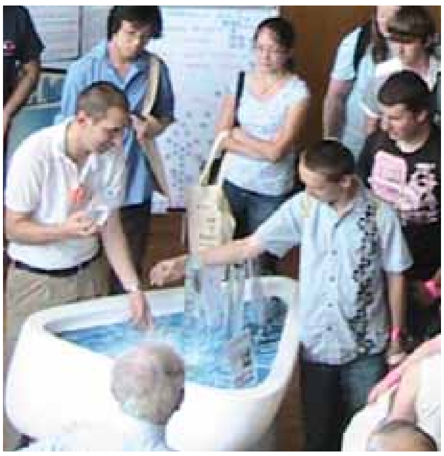
The 'Supercool Ice Show', where water was frozen instantly in the hands of brave volunteers.

The UCL team consisted of members from the departments of Chemistry, and Physics and Astronomy, the London Centre for Nanotechnology and the Thomas Young Centre. Their stand showcased some of the world-leading research at UCL into water and ice on the nanoscale.

Water is one of the fundamental elements to our existence, topics such as ice nucleation, water and climate change, and high pressure phases of ice were explained to the public. The earth's climate process is dominated by the role of water vapour, additionally virtually all chemical reactions take place in water.

One of the highlights of the exhibition was the 'Supercool Ice Show', with crowds of up to 40 people gathering to watch, the show was designed to display some of the more unusual properties of water. Demonstrations included water freezing instantly in the hands of brave visitors and heavy-water ice cubes sinking in normal water.

Support for the exhibition stalls came from EPSRC, STFC, UCL Chemistry, Physics and Astronomy, London Centre for Nanotechnology and the Thomas Young Centre.



The bespoke stand was designed to have the look and feel of an iceberg. It was built in collaboration with the UCL Bartlett School of Architecture.

Research Highlight

Electron-Like Scattering of Positronium

S. J. Brawley, J. Beale, D. E. Leslie, A. I. Williams, G. Laricchia
Science, 330, 6005, 789 (2010)

The observed imbalance between matter and antimatter in our universe is one of the greatest outstanding mysteries in science. Positrons are the antimatter counterpart to electrons with which they eventually annihilate releasing gamma-rays. However, prior to this, a positron often combines with an electron to form Positronium (Ps), the lightest known atom, analogous to hydrogen with the positron replacing the proton.

The Department houses the only operational Ps beam in the world (see picture) which is used to look at how Ps interacts with ordinary matter. Recently, the UCL team has unexpectedly discovered that positronium scatters from a wide variety of atomic and molecular targets in a similar manner to that of a bare electron at the same collision velocity. Guided by this discovery, the team has now observed the first manifestation of Ps resonant scattering.

Whilst the physical reason for the similarity is not yet understood, it looks like the positron in Ps is heavily screened from the target by its partner electron. From a practical viewpoint, this finding may yield significant benefits for advancing simulations of positron-transport in matter, ranging from interstellar clouds to radiation-dosimetry for Positron-Emission-Tomography (PET).

Staff Highlights and News

Promotions

Promoted to Professor

Professor Tony Harker
Professor Robert Thorne
Professor Matthew Wing

Promoted to Reader

Dr Ryan Nichol
Dr Giovanna Tinetti

Academic Appointments

Prof. Bruce Swinyard

Prof. Bruce Swinyard joined the Department in July 2010 as a joint appointment between UCL and the Science Technology and Facilities Council's Rutherford Appleton Laboratory (RAL), His research focuses on the development of astronomical instrumentation and observing techniques in the far infrared wavelength band, especially in space based systems. He is currently working on the analysis of astronomical data from the ESA Herschel Space Observatory SPIRE sub-mm instrument which he has been deeply involved in developing over the past decade (see p24).

Long-term Fellowships

Dr Gavin Hesketh
(Royal Society University Research Fellowship)

Retirements

Prof. Keith McEwen

Resignations

Dr Barbara Ercolano
(to the University of Exeter, then a Professorship at the Ludwig-Maximilians-University, Munich)

Dr Amy Connolly
(to take up an academic position at Ohio State University)

Dr Thorsten Kohler
(to return to Germany)

Artist in Residence joins Astrophysics Group

Artist Katie Paterson joined the Astrophysics group as their first Artist in Residence for the academic year 2010-11. She is supported by a special grant from the Leverhulme Trust.

Katie is a young artist who graduated from the Slade School of Fine Art, UCL, in 2007 and has since participated in important exhibitions, including Modern Art (Oxford), The Power Plant (Toronto), and Altermodern (Tate Britain).

Her work focuses on nature, geology and cosmology. Her artwork repertoire includes: 'Earth–Moon–Earth', which involved the transmission of Beethoven's Moonlight Sonata to the moon and back; 'Vatnajökull', a live phone line to an Icelandic glacier; and 'All the Dead Stars', a large map documenting the locations of all known dead stars (27,000), a collaboration with UCL astronomers and others throughout the world.

During the residency, Katie will investigate ideas of ancient darkness and early light in the Universe, involving dark energy, dark matter, and very distant objects.

All the Dead Stars, 2009
Laser etched anodised aluminium, 2000x3000mm
Photo credit: MJC © 2009

The Cosmic Enigma

On 22–23 June 2010, the Astro group hosted the Weizmann-UK Symposium, for a conference entitled ‘The Cosmic Enigma’. This brought together cosmologists and high-energy physicists from the Weizmann Institute and UK universities, some of the participants are pictured here at the Gala Dinner held at London’s Science Museum.

The symposium host was Prof. Ofer Lahav (second from left), co-organisers were Joe Silk (Oxford, first from left), Eli Waxman (WIS, fifth from left) and Moti Milgrom (third from right). The guests at the dinner included the President of the Weizmann, Daniel Zeifman (third from left) and historian Simon Schama (sixth from right).

Royal Society Pairing Scheme

Dr Emily Nurse with Croydon central MP, Gavin Barwell, her partner in the Royal Society’s pairing scheme for scientists and MPs/civil servants

Organised by the Royal Society, the aim was to build bridges between parliamentarians, civil servants and some of the best science research workers in the UK. The first part of the scheme consisted of a week in Westminster, including two days shadowing their respected pair. The second part involved a reciprocal visit where the MPs/civil servants shadowed the scientist.

Research Highlight

First Light for Remotely-Conducted Observations at ULO

The University of London Observatory (ULO) is developing the capability of remotely operating telescopes from off-site. A milestone in this process was passed on 21 July 2010, when undergraduate student **Jakub Bochinski** controlled a C14 telescope and its CCD camera from his home in central London, using a web-based interface – the first remote observation to be conducted at ULO.

As well as test and calibration frames, the accompanying ‘first light’ images of the planetary nebula M27 were obtained. The hot, blue tinted, white dwarf star visible at the centre is all that remains of a red giant that shed its outer envelope to form the nebula.

A number of operational matters have yet to be resolved, but further trials continue to be encouraging. The success of these experiments, attributable to the combined efforts of all the technical and academic staff at the Observatory, demonstrates great promise for future progress in this direction, and the goal is that fully unattended observing should be routine some time in 2011.

Staff Prizes and Awards

Institute of Physics (IOP) Awards

Holweck Medal and Prize

Prof. Steve Bramwell
(CMMP/LCN)

This award is conferred jointly between the Institute of Physics (IOP) and the French Physical Society.

"For pioneering new concepts in the experimental and theoretical study of spin systems".

Prof. Bramwell was also cited as number 99 in The Times 100 most important people in science and engineering.

Franklin Medal and Prize

Prof. Thomas Duke
(CMMP/ LCN)

"For the application of physical principles to the development of elegant molecular sorting devices, for providing new insights into the organising principles of cells and for his primary contributions to a new generation of theories of how the inner ear works".

Thomson Medal and Prize

Prof. Gaetana Laricchia
(AMOPP)

"For her contributions to the development of the world's only positronium beam and its use to probe the properties of atoms and molecules".

Business and Innovation Medal of the Institute of Physics

Prof. Sir Michael Pepper
(CMMP/LCN/Electrical Engineering)

"For translating advances in semiconductor physics into the commercial arena, including key roles in founding Toshiba Research Europe, Cambridge Laboratory, and TeraView".

UCL Awards

UCL Business Award

Prof. Quentin Pankhurst
(CMMP/ Royal Institution)

"[F]or his endeavors in the establishment of Endomagnetics Limited, which aims to improve healthcare through magnetic sensing technology."

MAPS Faculty Teaching Award

Prof. Raman Prinja (Astro)

"Raman is a teacher who goes out of his way to engage with students both in and outside of lectures and is always readily available to provide feedback. His friendliness, approachability and sheer enthusiasm for the subjects he teaches are well known in the faculty and to the students who have been fortunate enough to have been taught by him".

(Prof. M Lancaster)

Royal Astronomical Society (RAS) Awards

The Fowler Prize

Dr Barbara Ercolano
(Astro)

The Fowler Prize is awarded "to individuals who have made a particularly noteworthy contribution to the astronomical and geophysical sciences at an early stage of their research career".

Harold Jeffreys Lecture

Prof. Steven Miller
(Astro/ Science and Technology Studies)

Selected to give this prestigious lecture, "Professor Miller combines research into the atmospheres of other planets (aeronomy) with a deep interest in the public communication of science…"

The Times Higher Education Awards

Research Project of the Year

Dr Andrew Wills (Chemistry / LCN), **Profs Gabriel Aeppli, Steve Bramwell and Des McMorrow** (CMMP / LCN)

The project pioneered new types of materials magnetism, and included the discovery of 'magnetricity', the magnetic equivalent of electricity.

The judges said this breakthrough has changed our understanding of magnetic force in a way that "crosses the disciplinary boundaries of chemistry and physics, and has the potential for wider application".

Oxford Instruments

2010 Nicholas Kurti European Science Prize

Dr Christian Rüegg (CMMP/ LCN)

"…Christian Rüegg has pioneered experimental work on a number of prototypical magnetic model materials, including low-dimensional arrays of quantum spins, so called spin dimer and ladder systems…"

RAS Vice-President

Prof. Ofer Lahav (Astro) was elected as Vice-President of the Royal Astronomical Society (RAS) and the chair of its International Committee. In addition to this, he was appointed as the sole chair of the Science Committee of the international Dark Energy Survey (DES). In this role he is coordinating the work of over 100 scientists from 5 countries. The 'first light' at the telescope in Chile is expected in October 2011, and members of the Astro group are heavily involved in both the instrumentation and the science of the DES project.

Staff Profile

Prof. Tania Monteiro discusses how a meteorite in her grandparent's farm inspired a lifelong interest in quantum theory.

Prof. Tania Scheel Monteiro joined UCL in 1995 as an EPSRC Advanced Fellow in the AMOPP Group. Her research activity resides primarily in quantum theory, including applications to future quantum-based technologies.

Born in Mozambique, Tania Monteiro's interest in science begun at an early age. Inspired by the fact that the largest known meteorite on the Earth's surface, the Hoba Meteorite, lay on her grandparents' farmland in Namibia! A University of London Research Overseas scholarship enabled her to study for a PhD in Astrophysics at Queen Mary College London.

Despite her early career foundations in Astrophysics, she soon developed an interest in the interface between chaos and quantum theory. Chaos theory studies the behaviour of dynamical systems that are highly sensitive; an effect which is popularly referred to as the butterfly effect. Small differences in initial conditions (such as those due to rounding errors in numerical computation) yield widely diverging outcomes for chaotic systems, generally rendering long-term prediction impossible. Quantum theory on the other hand, cannot resolve behaviours on scales finer than Planck's constant- this is small but still places a limit on the complicated chaotic dynamics. Thus quantum theory tends to suppress chaos, but the interesting aspect is that quantum systems, whether atoms, molecules or small electronic devices, behave very differently in the chaotic regime.

It is the unknown and unpredictable which Tania most relishes in her work. She sees each new different project as a "treasure hunt"; no matter how meticulously a project or related experiment is planned, "nature has a way of behaving differently than one expects: surprises invariably turn up and this is what makes science most exciting".

During her career she proposed the first ever mechanism for a chaotic quantum ratchet with cold atoms. This was then demonstrated in an experiment at UCL. There is a lot of interest in the design and construction of microscopic devices and motors that can drive directed motion, while powered only by thermal and other noise. Driving such ratchet motion is what protein motors, perfected over the course of millions of years by evolution, do in the cells in our bodies. As modern technologies go down to smaller and smaller scales, quantum effects are expected to play a very important role and quantum ratchets are potentially useful in a number of technological applications. A key question, answered in the affirmative by her work is whether the effects of deterministic chaos could replace the random thermal noise which drives usual ratchets.

