UCL DEPARTMENT OF PHYSICS AND ASTRONOMY

PHYSICS AND ASTRONOMY
ANNUAL REVIEW
2008

Contents

Cover image: Threaded molecular wire

This image was produced by **Dr Sergio Brovelli** and refers to recent results obtained by the group of **Professor Franco Cacialli**. The molecular wire consists of a semiconducting conjugated polymer supramolecularly encapsulated (i.e. with no covalent bonds) into cyclodextrin macrocycles (in green). This class of organic functional materials gives highly controllable optical properties and higher luminescence efficiency when employed as the active layer in light-emitting diodes. The supramolecular shield prevents potentially detrimental intermolecular interactions and preserves single-molecule photophysics even at high concentration.

Introduction

The old Chinese curse says "May you live in interesting times" and 2008 was certainly an interesting year.

The years end was awaited with interest by all UK academics for the announcement of the results of the final Research Assessment Exercise (RAE). The results arrived using a new scoring system which makes them harder to interpret, or more precisely open to a number of differing interpretations. However what is clear in the outcome for Physics at UCL, which includes the Department of Space and Climate Physics (aka MSSL) and much of the Department of Medical Physics and Bioengineering, was a strong endorsement of our excellence in research. We are now clearly established as one of the four major centres of physics research in the UK. As I write we are awaiting a further announcement explaining the consequences of this for our finances.

The year started in less promising fashion with a major funding crisis in the Science and Technology Funding Council (STFC). Many members of the Department were involved in this both in trying to help pilot STFC through very choppy waters and as major recipients of their funding support. Our Astrophysics group were particularly unfortunate in the timing of the crisis, as it arrived just as the majority of the groups funding was due to be renewed. UCL has moved to ensure that years of research excellence in fundamental physics are not destroyed by what I hope is a short term funding blip. Besides offering targeted emergency support to make sure key projects are not abruptly terminated, the Provost has generously supported the new Institute for Origins, see page 15, which seeks to combine UCL strengths in fundamental physics and astronomy. The major investment in research computing as represented by Legion, see page 12, also provides key underpinning support to the STFC science area.

It was my pleasure a year ago to document that UCL had scooped no less than four of the major awards made by the Institute of Physics (IOP) for 2008. There is no such announcement this year for no other reason than the IOP have changed their schedules and the 2009 awards will be announced later in the year. However we have already heard that **Professor David Williams**, Emeritus Perrin Professor of Astronomy and still an active member of the Department, has been award the 2009 Gold Medal by the Royal Astronomical Society (RAS), their highest honour, for his work on astrochemistry. In addition, **Dr Sarah Bridle**, newly promoted to Reader in Astrophysics, has been awarded the RAS Fowler Prize for her early career work in cosmology. A full report on these prizes will appear in next year's annual review.

Fostering the career of young and talented scientists is key part of maintaining a flourishing Department. It is therefore with particular pleasure that I note the award of no less than six long-term Fellowships to young scientists wishing to start their independent academic careers at UCL, see page 8. These Fellowships are deeply competitive as they attract world wide attention resulting in success rates of 5% or less. In this context the award of no less than 4 Royal Society University Research Fellowship to be held in the Department (or jointly with the London Centre of Nanotechnology) is a particularly spectacular result. The Royal Society award just over 40 of these annually over all disciplines.

To end on a personal note: I am now in my fifth year of a five year term of office as Head of Department. I have recently accepted the offer to serve in this role for a further five year period. I hope (and fear) that the next five years will be as interesting as the last five.

Professor Jonathan Tennyson
Head of Department

Physics and Astronomy Students

Student Entry and Pass Figures for 2008

Undergraduates

Entrants: 100

BSc Degrees			
1st 9	**2:1** 5	**2:2** 1	**3rd** 4

MSc Degrees			
1st 20	**2:1** 21	**2:2** 10	**3rd** 1

Postgraduates

MSc entrants: 11
PhD entrants: 28

MSc Degrees	
Distinction 5	**Pass** 4

PhD Degrees
Pass 22

NB: Numbers specified are head counts

2008 PRIZE WINNERS

UNDERGRADUATE PRIZES

HOLLY ALEXANDER
Huggins Prize
(Best performance 2nd year Astronomy)
C.A.R. TAYLER PRIZE
(Best 2nd Year Essay)

SETRAK BALIAN
Wood Prize
(Best performance 2nd year Physics)

YUVAL BEN HAIM
Best Performance 3rd Year Physics
& **William Bragg Prize**
(Best overall undergraduate)