Tania's future research plans involve, amongst many things, a new collaboration with an experimental team at UCL working towards the development of a quantum computer. Although this remains a distant goal at present, the UCL team of **Gavin Morley** and others, recently discovered that bismuth atoms in silicon could form the building blocks of a quantum computer (see the Research Highlight opposite). This is a recently begun collaboration and Tania now plans to investigate theoretically the so-called 'forbidden transitions' of bismuth atoms in siliconto store quantum information.

Prof. Tania Monteiro by the grave of Charles Babbage, considered by many to be the 'father of the computer' and buried not far from UCL. His 'analytical engine', long predating the microchip, had to rely on heavy brass cogs and levers and was of limited use. Quantum computers are probably at a similar stage at present.

Public Lectures in 2010

The Department organises a number of public lectures throughout the year, aimed at an undergraduate physics level of understanding.

For details of the 2011 lectures please check the Physics and Astronomy website (**www.phys.ucl.ac.uk**).
Lectures will be advertised roughly one month prior to the event.

Physics Colloquium

Professor Gregory Scholes (Toronto),
'Quantum-coherent solar energy capture by marine algae'

January 2010

The Elizabeth Spreadbury Lecture

Professor James Hough (Glasgow),
'The detection and cosmological significance of gravitational waves'

March 2010

The Bragg Lecture

Professor Andre Geim (Manchester),
'Graphene: Magic of Flat Carbon'

October 2010

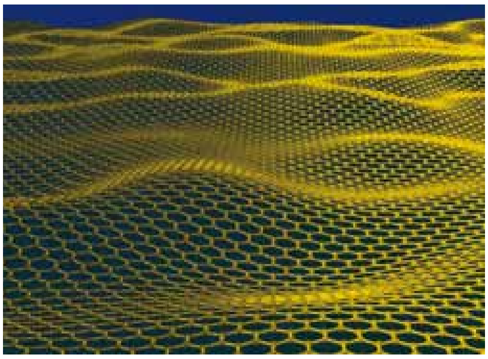
The Massey Lecture

Professor Paul Corkum (Ottawa University/National Research Council Canada), 'Attosecond-Angstrom Science'

November 2010

The Bragg Lecture

The Bragg Lecture is given annually by a distinguished scientist working in the field of condensed-matter and materials physics. Professor Andre Geim (Manchester) was the guest speaker for the 2010 lecture.



Artist's impression of a corrugated graphene sheet

Illustration: Jannik Meyer, Science vol 324, 15 May 2009

The lecture proved to be timely as he had recently been jointly awarded the 2010 Nobel Prize in Physics. The award was shared with his colleague, Prof. Konstantin Novoselov 'for their pioneering work on Graphene'. A record number of staff, students and members of the public arrived, filling two large lecture theatres.

Focusing on Graphene, Andre described it as the thinnest and strongest material ever measured. It is a single atomic plane pulled out of graphite and can sustain current densities a million times higher than copper. It shows a record thermal conductivity, stiffness, and is impermeable to gases or liquids.

Research Highlight

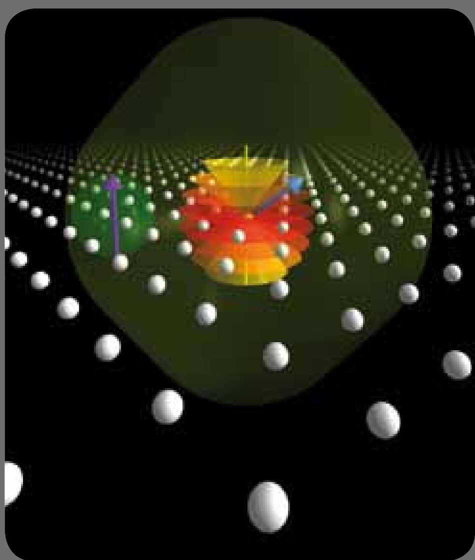
The Initialization and Manipulation of Quantum Information Stored in Silicon by Bismuth Dopants

G.W. Morley, M. Warner, A.M. Stoneham, P.T. Greenland, J. van Tol, C.W.M. Kay**, G. Aeppli.** Nature Materials, 9, 725–729 (2010)

Quantum computing aims to solve problems that would take longer than the lifetime of the universe on a normal computer. A major advance in this field occurred when a team of UCL-US scientists discovered that bismuth atoms in silicon could form the building blocks for a quantum computer.

Despite being compatible with silicon chips, bismuth atoms were previously overlooked by quantum computing researchers in favour of phosphorus atoms. However, the team discovered that bismuth atoms can store quantum information for longer than phosphorus. Bismuth is the heaviest stable atom and has a large nuclear 'spin'. Its quantum spin is like a tiny compass needle that can exist in one of ten states, corresponding to different tilts (see illustration by Manuel Voegtli) instead of the two directions available to a phosphorus nucleus. This allows bismuth nuclei to store more quantum information because the quantum state space is now ten- rather than two-dimensional.

In the future, bismuth atoms could be used to store quantum information while nearby phosphorus atoms control the information flow.



Research Groups

Atomic, Molecular, Optical and Positron Physics (AMOPP)

The Atomic, Molecular, Optical and Positron Physics (AMOPP) group perform high precision measurements coupled with theoretical work, aimed at improving our understanding of fundamental processes. The applications of their research are diverse and cover areas such as the development and structure of the exoplanets, environmental change, and the behaviour of biological systems.

Project in Focus: Ultrafast laser physics

Aim
To understand electron dynamics in atoms and molecules using very short pulses of high intensity light.

Results to Date
From multielectron effects in high-harmonic generation to some of the most comprehensive studies of strong-field electron-electron correlation so far.

UCL Involvement
Developing both classical and quantum theoretical models for a wide range of strong-field phenomena, and participation in leading experiments.

Modern lasers can deliver huge quantities of energy to very focused regions on extremely short timescales. When atoms and molecules are exposed to these extremely strong laser fields, novel and exciting processes can take place. Within the AMOPP group at UCL there is an active research programme in this area, encompassing experimental and theoretical work, with four staff members, and a fast growing number of research students and research fellows. This research programme is described below.

Light in Short Flashes

Femtosecond laser pulses, with durations of the order 10^{-15}s, provide a very powerful tool for examining atomic and molecular processes. The high laser intensities that can be achieved with short laser pulses allows the interaction of atoms and molecules with strong laser fields to be studied, opening the door to a new class of physics where measurements on the attosecond (10^{-18}s) timescale become possible. This is the timescale in which electrons move within an atom or molecule.

In recent years, understanding these processes has led to the possibility of using ultrashort laser pulses to image simultaneously: molecular processes on the attosecond timescale- the timescale in which electrons move; and the Angstrom length scale- the distance between neighboring atoms in a molecule.

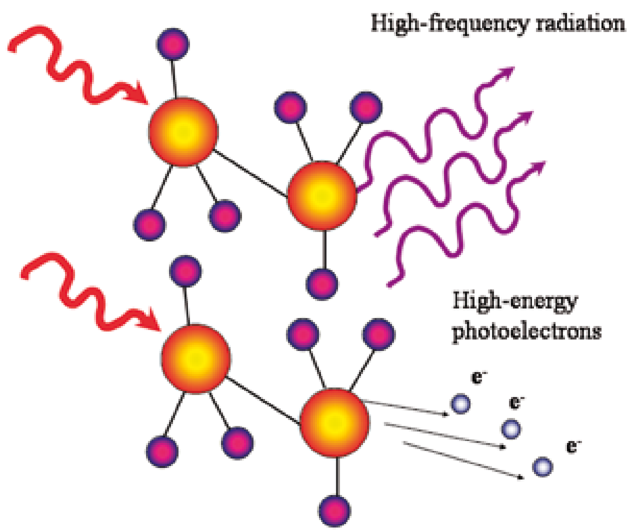


Figure 1: Femtosecond laser pulses, allow us to examine rapid atomic and molecular processes. This diagram shows two possible outcomes for electron recollision. The top image depicts a phenomenon referred to as high-order harmonic generation (HHG) in which the laser field may remove an electron from an atomic or molecular target and accelerate it back towards the target with high energy. Upon return, the electron may either re-collide with the target or recombine to reform one of its bound states emitting a high energy photon. Alternatively the bottom image shows that extra electrons may be produced or non-sequential double ionisation

The strong oscillating electric field associated with such laser pulses exceeds the electric field binding electrons to nuclei, and important new phenomena result. For example, the laser field may remove an electron from an atomic or molecular target and accelerate it back towards the target with high energy. Upon return, the electron may either re-collide with the target or recombine to reform one of its bound states.

If recombination occurs, the energy of the returning electron is liberated as a high-energy photon in the extreme ultraviolet part of the spectrum. This phenomenon is known as high-order harmonic generation (HHG). Such photons are emitted with pulse durations on the attosecond timescale, and have encoded within them, detailed information about the structure of the atom or molecule.

Alternatively, the electron may either elastically scatter or even knock out additional electrons from the target, causing multiple ionisation. The former and the latter process are the physical mechanisms that lead to above-threshold ionisation, and non-sequential double ionisation (NSDI), respectively. The photoelectrons generated in these ways also provide structural information about the target.

A detailed understanding of these processes may bring answers to very fundamental questions. For instance: how does an electron migrate in a photosynthetic molecule? How does a proton rearrange itself when an electron is ripped off an atom? Can we create compact X-ray light sources by driving high-order harmonic generation in a more efficient way?

Understanding these processes requires sophisticated theoretical models and experiments such as those ongoing at UCL. A topic lying centrally to the research is that of the correlated motions of the electrons within an atom or molecule. The attosecond tools described above hold the key to unravelling the detailed synchronized dance that electrons undergo in matter.

High-order Harmonic Generation (HHG)

HHG has attracted a huge amount of interest in recent years. On the one hand, if made sufficiently efficient, HHG will lead to a new generation of X-ray laser sources producing high-brightness attosecond pulses at extreme ultraviolet and X-ray energies. On the other hand, as explained above, HHG is a powerful attosecond imaging tool. Understanding how multiple electron interactions influence HHG is fundamental to this latter goal.

Dr Jonathan Underwood, PhD student **Imma Procino** and co-workers have recently used the Artemis Facility at the Rutherford Appleton Laboratory to explore both of these aspects of HHG science. In these experiments on atomic and molecular gases driven, they were able to observe the attosecond electron dynamics occurring between ionisation and recollision in CO_2 molecules. In addition, by combining two laser fields at wavelengths of 800 nm and 1300 nm they were able to enhance the HHG efficiency by more than two orders of magnitude as well as significantly extending the maximum energy of the X-ray photons produced.

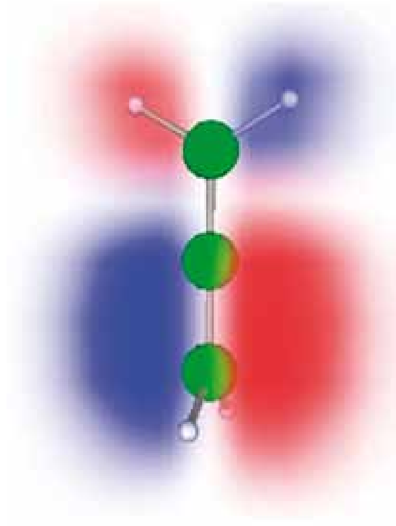


Figure 2: The allene C_3H^4 molecule is one of the targets employed by Jonathan Underwood and co-workers in order to generate high-order harmonics.

In related theoretical work, **Dr Carla Faria** and PhD student **Brad Augstein** developed analytical many-electron models for HHG in diatomic molecules. This model goes beyond most analytical approaches, which consider that only the electron in the highest occupied molecular orbital (HOMO) is active. They found that different orbitals are mapped into different regions in the spectra.

Pathways to Non-sequential Double Ionisation

Electron-electron correlation has a huge influence on multiple ionisation processes including laser-induced nonsequential double (NSDI). ‘Nonsequential’ means that the active electrons act in concert as they leave the atom or molecule, and cannot be disentangled.

NSDI is caused by an inelastic rescattering mechanism involving an electron and its parent ion, this can happen along several pathways. Both electrons may, for instance, leave simultaneously. This route is known as ‘electron-impact ionisation’. There are also the so-called ‘time-delayed pathways’, where one of the electrons gets temporarily trapped in the atomic potential. Hence, they reach the continuum at different times. A key challenge is tracing back these different pathways from the observed electron momentum distributions.

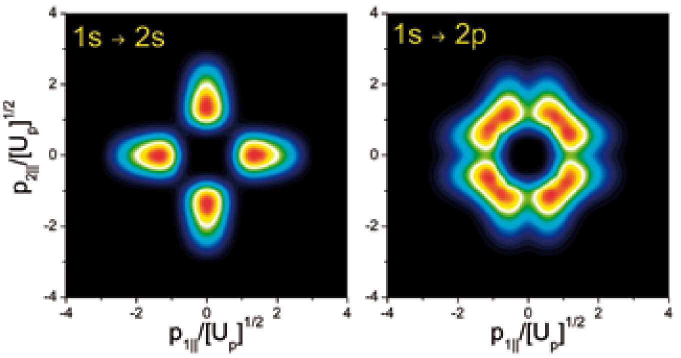


Figure 3: Electron momentum distributions in helium. These distributions are computed for the recollision and excitation of the He^{+} ion to its 2s or 2p state. The electron-momentum components are perpendicular to the laser-field polarization for the Helium atom in a field of intensity 2.16×10^{14} W/cm^2

In 2010, **Carla Faria** and PhD students **Tahir Shaaran**, **Brad Augstein** and **Tom Nygren** performed a detailed study of the NSDI pathway in which the first electron, upon return, may promote the second electron to an excited state, from which it subsequently 'tunnels' out. They performed some of the most comprehensive analytic studies of this mechanism, which ranged from rigorous kinematic constraints to potential imaging applications. They showed that the bound state to which the second electron was excited can be clearly discerned in the measured electron-momentum distributions.

The Two-Electron Streak Camera

Dr Agapi Emmanouilidou and her group have developed three-dimensional classical models where the Coulomb singularities, which occur when charged particles get very close to each other, are fully accounted for. Such models provide a very clear physical picture of often complex processes and complement fully quantum mechanical (QM) approaches, allowing questions to be asked for which QM calculations would be too difficult.

For example, **Agapi Emmanouilidou** and PhD student **Hugh Price** have looked at how multi-electron ionisation takes place and how intra-atomic collision processes via two electron ionisation can be probed.

As a result of these investigations, the two-electron streak camera was formulated which allowed them to look at when the ionising electrons collide following an XUV attosecond pulse. This work was developed in collaboration with Dr Paul Corkum and Dr Andre Staudte in Ottawa.

This general scheme allows for processes triggered by XUV attosecond pulses to be probed using weak infrared laser fields. It will be applied in the future to time-resolve multi-electron ionisation in many electron atoms and molecules, problems at the forefront of attosecond science.

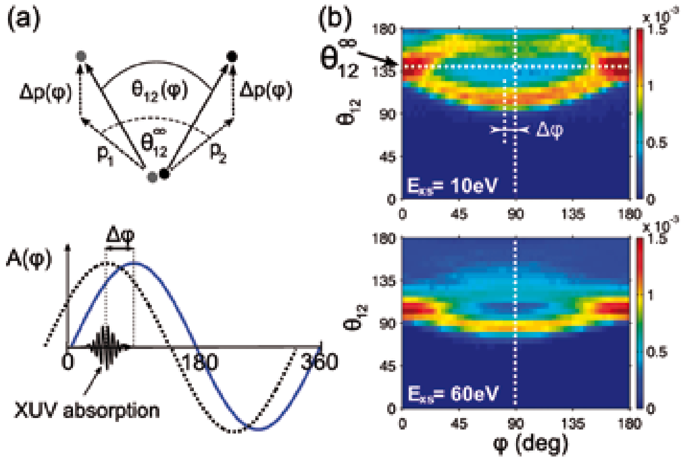


Figure 4.
Figure 4a) Illustrates the concept of the two electron streak camera. When an XUV-attosecond pulse (single photon) is absorbed, the two electrons ionize with an inter-electronic angle of escape θ_{12} and momenta p_1 and p_2. To infer the time the two electrons collide, we drive the system with a weak infrared laser field (streaking field). This field changes the momenta of the two electrons by Δp(φ) the momentum change depends on the phase of the field.

Thus depending on whether the electron that absorbs the single photon escapes in the same / opposite direction as the streaking field, the two electrons escape with a smaller / larger angle.
This accounts for the splitting of θ_{12} as a function of φ, shown in Figure 4b), for two different photon excess energies. If no collision was present, the maximum split in $\theta_{12}(\varphi)$ would be at φ=90°; the shift of the maximum split by Δφ corresponds to the collision time.

High Energy Physics (HEP)

High energy particle physics is about looking at extremely small sizes, or equivalently at extremely high energies. It teaches us about the underlying nature of the physical universe, and the forces and laws that govern its development, from the first moments of the big bang, through to the present day, and far into the future.

Project in Focus: The ATLAS experiment at the LHC

Aim

To understand the fundamental theory describing the building blocks of our Universe and the interactions between them by smashing together subatomic particles known as protons.

Results to Date

Rediscovery of most known processes in an unprecedented energy regime : low energy particles, high energy 'jets' of particles, the W and Z bosons responsible for the weak nuclear force and the massive 'top' quark (a fundamental particle with the mass of a gold nuclei!). We have also placed limits on the existence of new particles.

UCL Involvement

UCL has been heavily involved in the early day measurements, in particular the low energy particles and the high energy 'jets' of particles.

One project which has recently stirred much public interest is the Large Hadron Collider (LHC), based at CERN in Geneva, **Dr Emily Nurse** describes the HEP involvement in the LHC project, more specifically the ATLAS experiment.

ATLAS is a large international experiment which makes measurements in the LHC. The HEP group made essential hardware and software contributions to the experiment and its first results were released on Weds 21st April 2010. The experiment is enabling scientists to search for new particles, forces and dimensions in completely new territory.

The Large Hadron Collider (LHC)

The Large Hadron Collider (LHC) is a huge particle accelerator that began colliding two circulating beams of protons together at a centre-of-mass energy of 7 TeV (one TeV is a 10^{12} electron-volts) in March 2010. When the protons collide, they break up and produce a whole host of different particles. The most common occurrence is the production of well-known particles, however there is also the exciting possibility of undiscovered particles being produced.

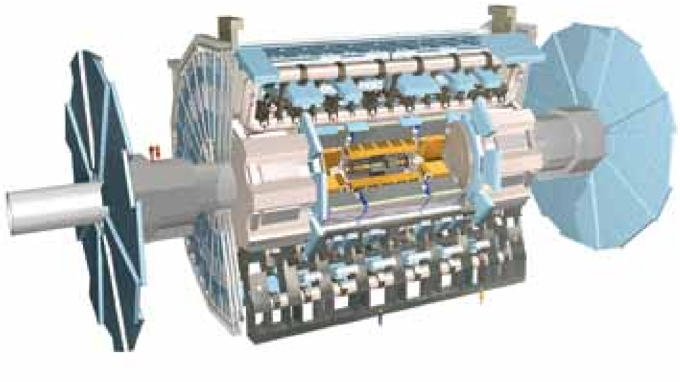


Figure 1: The ATLAS detector, which consists of several sub-components shown in different colours. Particles are created when the protons collide and pass through the detector.

The ATLAS experiment

ATLAS (shown pictorially in figure 1) is a particle detector which surrounds one of the points on the LHC ring where the circulating proton beams are focused together to collide. It detects the particles that are produced when the protons interact, identifies them and measures their kinematic properties.

The aim of the approximately 3,000 scientists in the ATLAS collaboration (including about 20 from UCL) is to discover new particles and to make precise measurements of known particles, in an attempt to understand how our Universe works at a fundamental level. Our current best theory of the building blocks of matter and their interactions is known as the Standard Model (SM) of particle physics, which was developed in the 1960s. While the successes of the theory have been remarkable, there are some weaknesses and experimentalists at ATLAS are working hard to scrutinise it further.

Early Measurements

One of the aims of the LHC is to discover, or exclude, the existence of an elusive particle known as the Higgs boson.

This particle is pivotal to the success of the Standard Model – without it all particles would be massless. If the Higgs exists, the LHC experiments will find it; this is ensured by the unprecedented energy of the proton collisions. As well as the Higgs, many other particles predicted by theories beyond the SM are being searched for at the LHC.

In order to discover new particles, or to study known ones, it is necessary to record and analyse the detector's data from as many collisions of the beams (events) as possible. The number of events of a certain type of process 'seen' by the ATLAS detector is given by multiplying together the cross-section of that process and the integrated luminosity of the colliding beams. The cross-section is a measure of the likelihood of a certain interaction, and is given in units of barns (1 barn = $10^{-28}m^2$). The integrated luminosity is a measure of the number of potentially interacting protons in the beams; it depends on the number of times the beams pass through each other and the density of protons, and is given in units of inverse barns.

There is a huge variation in the size of the cross-section of different possible processes. As an example the total cross-section (i.e. that for any type of interaction to occur) is around 10 orders of magnitude larger than the predicted cross-section for the production of a Higgs boson! In general, potential new particles are produced much less often than many known SM processes; in order to dig out the rare and interesting processes from this large background, it is necessary to first have a good understanding of all these SM processes. During 2010 the LHC delivered 45 x 10^9b^{-1} (45 pb^{-1} (1 pb^{-1} = 10^9b^{-1})) of data to ATLAS, and the collaboration has made many measurements of these SM processes and has already performed searches for new particles.

The total cross-section is dominated by soft (low momentum) interactions, mediated by the strong nuclear force. ATLAS has made measurements of the kinematic distributions of the particles produced in these processes, providing vital input to theoretical models that aim to simulate them.

Less frequently, the strong force is responsible for the production of higher energy particles. Many particles are produced, which cluster together to form a collimated 'jet'. Such jets are among the decay products of many interesting processes, and must be well understood. ATLAS has performed measurements of the kinematic distributions and cross-sections of jets. Encouragingly, the current best theoretical prediction of these distributions is very good.

UCL scientists were among the key authors for these early measurements that are important for laying the groundwork for the rest of the LHC program.

Rediscovering Known Particles and Searching for New Ones

ATLAS has also studied some rare processes. When the protons collide it is possible that two of the constituent particles interact to momentarily produce one of the massive bosons responsible for the weak nuclear force. These particles (known as W and Z bosons) decay almost instantaneously (within about 10^{-25} seconds) and it is their decay products that are seen in ATLAS. They decay either to jets, or to particles known as leptons (lepton is a generic word for electron, muon, tau and neutrino). These leptonic decays leave a striking signature, figure 2 shows a graphical display of a candidate Z boson event, decaying to a muon and an antimuon (the antimatter partner of the muon). Measurements of the cross-section for W and Z production have been performed, which are in excellent agreement with the SM prediction.

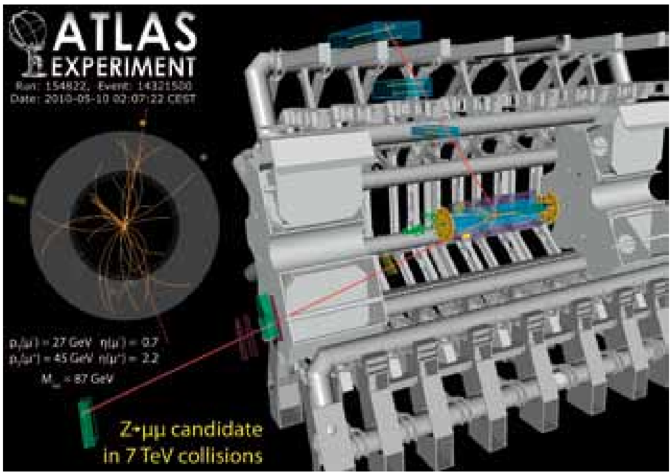


Figure 2: A graphical display of a candidate Z event decaying into a muon and an antimuon. The (anti)muons are shown as red lines. Unlike most other particles, which get absorbed in the calorimeters shown in figure 1, muons pass through the entire ATLAS detector. They can be identified by their presence in the outer most sub-components, known as the muon detectors.

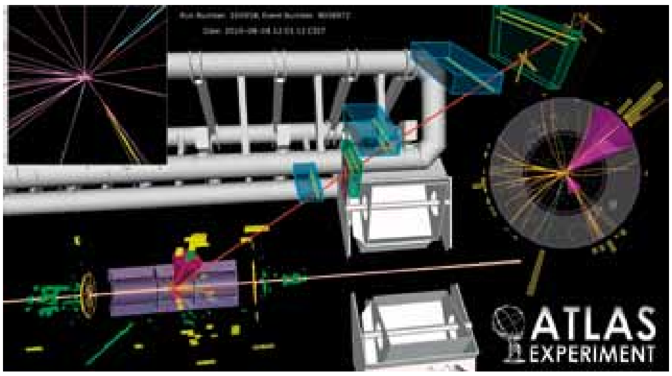


Figure 3: A graphical display of a candidate top quark-antiquark pair. With the top decaying to a jet, an antielectron (positron) and an electron-neutrino, and the antitop decaying to a jet, a muon and an antimuon-neutrino. The muon is indicated by the red line, the antielectron by the green line and the jets by the pink cones. Neutrinos are not directly detected in ATLAS and are therefore not shown.