ALEXANDER DUNNING
Corrigan Prize
(Best performance in experimental work, 2nd year)

DAVID JOHNSON
David Ponter Prize
(Most improved performance in Department, 2nd year)

KALLE KARHUNEN
Best Performance 3rd Year Astronomy

KATARINA MARKOVIC
Brian Duff Memorial Prize
(Best 4th Year project in the department)

KIRITHIKA MOHAN
Halley Prize
(Best performance 1st year Astronomy)

CALLUM NOBLE
Burhop Prize
(Best performance 4th year Physics)

FRANCISCUS PRINS
Additional Sessional Prize for Merit

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

DANIEL SHORT
Herschel Prize
(Best performance 4th year Astronomy)

SIDNEY TANOTO
Additional Sessional Prize for Merit

WEI ZHOU
Oliver Lodge Prize
(Best performance 1st year Physics)

POSTGRADUATE PRIZES

CHRISTOPHER HADLEY
Carey Foster Prize
(Postgraduate Research, Physics AMOPP)

TOMMI KOSKINEN
Jon Darius Prize
(Outstanding Postgraduate Research, Astronomy)

ARTHUR LOVELL
Marshall Stoneham Prize
(Postgraduate Research, Physics CMMP)

DANIEL NICHOLASS
Hepp Group
(Postgraduate Research, Physics HEP)

ZIRI YOUNSI
Harrie Massey Prize
(Most Outstanding MSc student)

PhDs AWARDED

Jennifer C Brookes
A microscopic model of signal transduction mechanisms: Olfaction (Supervisor Prof. Marshall Stoneham)

Mark Dorman
Cross section measurements for quasi-elastic neutrino-nucleus scattering with the MINOS near detector (Supervisor Prof. J Thomas)

Natasha Doss
Calculated final state probability distributions for T_2 β-decay measurements (Supervisor Prof. Jonathan Tennyson)

Christina Dunn
Pseudo-random toolpaths for deterministic surface processing (Supervisor Dr D Walker)

Flemming Ehlers
Modelling of the interaction of Cu and rare earth metal with Si(001) (Supervisor Dr D Bowler)

Hannah Fox
New statistical mechanical simulation methods for the calculation of surface properties (Supervisor Prof. M J Gillan)

Gabriela Halmova
R-matrix calculations of electron-molecule collisions with C_2 and C_2^- (Supervisor Prof. Jonathan Tennyson)

Clare E Jenner
A new semi-analytical treatment of the effect of supernovae on ULIRG spectral energy distributions (Supervisors Prof. M J Barlow, Dr J Yates)

Christopher King
A new approach to stitching optical metrology data (Supervisor Dr D Walker)

Tommi Koskinen
Stability of short-period exoplanets (Supervisor Prof. Alan Aylward)

Ho-Chih Lin
Local approach to quantum entanglement (Prof. Andrew Fisher)

Daniel Nicholass
The study of D+- and D0 meson production in deep inelastic scattering at HERA II with the ZEUS detector (Supervisor Dr M Wing)

Nick Nicolaou
Single and two-photon fluorescence studies of linear and nonlinear optical chromophores (Supervisor Dr A J Bain)

Matthew North
Rapid rotation in Be Stars
(Supervisor Prof. Ian Howarth)

Chiara Piccarreta
Calculation of resonance effects in low-energy electron-water collisions
(Supervisor Prof. Jonathan Tennyson)

Julia Roberts
The chemical evolution of low mass prestellar cores and young stellar objects (Supervisor Prof. J Rawlings)

Mischa Stocklin
Quantum chaos with cold atoms and spin waves
(Supervisor Prof. T S Monteiro)

Jiayu Tang
Investigating future probes of cosmic acceleration
(Supervisor Prof. J Weller)

Paolo Emilio Trevisanutto
Theoretical models of photo-induced processes at surfaces of oxide nanoparticles
(Supervisor Prof. Alexander Shluger)

Troy Vine
A Direct measurement of the W decay width
(Supervisor Prof. M Lancaster)

Nicholas J Wright
The structure and chemistry of evolved stars and nebulae
(Supervisor Prof. M J Barlow)

*(Left to right) Jayantha Dhanapala, **Emmet Farragher** and **John Finney***

Emmet Farragher, a first year student in Physics and Astronomy was awarded the inaugural Joseph Rotblat essay prize. The award was launched this year to honor the centenary birth of one of the founders of the Pugwash Conferences on Science and International Affairs, Sir Joseph Rotblat. Rotblat, who shared the 1995 Nobel Peace Prize with the Pugwash Conferences, was an ardent advocate of young people and believed that drawing on their creativity and energy could be crucial in creating a better world.