An even rarer process is the production of a top quark and its antimatter partner. The top quark is the heaviest known SM particle (roughly 200 times the mass of the proton!).

Both the top quark and antiquark decay almost instantaneously to a W boson and a jet. The W boson then decays as discussed above. A graphical display of a candidate for such a process is shown in figure 3, the event is very striking, with many high-energy particles. The cross-section for this process has been measured and again, the results are in excellent agreement with the SM prediction.

As well as re-discovering the known SM particles produced at the unprecedented energy of the LHC, limits have been placed on the existence of potential new particles. It is possible that new particles produced at the LHC could decay into two high-energy jets, their existence would be apparent as bumps in the invariant mass distribution of the jet-pair, centred at the mass of the new particle (the invariant mass of a system of final state particles is a combination of the particle energies and momenta that corresponds to the mass of the decaying particle). Figure 4 shows that the invariant mass distribution contains no such bumps, leading to an exclusion of particles known as 'excited-quarks' with masses less than 1.5 TeV. The existence of excited-quarks would indicate that quarks are not fundamental particles as is currently believed, but rather an agglomeration of as yet unknown constituent particles. ATLAS has also searched for quark compositeness by looking at the angular distribution of the jets – so far no evidence has been found there either.

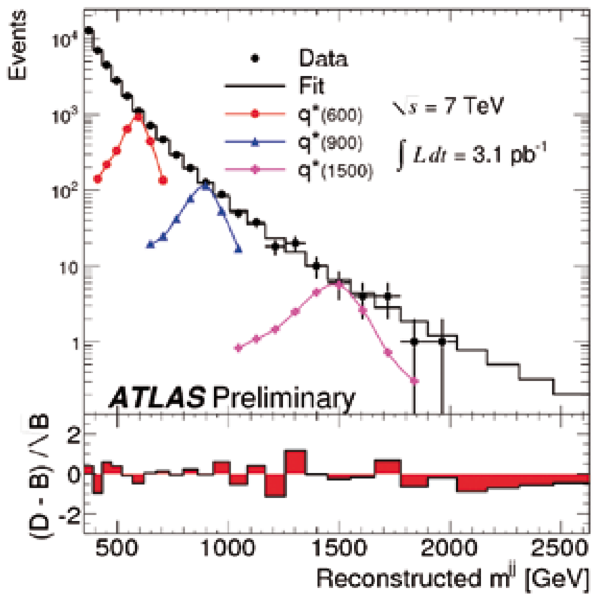


Figure 4: The di-jet invariant mass distribution. The ATLAS data is shown as black points, it is consistent with a smooth distribution and does not contain any bumps. The coloured lines indicate what the distribution would look like if excited quarks existed with various masses.

Switching from Proton to Ion Collisions

Towards the end of 2010 the LHC switched from proton collisions to lead ion collisions, at a reduced centre-of-mass energy of 2.76 TeV. When the lead ions collide, many thousands of particles are produced. ATLAS has investigated the production of jets in these events and observed an interesting phenomenon. Events containing two jets show a very significant imbalance in their momentum component in the direction transverse to the incoming beams (naively one would expect the modulus of the momenta of the jets to be similar due to momentum conservation). The most likely interpretation of this phenomenon is that the lower energy jet has lost most of its momentum through interactions with a hot dense medium formed when the ions collide. This medium is known as a quark-gluon plasma, where quarks and gluons behave like free particles, rather than being confined into protons, neutrons or other 'hadrons'. Figure 5 shows a schematic view of this 'jet-quenching' effect.

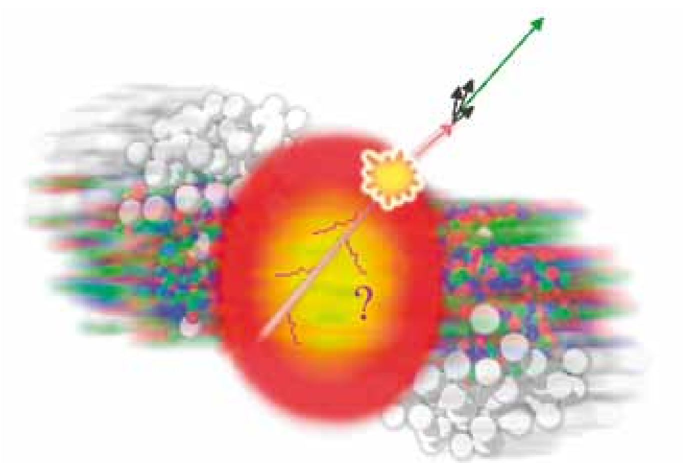


Figure 5: A schematic view of a heavy ion collision. A hot dense medium is indicated by the large circle. The production of a di-jet is shown at the top edge of the medium. One jet enters the ATLAS detector without passing through the medium, the other passes through it and therefore looses a lot of its energy (this process is known as 'jet-quenching').

The Future

In 2010 the ATLAS collaboration performed a successful exploration of many of the known SM processes at the LHC's unprecedented centre-of-mass energy, and is already sensitive to very rare processes. The LHC will continue to run at even higher energies and the next steps will be to re-discover even rarer known processes and to discover, or exclude, the existence of new hypothetical particles. Putting the possible theories of our Universe through thorough experimental tests.

Astrophysics (Astro)

The Astrophysics group at UCL is one of the largest and most active in the UK. Their activities cover a wide range of topics, with subgroups in Atmospheric Physics (APL), Extrasolar Planets, Circumstellar and Interstellar Environments, Massive Stars and Clusters, Galaxies and Cosmology, Star Formation and Astrochemistry, Astronomical Instrumentation (Optical Science Laboratory) and the University of London Observatory (ULO).

First Results from the Herschel Satellite

Project in Focus: Herschel

Aim
To observe the Universe in the far-infrared (where both stars and galaxies which are forming can be discovered)

Results to Date
Many, among which the discovery of warm water vapour around a hot carbon star.

UCL Involvement
A number of UCL staff (see main text) have been involved in both the hardware development and current data analysis.

Last year it was reported on how the Planck and Herschel satellites had been successfully launched, reaching the second Lagrangian point L2 at 1.5 million km from Earth, and had started to send back some amazing pictures. The year 2010 saw the three instruments on board the Herschel Space Observatory producing a large number of images and spectra of objects varying from planets, comets and asteroids in our own solar system; star forming regions, massive stars and supernova remnants in our Milky Way galaxy; out to distant clusters of galaxies at high redshifts. UCL is largely involved with the observation programs of the Herschel satellite. **Prof. Mike Barlow**, **Prof. Bruce Swinyard** and **Dr Roger Wesson** are among the lead authors of the first scientific papers published on the early scientific results from the observatory. **Dr Serena Viti**, **Dr Jeremy Yates**, **Dr Mikako Matsuura** and **Dr Giorgio Savini** are also involved in the data analysis and science exploitation.

Water Vapour found in Carbon Star

One of the main results published was the observations of warm water vapour in the wind from a highly evolved carbon star. The advanced evolution of low and intermediate mass stars (up to 8 times the solar mass) after their main nuclear energy source (hydrogen) is exhausted through a transition to what is called the Asymptotic Giant Branch (AGB) phase. During this period, the star inflates, to hundreds of times its original size, into a red giant that expels most of its mass via a stellar wind containing dust and molecules. Leaving a carbon-rich core which contracts to become a hot white dwarf that can ionize the ejected material, creating what is known as a planetary nebula.

The closest and brightest (in the infrared) AGB star is the carbon star CW Leonis, which has been observed with Herschel's SPIRE and PACS spectrometers. They detected hundreds of emission lines belonging to more than 18 different molecule species, along with an unexpectedly large number of water vapour lines. The first time water was detected from CW Leo was in 2001, when a single transition at around 60 Kelvin had been interpreted as indicating the presence of water only in the outer and cooler layers of the star.

However, the vastly improved data from Herschel has allowed the identification of more than 60 emission lines from water, with excitation temperatures of up to 1000 Kelvin, implying that water is also present in the hotter inner and intermediate envelope of the star. The detection of water vapour lines from the out-flowing wind of a carbon star has required a complete re-evaluation of models for the chemical processes in such flows and testifies to the exceptional capabilities of the spectrometers on-board the Herschel Space Observatory.

Dust Found in Young, Distant Galaxies

Another important result published by members of the Herschel Team at UCL regards new evidence of cold dust in the supernova remnant Cassiopeia A. Observations from ground-based sub-millimetre telescopes have shown evidence of large amounts of dust in young distant galaxies at very high redshifts. Due to their young ages, it has been

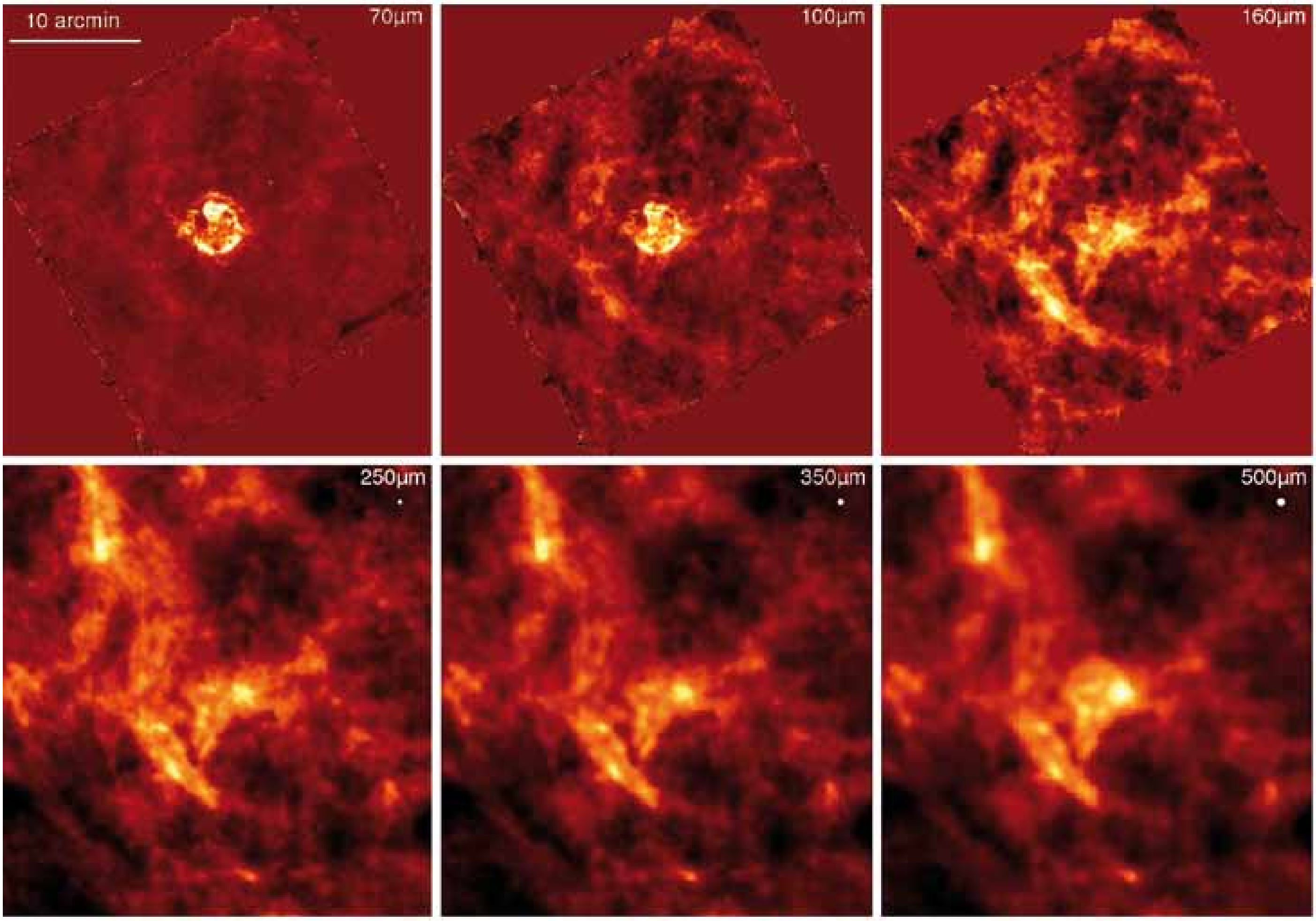


Figure 1: Six images of Cassiopeia A. Precise measurements have been conducted of the thermal dust emission components in the remnants of the supernova, Cassiopeia A. The Herschel PACS and SPIRE photometers were used. The top row shows the three PACS bands at 70, 100 and 160 μm, respectively, the bottom row displays the three SPIRE bands at 250, 350 and 500 μm.

(Reprinted courtesy of Astronomy and Astrophysics)

proposed that the only efficient way of producing dust quickly enough (for the amounts observed) is through the presence of a specific type of supernova caused by the core collapse of massive stars. Theoretical models predict that each supernova could produce an amount of dust equal to between 0.1 and 1 times the mass of our Sun. To study this problem, a relatively young supernova remnant (SNR) needs to be observed, so that the amount of interstellar dust swept up by the expanding shock is insignificant compared with that generated by the supernova itself. With an age of just over 300 years, Cassiopeia A is one of the youngest SNR's known in our galaxy. Previous studies based on ground-based observations and earlier satellite observations (IRAS, ISO) did not succeed in constraining the total dust mass content of Cassiopeia A, for which dust mass estimates had ranged from 0.02 – 4 solar masses.

Observations conducted by Herschel with the PACS and SPIRE photometers led by members of the Astro group have allowed a remarkable improvement, yielding a more precise quantification of the thermal dust emission components present. A bright ring of warm (about 80 Kelvin) dust emission is identified, corresponding to the reverse shock of the SNR. By combining these observations with near-infrared images from the Spitzer Space Telescope and radio maps from the Very Large Array radio-interferometer, an underlying non-thermal component was identified and removed. With the subtraction of the warm dust component and a foreground cold dust component from the PACS and SPIRE maps, a resulting 'cool' (roughly 35 Kelvin) dust component was measured, accounting for 0.08 solar masses of dust.

The First Year of Planck Results

The Planck satellite, in orbit close to Herschel at the second Lagrangian point, has completed its first all sky map in 9 different wavelengths spanning from the radio band (1cm) up to the far-infrared (300 µm). A composite image of the sky, obtained by combining some of these 'colours', can be seen in figure 2a. The satellite, which has also an improved resolution with respect to previous satellites, has released a catalogue identifying more than 15,000 point sources at these long wavelengths.

Project in Focus: Planck

Aim
To perform the most accurate measurements of the cosmic microwave background and learn about the initial conditions of the Universe.

Results to Date
The Early Release Compact Source Catalog contains an all-sky list of point sources found in 9 wavelengths from the far-infrared to radio wavelengths.

UCL Involvement
The high frequency optics on board the satellite were selected and calibrated by Dr G Savini. Cosmological data analysis will be performed at UCL.

Some show the infrared emission of objects known previously from observing at visible or X-ray wavelengths, the catalogue also contains some of the most distant objects ever observed. As a result, many ground-based telescopes have been following up this all-sky coverage by trying to observe optical or radio counterparts to these previously unknown objects.

The X-ray telescope XMM-Newton has also been employed to point at very distant (hence very young) clusters of galaxies. Confirming that the excess of far-infrared and radio signatures in localised areas, corresponds to the presence of large quantities of thermal electrons which also emit at X-ray wavelengths. These electrons 'boost' the underlying microwave background signal (which Planck is designed to accurately measure) and allow us to obtain important information on these objects forming in the first stages of evolution of our universe.

Planck is a multi-national collaboration involving 16 countries, including seven UK institutions. The UCL participation in Planck includes **Dr Giorgio Savini**, who selected and calibrated the optics for the High Frequency Instrument, and **Dr Hiranya Peiris**, who is involved with preparing and interpreting the cosmological data that Planck will harvest in the coming years.

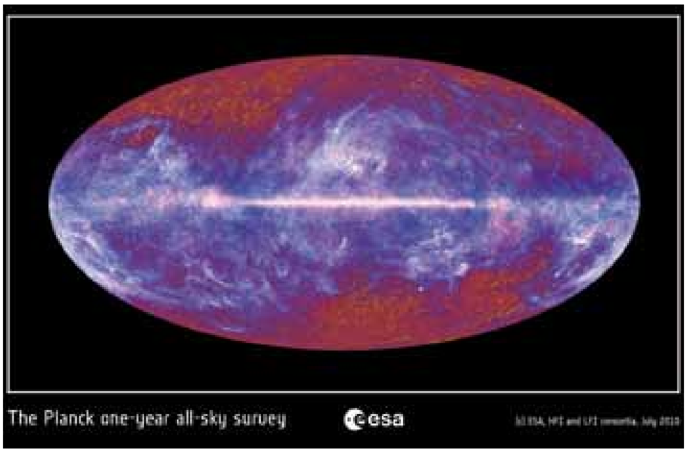


Figure 2a: The first all sky image measured by the Planck satellite. Released by the European Space Agency, it is obtained by combining 9 different wavelengths. The yellow and red channels are the lower frequencies (longer wavelengths), showing the radio emission from the cosmic microwave background. The blue-white colours represent the shorter wavelength thermal emission from the warm and hot dust mainly present in our Galaxy. This emission clearly identifies our Galactic plane at the centre (the image is in Galactic coordinates).

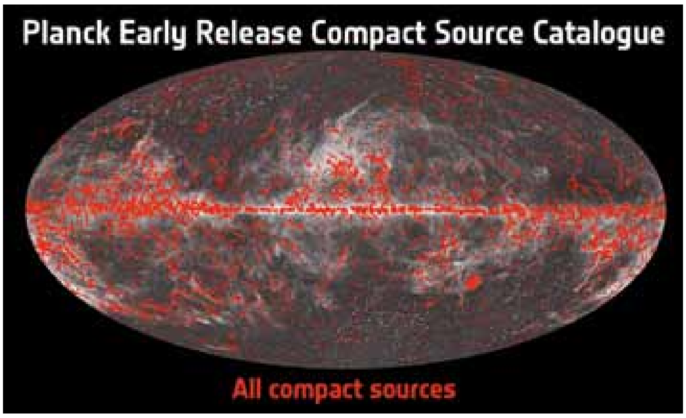


Figure 2b: The compact sources measured by the Planck satellite are superimposed on a greyscale image of the whole sky observed by Planck (by combining 9 different wavelengths, shown here in Galactic coordinates). The horizontal central line, representing the projected disk of our own Galaxy, also shows how most compact sources observed in our Galaxy are cold clumps of dust which are concentrated in the Galactic plane. At higher and lower Galactic latitudes, sources are mainly extragalactic and relatively uniformly distributed.

The Cassini Spacecraft

Project in Focus: Cassini/ Saturn

Aim
To advance our understanding of the physical connections between Saturn's atmosphere, moons, magnetosphere and interplanetary space.

Results to Date
Discovering that the 'water plume' of the icy moon Enceladus is is the main source of material for the planet's E ring. Along with detecting a quasi-periodic 'signal' in the field and particle data whose origin, probably linked to planetary rotation, remains elusive.

UCL Involvement
Scientists at UCL Physics and Astronomy and MSSL are involved in mission science and planning, and in operating the electron spectrometer onboard the spacecraft.

The Cassini-Huygens Spacecraft is one of the most ambitious missions ever launched into space. Loaded with an array of powerful instruments and cameras, the spacecraft is capable of taking accurate measurements and detailed images in a variety of atmospheric conditions and light spectra.

The spacecraft comprises of two elements. The Cassini orbiter and the Huygens probe. In 2004, Cassini-Huygens reached Saturn and its moons. There, the spacecraft began orbiting the system. Huygens entered the murky atmosphere of Titan, Saturn's biggest moon, and descended via parachute onto its surface.

In recent months the Cassini orbiter observed a 'whirlpool' in Saturn's outer magnetosphere. This observation is significant as it indicates that these kinds of vortices, which are also seen at the Earth, seem to be a common mechanism throughout the Solar System. **Dr Nick Achilleos** is involved in analysing this data.

When the Cassini spacecraft travelled towards Saturn it crossed the boundary of the planet's magnetosphere multiple times. The motion of charged particles in this region is dominated by Saturn's magnetic field. During the transition from interplanetary space (the Solar Wind - see below) into the magnetosphere itself, the instruments on board observed a twisted magnetic field topology, and high energy (>20keV, equivalent to >240 million Kelvin) populations of electrons.

These observations are consistent with the presence of a vortex or `whirlpool' at the inner edge of the boundary layer where the growth of the Kelvin-Helmholtz (KH) instability is expected to occur. This is the same instability which produces waves on the Earth's ocean in response to strong winds blowing across the water. The size of this observed vortex was about half the radius of Saturn, or ~30000 km.

The Solar Wind is a stream of protons and electrons which continually moves outwards from the Sun past all of the planets. When this material flows around a magnetosphere, it can become caught up on the ripples or bumps of the Kelvin-Helmholtz vortices. In extreme cases, this process has led to individual 'blobs' of solar plasma breaking off from the flow and penetrating into Earth's magnetosphere, future investigations will look into whether the same thing can happen at Saturn.

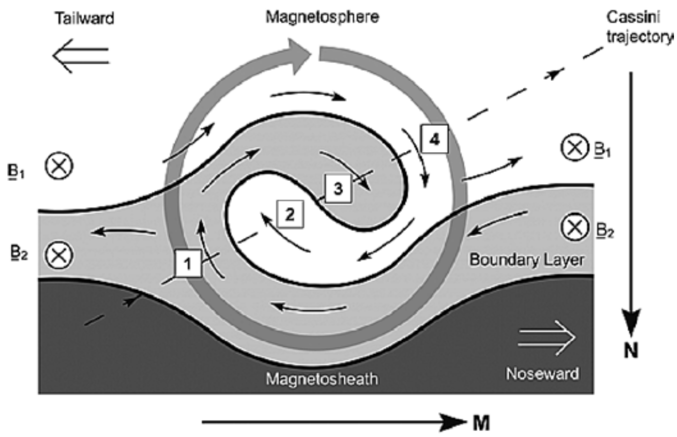


Figure 3: Saturn's whirlpool. A schematic illustration of the 'whirlpool' detected in Saturn's outer magnetosphere by the Cassini obiter. This is a significant observation as it indicates that these kinds of vortices, also seen at the Earth, may be a common mechanism throughout the Solar System.

The labelled regions are: (1) Boundary layer, with mixed solar wind and planetary ion populations; (2) and (3) The 'rolling' vortex structure containing 'twisted up' solar and planetary plasmas and magnetic fields – Cassini observed strong rotations of the field in this region; (4) Saturn's interior magnetosphere.

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Condensed Matter and Materials Physics (CMMP)

Exotic physics is not confined to atomic nuclei or black holes. The materials around us support extraordinary properties that cannot be anticipated by considering fundamental physics. These so-called 'emergent' properties are an increasing focus of attention for materials physicists.

Project in Focus: Magnetricity

Aim
To characterise the magnetic equivalent of electricity carried by magnetic monopoles in spin ice.

Results to Date
Measurement of the charge and current of magnetic monopoles.

Measurement of free and bound magnetic currents and observation of a capacitor effect.

UCL Involvement
Spin ice was discovered at UCL in 1997 and UCL has been the leader in this project for the last 16 years.

The CMMP group at UCL covers the whole spectrum of materials physics from the important and practical (radiation damage, energy research) to the strikingly exotic (emergent quasiparticles). Experimental work on emergent properties involves many techniques, both in-house, and at large central facilities, such as ISIS in the UK or the Institut Laue-Langevin in Grenoble.

The 'emergent' property of magnetism has been studied by **Prof. Steve Bramwell**. The following describes how his research has served to partly restore magnetism's equivalence with electricity.

Magnetism versus Electricity

Magnetism has found technological applications for thousands of years. The ancient Chinese used magnetic rocks in compasses for navigation, and by medieval times such devices were in widespread use across Europe, India and Arabia. Some of the earliest physics of magnetism is traced to the work of William Gilbert of Colchester, who published a great work on the subject, De Magnete ('On the Magnet'), in 1600. He recognised that the earth behaves like a giant bar magnet and that the sources and sinks of its magnetism are close to the north and south poles. Gilbert regarded magnetism as a great force of nature, while he regarded static electricity, which he studied in amber (Latin electricus, 'like amber') as a related, but less important phenomenon. For a while, other physicists, including Kepler, shared this view.

The ascendency of magnetism came to an end in the early 19th century. The voltaic pile had been developed, which allowed physicists like the Danish Professor Hans Christian Oersted, to study electric currents. On 21st April 1820, he noticed during a lecture that a compass needle moved when a nearby electric current was switched off. Further study revealed that magnetism was a by-product of electricity, a property associated with the motion of electrical charge.

Although electromagnetism proved to be an extremely useful property; a crucial component of the electric motor (1821), transatlantic telegraph (1866), and the radio wave (1887), magnetism itself no longer appeared so fundamental.

Nature seemed a distinctly electrical phenomenon and as the properties of matter were gradually elucidated, it became clear that properties of electricity were more versatile and. ultimately, more useful than those of magnetism.

In particular Maxwell's Laws (1861) made it clear that electrical charge is essentially monopolar (individual packets of positive or negative charge can pass through any medium and so conduct electricity), while magnetism is essentially dipolar (they cannot). Furthermore, by the early 20th century, it was realised that magnetic dipoles (which occur in magnetic atoms) are not even a true pair of positive and negative magnetic particles, but merely look like that. An illusion caused by circulating or spinning electrical charges in the atom. Magnetic poles, or charges, can never be separated and it was concluded that there can be no magnetic monopoles, hence no 'magnetricity' to rival the electricity that has become so important in physics, as in our everyday lives.

Dirac's Monopoles

One physicist who did not give up on the possibility of magnetic monopoles was Paul Dirac. He knew that, even if the ends of magnets are not real magnetic monopoles, then they can behave like them. For example, the ends of long thin magnets precisely obey Coulomb's law, as proved by Coulomb himself a century earlier. Dirac realised that the new method of quantum mechanics, of which he was a principal architect, could offer a lifeline to the magnetic monopole.
In 1931 he showed that magnetic monopoles could exist if the electron charge is quantised, and we know that it is! If you consider a long thin bar magnet as a line of magnetic dipoles (a 'Dirac string'), then the magnetic fields of these dipoles sum to make a monopole at each end (figure1). If the electron charge is quantised, this string may become invisible to electrons and effectively ceases to exist, leaving only the monopoles.

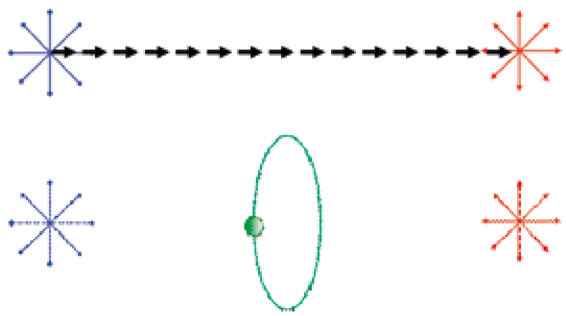


Figure 1: Dirac's vision of the magnetic monopole. (a) A long thin bar magnet consists of a string of magnetic dipoles (pink) whose magnetic fields sum to make a magnetic monopole at either end. (b) The string of dipoles effectively disappears to an orbiting electron if the electron charge and the monopole charge are appropriately quantised.

Today it is believed that Dirac's argument was basically correct and that magnetic monopoles should exist somewhere in the universe. However, they have never been found in experiment, which is said to have left Dirac disillusioned.

Although Dirac's insight somewhat restored the balance between electricity and magnetism, until very recently the prospect of creating magnetic phenomena to rival the diverse properties of electricity seemed very bleak. Nevertheless a ray of hope was offered by American Nobel Laureate Phil Anderson, who's maxim "more is different" can be interpreted as meaning that large assemblies of atoms can produce properties that have no counterpart whatsoever at the microscopic level. Another word for this is 'emergence', new properties are said to emerge from the many-body interactions between atoms, this includes new particle-like objects, called emergent quasiparticles. In every practical sense these quasiparticles are real; one example is so-called 'holes' in semiconductors, positively charged quasiparticles used in silicon electronics, that enable computers or mobile phones to function as they do.

Spin Ice Monopoles

In 1997 a remarkable type of magnetic material called 'spin ice' was discovered at UCL. Spin ice is a simple oxide containing magnetic atoms of 'rare earth' elements such as Dy (dysprosium) or Ho (holmium). For many years it was known that spin ice displayed many intriguing analogies with a well-known electrical material; ice, or solid water, which contains mobile protons (the analogy with ice accounts for the 'ice' in the name spin ice, the 'spin' refers to the electron motion that produces magnetism). However it was only in 2008 that it was realised that spin ice could produce emergent magnetic monopoles, precisely analogous to the protons in ice.

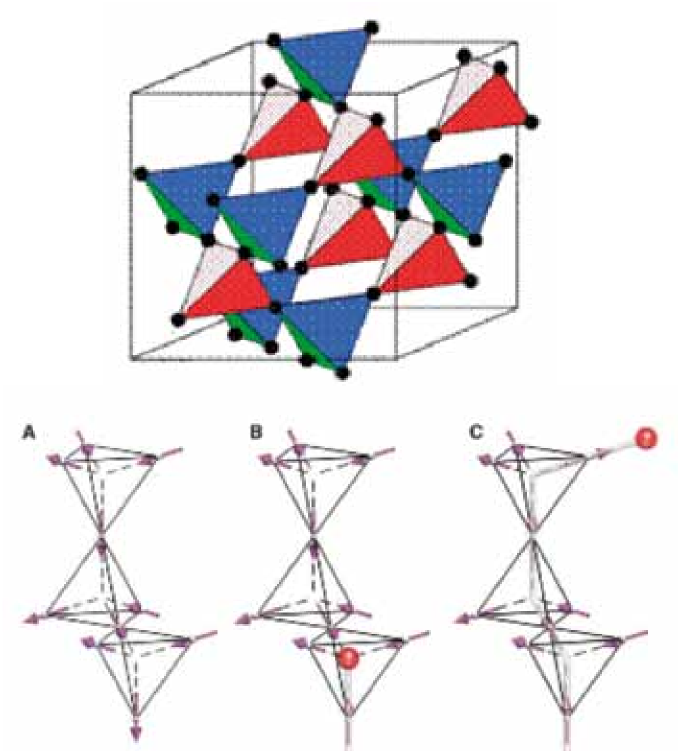


Figure 2: Emergent magnetic monopoles in spin ice. Top: a tiny fragment of the nearly infinite lattice occupied by atomic magnetic dipoles or 'spins' in spin ice. Bottom: (a) the spin ice ground state has two spins in, two out on every tetrahedron. (b) A thermal spin flip generates a pair of defective tetrahedra that behave as magnetic monopoles. (c) The monopoles separate. Although apparently connected by a 'Dirac string' of flipped spins, the strings do not uniquely pair the monopoles, which are therefore free to roam the spin ice crystal, and can even carry current like electrical charges.

What the existence of spin ice proves is that although you can't create magnetic monopoles by chopping magnets in half, you can create them by adding multiple magnets together, a perfect illustration of Anderson's "more is different".

The many-body trick is shown in figure 2. The atomic magnetic dipoles ('spins') of spin ice lie on a tetrahedral lattice. In the ground state, two spins point into, and two out of every tetrahedron. The monopoles are three-in/one-out, or three-out/one-in defects, which are generated thermally like the charge carriers in a semiconductor. Two monopoles of opposite charge appear to be connected by a string of dipoles, but as in Dirac's argument, the string 'disappears'. However, in this case, this is not due to quantum mechanics but as a result of the topology (connectivity) of the problem in three dimensions renders the strings non-unique, thus meaning that the emergent monopoles have no natural partners (formally they are said to be 'deconfined'). The monopoles are thus free to move independently and behave like electrical charges. The charge of the magnetic monopole can be measured in Coulombs and it is found to be about 1/100 of the electron charge.

'Magnetricity'

Recent experimental work at UCL has shown that spin ice supports currents of these magnetic monopoles: a magnetic equivalent of electricity or 'magnetricity'. The monopoles cannot escape the sample, so these currents eventually die away, but they have been observed for several minutes, so are long-lived. Spin ice is found to conduct magnetricity in the same way that an electrolyte conducts electricity, which is much different to the more familiar conduction of a copper wire. In electrolytic conduction, ions hop around randomly but gradually drift in the direction of the electric field or potential. Such electrolytic currents form the basis of important applications in batteries as well as in many biological processes, such as channels in the cell wall.

The magnetic currents of spin ice, like the electrical currents of an electrolyte, show deviations from Ohm's law at strong field. In electrolyte physics, these deviations are universal. The Norwegian theoretician Onsager (1934) defined a dimensionless electric field and showed that when the relative increase in conductivity is plotted against this number, all (weak) electrolytes fall onto the same curve. Onsager's universal curve is shown in figure 3, where the magnetic conductivity of spin ice, measured by two different methods, is shown to collapse onto the curve after simply substituting the electric field for the magnetic field. For good measure, classic electrical data for acetic acid is also shown. This curve proves that an extraordinary symmetry between electricity and magnetism may be restored by the many-body effects of condensed matter.

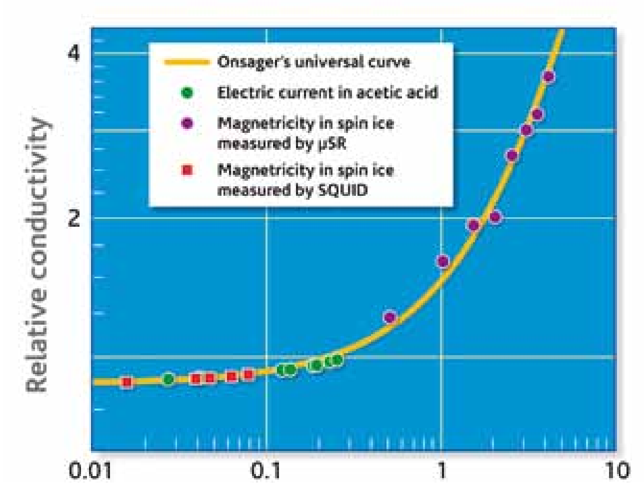


Figure 3: A perfect symmetry between electricity and magnetism revealed by deviations form Ohm's law. The plot shows the relative increase in conductivity versus Onsager's dimensionless electric or magnetic field. The green points refer to electrical conductivity in acetic acid while the red/blue points refer to conductivity of magnetic monopoles in spin ice (measured by magnetometry and muon spin rotation respectively). There are no fitting parameters.

Biological Physics (BioP)

The BioP group is a virtual research group which aims to form 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.

Dr Alexandra Olaya-Castro describes research on the role of quantum phenomena in Biology. This is a question which has fascinated many scientists since the early developments on the quantum theory.

Quantum Effects in Biology

It is well known that quantum mechanics explains the structure and stability of the molecular components of biological systems, what is unknown is how important quantum dynamics are for their biological function, adaptation, fitness and, in general, evolution. In the last decade, sophisticated experimental and theoretical studies are indicating that, indeed, some biomolecular units operate in regimes where quantum dynamics are relevant for their robust and efficient function.

Photosynthetic light-harvesting antennae are biological assemblies where signatures of quantum dynamics such as collective sharing and transfer of electronic excitation, have been detected. These light-harvesting antennae are pigment-protein units present in some bacteria, algae, and higher plants. They are responsible for very efficiently performing the first step in the photosynthesis process, whereby sunlight is absorbed and the associated electronic excitation is transferred to molecular reaction to initiate chemical energy storage.

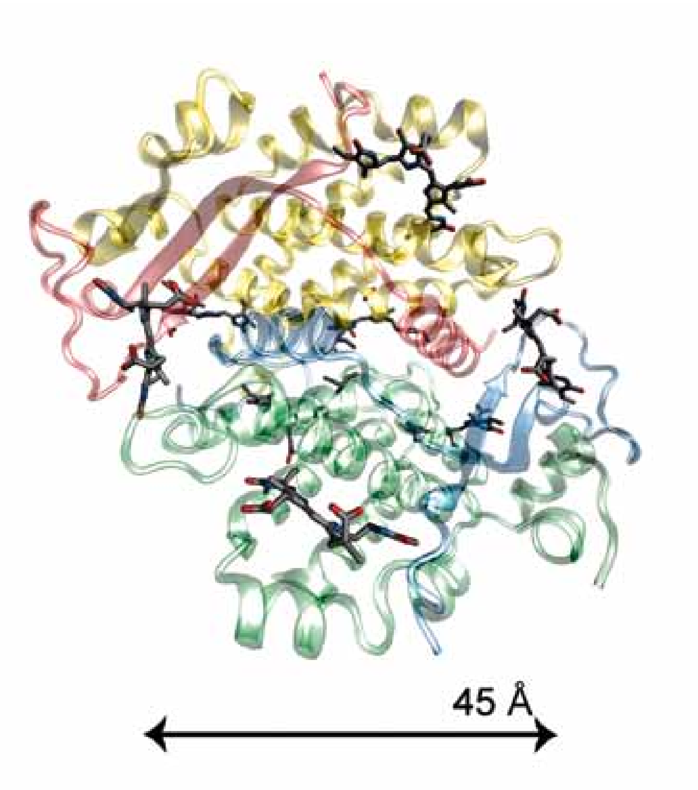
Dr Olaya-Castro is building a research group focused on providing theoretical insights into the way quantum dynamics may be exploited in biological systems. The group is currently investigating the quantum character of energy transfer in photosynthetic complexes. One of the objectives of this research is to explore quantum information metrics that can help elucidate the biological relevance of quantum phenomena for light-harvesting processes in nature.

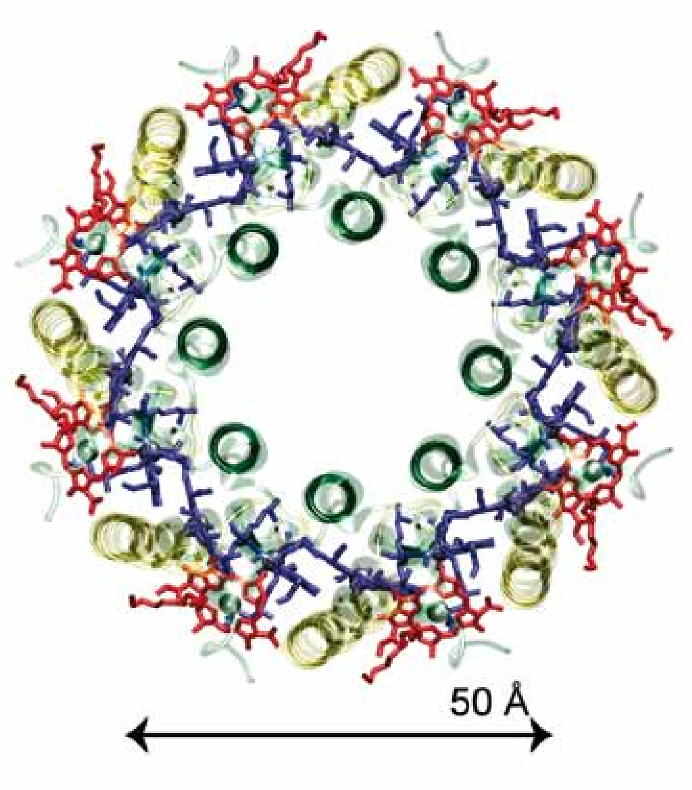
The targeted outcome is a set of quantitative indicators that allow systematic comparison of quantum traits in different light-harvesting antennae. An example of such indicators is how strongly different pigments share an electronic excitation just before energy is transferred from a light-gathering antenna to a reaction centre. In collaboration with Prof. Gregory D Scholes at the University of Toronto, this framework will be used to compare quantum dynamics in light-harvesting antennae that are closely related from an evolutionary perspective. The work will help to assess whether such quantum features may have been selected through biological evolution.

A specific project currently developed by **Dr Olaya-Castro** along with postdoctoral research associate **Dr Avinash Kolli** is a theoretical comparison of photoexcitation dynamics in different cryptophyte antennae proteins found in marine algae. The results indicate important differences according to how pigments are organised and the energy they can absorb (spectral properties). To unravel such differences the group collaborated with a former UCL research fellow, **Dr Ahsan Nazir** to implement a theoretical approach that allows description of quantum dynamics beyond standard approximations.

One of the most interesting biological aspects of some photosynthetic bacteria is their ability to adapt spectral properties of their light-harvesting antennae according to illumination conditions during growth. Currently, very little is known about differences in the energy transfer dynamics associated to such spectral changes. Under the supervision of **Dr Olaya-Castro**, PhD student **Edward O'Reilly** is currently conducting a theoretical study on the variations of the energy transfer properties that go along with spectral adaptation of light-harvesting antennae in photosynthetic purple bacteria.

Understanding the wider implications of quantum phenomena in biology has the potential both to revolutionise our knowledge of the foundations of life as known on Earth and to advance the development of future bio-mimetic quantum technologies with impact to the energy, sensing, and health sectors.





Quantum mechanics explains the structure and stability of the molecular components of biological systems, but it is currently unknown how important quantum dynamics are for their biological function, adaptation and fitness.

***Left**: Structural model of phycoerythrin 545. A light-harvesting antenna isolated from the unicellular cryptophyte marine algae Rhodomonas CS24 whose bilin pigments (black) typically absorb blue to green light (wave lengths from 450nm to 640nm) and are strongly coupled to four protein subunits (blue, yellow, red and green ribbons).*

***Right**: Structural model of a light-harvesting antenna II (LH2). Isolated from purple bacteria Rhodospilirum molischianum. An LH2 contain a large number of densely packed pigments (red and blue) attached to a protein (green and yellow ribbons) and interacting optimally for absorption of light in the blue and red region (800-850 nm). The absorption properties of these LH2's can change according to the light conditions the photosynthetic organism was exposed to while growing.*

These pigment-protein complexes work collectively to absorb sunlight and rapidly transfer light energy to other proteins and eventually to molecular reaction centers where conversion into chemical energy for life processes begins.

Active Grants and Contracts (Jan 2010 – Dec 2010)

Astrophysics

Smart X-Ray Optics (EPSRC) £2,806,334 PI: Doel, Dr Peter

A Wide-Field Corrector for the Dark Energy Survey (STFC) £1,762,660 PI: Lahav, Prof Ofer

Integrated Knowledge Centre in Ultra Precision and Structured Surfaces (EPSRC) £391,852 PI: Walker, Prof David

On-Machine Metrology for Surface Fabrication (STFC) £298,258 PI: Walker, Prof David

Detecting Biosignatures from Extrasolar Worlds (STFC) £274,039 PI: Tinetti, Dr Giovanna

The E-Merlin Radio Astronomy Revolution: Developing the Science Support Tool (Leverhulme Trust) £124,272 PI: Prinja, Prof Raman

Observing Dark Energy (Royal Society) £100,000 PI: Lahav, Prof Ofer

Modelling and Observations of Planetary Atmospheres: The Solar System and Beyond (STFC) £700,631 PI: Aylward, Prof Alan

Cosmology: From Galaxy Surveys to Dark Matter and Dark Energy (STFC) £829,993 PI: Lahav, Prof Ofer

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

Universe Today: Cosmology, Astrophysics and Technology in Your Classroom (STFC) £7,500 PI: Howarth, Prof Ian

Quantifying the Dark Universe Using Cosmic Graviational Lensing (Royal Society) £268,740 PI: Bridle, Dr Sarah

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

KTP with Zeeko Ltd (Zeeko Ltd) £82,261 PI: King, Dr Christopher

KTP with Zeeko Ltd (AEA Technology Plc) £126,409 PI: King, Dr Christopher

Europlanet RI – European Planetology Network Research Infrastructure (European Commission FP7) £222,209 PI: Miller, Prof Steven

Exploring Extrasolar Worlds: From Terrestrial Planets to Gas Giants (Royal Society) £416,740 PI: Tinetti, Dr Giovanna

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

Effects of Radiation Feedback on Star and Planet Formation (STFC) £410,179 PI: Barlow, Prof Michael

Comets as Laboratories: Observing and Modelling Cometary Spectra (STFC) £185,912 PI: Miller, Prof Steven

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

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

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

University Research Fellowship (Royal Society) £473,093 PI: Abdalla, Dr Filipe

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

The Miracle Consortium: Modelling the Universe - from Atomic to Large Scale Structures (STFC) £557,483 PI: Miller, Prof Steven

Large Aperture Telescope Technology (European Space Agency (ESA)) £22,921 PI: Doel, Dr Peter

Astronomy in the Classroom: School and Observatory Visits (STFC) £7,465 PI: Howarth, Prof Ian

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

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

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

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

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

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

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

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

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

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

High Energy Physics

EUDET- Detector Research and Development Towards the International Linear Collider (European Commission) £272,000 PI: Wing, Prof Matthew

Investigation of the Electroweak Symmetry Breaking and the Origin of Mass Using the First Data of the ATLAS Detector at the LHC (European Commission) £293,000 PI: Konstantinidis, Dr Nikolaos

Investigating Neutrino Oscillations with MINOS and Neutrino Astronomy with ANITA (Royal Society) £447,868 PI: Nichol, Dr Ryan

Experimental High Energy Particle Physics Research at UCL (STFC) £5,724,080 PI: Lancaster, Prof Mark

MCNET – Monte Carlo Event Generators for High Energy Particle Physics (European Commission) £171,986 PI: Butterworth, Prof Jonathan

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

ATLANTIS Event Display (STFC) £138,166 PI: Konstantinidis, Dr Nikolaos

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

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

Search for a Vector Boson Fusion Produced Higgs Boson at ATLAS (Royal Society) £395,133 PI: Nurse, Dr Emily

Deputy Chair of Science Board and PP&N KE Coordinator (STFC) £209,644 PI: Thomas, Prof Jennifer

PNPAS Knowledge Exchange Award: CREAM TEA – Phase 1 (STFC) £125,000 PI: Nichol, Dr Ryan

Electroweak Symmetry Breaking and Jet Physics with ATLAS at the LHC (Royal Society) £85,000 PI: Butterworth, Prof Jonathan

Studentship for SuperNEMO Design Study (STFC) £15,808 PI: Saakyan, Dr Ruben

IPPP Associateships 2009-10 (University of Durham) £8,000 PI: Thorne, Prof Robert

HIGGS-ZAP – Understanding the Origin of Mass with the ATLAS Experiment at the Large Hadron Collider (European Commission FP7) £33,750 PI: Konstantinidis, Dr Nikolaos

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

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

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

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

SuperNEMO Demonstrator Module Construction (STFC) £297,427 PI: Saakyan, Dr Ruben

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

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

GRIDPP3 Tranche 2 Londongrid UCL Grant (STFC) £8,100 PI: Waugh, Dr Ben

Royal Society Leverhulme Trust Senior Fellowship (Royal Society) £20,705 PI: Thomas, Prof Jennifer

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

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

Higgs Physics and the Mystery of Particle Masses (Royal Society) £521,334 PI: Hesketh, Dr Gavin

Atomic, Molecular, Optical and Positron Physics

Manipulating Molecules with Optical Fields (EPSRC) £237552 PI: Barker, Prof Peter

Fellowship: Dr S Bose: Spin Chain Connectors, Entanglement by Measurements and Mesoscopic Quantum Coherence (EPSRC) £776411 PI: Bose, Prof Sougato

Joint Appointment for Dr Jonathan Underwood (STFC) £184,743 PI: Underwood, Dr Jonathan

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

Pairing and Molecule Formation in Cold Atomic Bose and Fermi Gases (EPSRC) £855,267 PI: Kohler, Dr Thorsten

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

Quantum Information Uses of Complex Systems and Limits of the Quantum World (Royal Society) £75,000 PI: Bose, Prof Sougato

Suppressing Decoherence in Solid-State Quantum Information Processing (EPSRC) £258,549 PI: Nazir, Dr Ahsan

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

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

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

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

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

Fundamental Issues in the Aerothermodynamics of Planetary-Atmosphere (re) Entry (European Space Agency (ESA)) £27,843 PI: Tennyson, Prof Jonathan

A Database of Water Transitions (NERC) £185,336 PI: Tennyson, Prof Jonathan

Pairing and Molecule Formation in Ultracold Atomic Gases (Royal Society) £268,740 PI: Kohler, Dr Thorsten

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

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

VAMDC – Virtual Atomic and Molecular Centre (European Commission FP7) £329,960 PI: Tennyson, Prof Jonathan

Quantum Networks Dynamics (Royal Society) £84,000 PI: Bose, Prof Sougato

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

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

Dynamics of Information in Quantum Many-Body Systems (Royal Society) £378,192 PI: Anders, Dr Janet

Metrology in Cold Atoms (British Council) £3,240 PI: Renzoni, Prof Ferruccio

Phys4entry – Planetary Entry Integrated Models (European Commission FP7) £139,200 PI: Tennyson, Prof Jonathan

Efficient Silicon Multi-Chip System-In-Package Intergration – Reliability Failure Analysis and Test (Technology StrategyBoard) £283,488 PI: Tennyson, Prof Jonathan

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

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

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

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

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

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

Condensed Matter and Materials Physics

Development of Structural Coherent X-Ray Diffraction (Royal Society) £9,988 PI: Robinson, Prof Ian

Laser Materials Interaction: Ashley Garvin (Pacific Northwest National Laboratory) £42,400 PI: Shluger, Prof Alexander

Development of Simultaneous Diffraction-Conductance Measurements at ISIS (STFC) £29,000 PI: Skipper, Prof Neal

Advanced Gate Stack and Dielectric in Resistive Memory Material (International Sematech) £38,333 PI: Shluger, Prof Alexander

Threaded Molecular Wires as Supramolecularly Engineered Multifunction Materials (European Commission) £569,585 PI: Cacialli, Prof Franco

Plasmonic Nanostructures for Enhanced Sensitivity in Sensors and Biosensors (British Council) £4,000 PI: Cacialli, Prof Franco

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

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

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

Nanomaterials for Biomolecular Sciences and Nanotechnology (Royal Society) £136,008 PI: Nguyen, Dr Thanh

ONE-P – Organic Nanomaterials for Electronics and Photonics: Design, Synthesis, Characterization, Processing Fabrication and Applications (European Commission FP7) £301,788 PI: Cacialli, Prof Franco

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

Bio-Functional Magnetic Nanoparticles: Novel High-Efficiency Targeting Agents for Localised Treatment of Metastatic Cancers (EPSRC) £12,635 PI: Pankhurst, Prof Quentin

Computer Simulation of Redox and Hydrolysis Reactions in Enzymatic Systems (Royal Society) £197,606 PI: Blumberger, Dr Jochen

Computational Modelling of Two- and One-Dimensional Electron Gas in Oxide Heterostructures (Tohoku University) £7,500 PI: Sushko, Dr Peter

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

Electron Gas in Reduced Ionic Insulators and Semiconductors (Royal Society) £473,769 PI: Sushko, Dr Peter

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

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

Modelling Electron Transport in Multi-Heme Proteins (Pacific Northwest National Laboratory) £10,673 PI: Blumberger, Dr Jochen

Publications 2010

Astrophysics

1. Ladjal D, Justtanont K, Groenewegen MAT, Blommaert JADL, Waelkens C, Barlow MJ, **870 µm observations of evolved stars with LABOCA**, Astronomy & Astrophysics (A&A), 513, A53 (2010)

2. Swain MR, Deroo P, Griffith CA, Tinetti G, Thatte A, Vasisht G, Chen P, *et al*, **A ground-based near-infrared emission spectrum of the exoplanet HD 189733b.**,Nature, 463, 637-639 (2010)

3. Barlow MJ, Krause O, Swinyard BM, Sibthorpe B, Besel MA, Wesson R, Ivison RJ, et al, **A Herschel PACS and SPIRE study of the dust content of the Cassiopeia A supernova remnant**, A&A, 518, L138 (2010)

4. Cernicharo J, Waters LBFM, Decin L, Encrenaz P, Tielens AGGM, Agundez M, Beck ED, *et al*, **A high resolution line survey of IRC+10216 with Herschel. First results: Detection of warm silicon dicarbide SiC2**, A&A, 521, L8 (2010)

5. Evans CJ, Walborn NR, Crowther PA, Henault-Brunet V, Massa D, Taylor WD, Howarth ID, *et al*, **A massive runaway star from 30 doradus**, Astrophysical Journal Letters (AJL), 715, L74-L79 (2010)

6. Achilleos N, Guio P, Arridge CS, **A model of force balance in Saturn's magnetodisc**, Monthly Notices of the Royal Astronomical Society (MNRAS), 401, 2349-2371 (2010)

7. Fridlund M, Eiroa C, Henning T, Herbst T, Kaltenegger L, Léger A, Liseau R, *et al*, **A roadmap for the detection and characterization of other Earths.**, Astrobiology, 10, 113-119 (2010)

8. Stock DJ, Barlow MJ, **A search for Ejecta Nebulae around Wolf-Rayet Stars using the SHS Hα survey,** MNRAS, 409, 4, 1429-1440 (2010)

9. Barnes JR, Barman TS, Jones HRA, Barber RJ, Hansen BMS, Prato L, Rice EL *et al*, **A search for molecules in the atmosphere of HD 189733b**, MNRAS, 401, 445-454 (2010)

10. Bockelée-Morvan D, Hartogh P, Crovisier J, Vandenbussche B, Swinyard BM, Biver N, Lis DC *et al*, **A study of the distant activity of comet C/2006 W3 (Christensen) using Herschel and ground-based radio telescopes**, A&A, 518, L149 (2010)

11. Ita Y, Onaka T, Tanabe T, Matsunaga N, Matsuura M, Yamamura I, Nakada Y *et al*, **AKARI near- to mid-infrared imaging and spectroscopic observations of the small magellanic cloud. I Bright Point Source List**, Publications of the Astronomical Society of Japan (Pub. Ast. Soc. Jpn.), 62, 273-286 (2010)

12. Ita Y, Matsuura M, Ishihara D, Oyabu S, Takita S, Kataza H, Yamamura I *et al*, **AKARI's infrared view on nearby stars using AKARI infrared camera all-sky survey, 2MASS, and hipparcos catalogs**, A&A, 514, A2 (2010)

13. van der Werf PP, Isaak KG, Meijerink R, Spaans M, Rykala A, Fulton T, Loenen AF *et al*, **Black hole accretion and star formation as drivers of gas excitation and chemistry in Markarian 231**, A&A, 518, L42 (2010)

14. Masters A, Achilleos N, Kivelson MG, Sergis N, Dougherty MK, Thomsen MF, Arridge CS *et al,* **Cassini observations of a Kelvin-Helmholtz vortex in Saturn's outer magnetosphere,** Journal of Geophysical Research – Space Physics (JGR-Space Phys), 115, 7225 (2010)

15. Lerate MR, Yates JA, Barlow MJ, Viti S, Swinyard BM, **Chemical and radiative transfer modelling of the ISO-LWS Fabry-Perot spectra of Orion-KL water lines**, MNRAS, 406, 2445-2451 (2010)

16. Molinari S, Swinyard B, Bally J, Barlow M, Bernard JP, Martin P *et al*, **Clouds, filaments, and protostars: The Herschel Hi-GAL Milky Way**, A&A, 518, L100 (2010)

17. Peiris HV, Smith TL, **CMB isotropy anomalies and the local kinetic Sunyaev-Zel'dovich effect**, Physical Review D (Phys. Rev. D), 81,123517 (2010)

18. Grenfell JL, Rauer H, Selsis F, Kaltenegger L, Beichman C, Danchi W, Eiroa C *et al*, **Co-evolution of atmospheres, life, and climate**, Astrobiology, 10, 77-88 (2010)

19. Kim S, Kwon E, Madden SC, Meixner M, Hony S, Panuzzo P, Sauvage M *et al*, **Cold dust clumps in dynamically hot gas**, A&A, 518, L75 (2010)

20. Boyer ML, Sargent B, van Loon JT, Srinivasan S, Clayton GC, Kemper F, Smith LJ *et al*, **Cold dust in three massive evolved stars in the LMC**, A&A, 518, L142 (2010)

21. Guio P, Pecseli HL, **Collisionless plasma shocks in striated electron temperatures**, Physics Review Letters (Phys. Rev. Lett.),104, 31301 (2010)

22. Cypriano ES, Amara A, Voigt LM, Bridle SL, Abdalla FB, Refregier A, Seiffert M *et al*, **Cosmic shear requirements on the wavelength-dependence of telescope point spread functions**, MNRAS, 405, 494-502 (2010)

23. Pontzen A, Peiris H, **Cosmology's not broken**, New Scientist, 207, 22- 23 (2010)

24. Calder L, Lahav O, **Dark energy: how the paradigm shifted**, Physics World, 23, 1, 32-37 (2010)

25. Martins F, Donati JF, Marcolino WLF, Bouret JC, Wade GA, Escolano C, Howarth ID *et al*, **Detection of a magnetic field on HD108: clues to extreme magnetic braking and the Of?p phenomenon**, MNRAS, 407, 1423-1432, (2010)

26. Cernicharo J, Decin L, Barlow MJ, Agundez M, Royer P, Vandenbussche B, Wesson R *et al*, **Detection of anhydrous hydrochloric acid, HCl, in IRC+10216 with the Herschel SPIRE and PACS spectrometers Detection of HCl in IRC+10216**, A&A, 518, L136 (2010)

27. Ossenkopf V, Müller HSP, Lis DC, Schilke P, Bell TA, Bruderer S, Bergin E *et al*, **Detection of interstellar oxidaniumyl: abundant H_2O^+ towards the star-forming regions DR21, Sgr B2, and NGC6334**, A&A, 518, L111 (2010)

28. Bewsher D, Brown DS, Eyles CJ, Kellett BJ, White GJ, Swinyard B, **Determination of the Photometric Calibration and Large-Scale Flatfield of the STEREO Heliospheric Imagers: I. HI-1**, Solar Physics, 264, 433-460 (2010)

29. Gordon KD, Galliano F, Hony S, Bernard JP, Bolatto A, Bot C, Engelbracht C *et al*, **Determining dust temperatures and masses in the Herschel era: The importance of observations longward of 200 micron**, A&A, 518, L89, (2010)

30. Bayet E, Awad Z, Viti S, **Deuterated species in extragalactic star-forming regions**, Astrophysical Journal (ApJ), 725, 214, (2010)

31. Muxlow TWB, Beswick RJ, Garrington ST, Pedlar A, Fenech DM, Argo MK, van Eymeren J *et al*, **Discovery of an unusual new radio source in the star-forming galaxy M82: faint supernova, supermassive black hole or an extragalactic microquasar?,** MNRAS, 404, L109-L113 (2010)

32. Otsuka M, van Loon JT, Long KS, Meixner M, Matsuura M, Reach WT, Roman-Duval J *et a*l, **Dust in the bright supernova remnant N49 in the LMC**, A&A, 518, L139 (2010)

33. Dvorak R, Pilat-Lohinger E, Bois E, Schwarz R, Funk B, Beichman C, Danchi W *et al*, **Dynamical habitability of planetary systems.**, Astrobiology, 10, 33-43 (2010)

34. Hwang HS, Elbaz D, Magdis GE, Daddi E, Symeonidis M, Altieri B, Amblard A *et al*, **Evolution of dust temperature of galaxies through cosmic time as seen by Herschel**, MNRAS, 45, 75-82 (2010)

35. Abergel A, Arab H, Compiegne M, Kirk JM, Ade P, Anderson LD, Andre P *et al*, **Evolution of interstellar dust with Herschel. First results in the photodissociation regions of NGC7023**, A&A, 518, L96 (2010)

36. Tinetti G, Griffith CA, Swain MR, Deroo P, Beaulieu JP, Vasisht G, Kipping D *et al*, **Exploring extrasolar worlds: from gas giants to terrestrial habitable planets**, Faraday Discussions Royal Society of Chemistry, 147, 19 (2010)

37. Tinetti G, Griffith CA, **Exploring extrasolar worlds today and tomorrow**, Astronomical Society of the Pacific Conference Series, Pathways Towards Habitable Planets, 430, 115 (2010)

38. Banerji M, Ferreras I, Abdalla FB, Hewett P, Lahav O, **Exploring the luminosity evolution and stellar mass assembly of 2SLAQ luminous red galaxies between redshifts 0.4 and 0.8**, MNRAS, 402, 2264-2278 (2010)

39. Bacmann A, Caux E, Hily-Blant P, Parise B, Pagani L, Bottinelli S, Maret S, et al, **First detection of ND in the solar-mass protostar IRAS16293-2422**, A&A, 521, L42 (2010)

40. Eales SA, Raymond G, Roseboom IG, Altieri B, Amblard A, Arumugam V, Auld R *et al*, **First results from HerMES on the evolution of the submillimetre luminosity function**, A&A, 518, L22 (2010)

41. Lahav O, Kiakotou A, Abdalla FB, Blake C, **Forecasting neutrino masses from galaxy clustering in the Dark Energy Survey combined with the Planck measurements**, MNRAS, 405, 168-176, (2010)

42. Abdalla FB, Blake C, Rawlings S, **Forecasts for dark energy measurements with future H i surveys**, MNRAS, 401, 743-758 (2010)

43. Islam F, Cecchi-Pestellini C, Viti S, Casu S, **Formation pumping of molecular hydrogen in dark clouds**, ApJ, 725, 1111-1123, (2010)

44. Banerji M, Lahav O, Lintott CJ, Abdalla FB, Schawinski K, Bamford SP, Andreescu D *et al*, **Galaxy Zoo: reproducing galaxy morphologies via machine learning star**, MNRAS, 406, 342-353 (2010)

45. Lammer H, Selsis F, Chassefière E, Breuer D, Griessmeier JM, Kulikov YN, Erkaev NV *et al*, **Geophysical and atmospheric evolution of habitable planets.**, Astrobiology, 10, 45-68 (2010)

46. Carbary JF, Achilleos N, Arridge CS, Khurana KK, Dougherty MK, **Global configuration of Saturn's magnetic field derived from observations,** Geophysical Research Letters (GRL), 37, 21806 (2010)

47. Cava A, Rodighiero G, Perez-Fournon I, Buitrago F, Trujillo I, Altieri B, Amblard A *et al*, **HerMES : SPIRE detection of high redshift massive compact galaxies in GOODS-N field**, MNRAS, 409, L19-L24 (2010)

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