The prize essay analysed the scenarios in which an independent British nuclear weapon could arguably be used, together with an examination of non-nuclear alternatives in each case.

Emmet received his award from Ambassador Jayantha Dhanapala, the President of Pugwash and a past UN Under-Secretary-General for Disarmament Affairs, following a keynote address on the Urgency of Disarmament at an event jointly hosted by British Pugwash and the SOAS Centre for International Studies and Diplomacy.

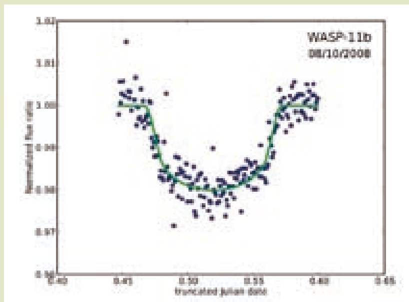
NEWS HIGHLIGHTS

Follow-up Monitoring of Transiting Extrasolar Planets from ULO

UCL undergraduates are participating in a collaborative observational project to study the transits of extrasolar planets. Transitting extra solar planets are a particular class of planets who, when viewed from earth, pass directly in front of their star. These planets are particularly interesting because they can be studied by observing the light from their star.

The scientific aim of the project is to use UCL's observatory (ULO) to monitor the transits of known and candidate extrasolar planets, with a view to characterizing the planetary companions in confirmed systems, and checking the status of transit candidates which have been discovered by wide-field surveys elsewhere.

The observing programme is engaging undergraduates across all years directly with astronomical research in a field which is growing fast, providing opportunities for the further development of their own practical and research skills, and supporting on-going final-year MSci project work.



The Figure shows a transit event (October 2008) of the recently-discovered system WASP-11b, obtained at ULO by 4th-yr MSci student **Ingo Waldmann** (Natural Sciences). The observed starlight measurements are in blue, and the green line is a model fit.

Transit observations such as these show that WASP-11b, a planet with half Jupiter's mass and orbiting its parent star in just 3.7 days, has a radius about the same as Jupiter, indicating a low-density gas-giant with a low-mass core.

These findings have recently been accepted for publication in Monthly Notices of the Royal Astronomical Society (MNRAS).

Physics Outreach Project

This is a voluntary based project aimed at improving the public image of physics amongst primary and secondary school pupils. The project is led by a group of five UCL physics students, **Nick Elias**, **Robin Gajria**, **Salim Damani**, **Jennifer Lardge** and **Luisa Pruessner**, and is supported by the Voluntary Services Unit, part of the UCL Union. The idea is to entice and enthuse students to the captivating world of physics through talks and presentations delivered by our volunteers.

Each volunteer, with the help and support of the project leaders, will create their own talk based on an aspect of physics that interests them personally. The nature of these talks therefore varying widely in content, however they all have the common purpose of explaining the basic principles of physics in both an entertaining and educational manner. Previous presentations have included 'Physics of ice cream' and 'What to do with a degree in Physics.'

The students are always enthusiastic and attentive. Things can get a little chaotic during demonstrations with a class of 30 but that's all part of the fun. The students are encouraged to ask questions and join in the talks. Their response, as well as that from teachers has been very inspiring. Peter Turner, the Extended Schools Manager of Central Foundation School for Boys said 'Can I thank the UCL students who came to the school for their excellent presentations. They were a credit to your University.'

The scheme has been running for over three years now and it will be continuing this year with one returning Project Leader and four new Project Leaders from various year levels, which makes this a great opportunity for the volunteers to meet students on other years and disciplines within the department. It's also an excellent way to practice presentation skills and in particular, it's great for explaining scientific ideas in simple terms.

The Physics Outreach Project can be contacted by email at **physics.outreach@hotmail.co.uk**

Annual Weekend at Cumberland Lodge

'Heros and Villans': Sometimes the alter-egos of a few of our students get to 'play' a part in the Department's life

The picture above features some of our undergraduate cast who stared in a play at Cumberland Lodge based on the Batman story. The department organises an annual weekend at Cumberland Lodge in Windsor Great Park for undergratuate students as part of the first year induction. Although the planned activities vary from year to year the production of a play has been a very popular addition for many years and involves both students and staff.

Careers with Physics and Astronomy Degrees

Andrew Wilson

IT Developer (BSc Astronomy & Physics 1994)

Since graduating from UCL in 1994 I have spent the majority of my working life in the City. For the last three years I have been working as an IT developer in the risk department of a Japanese investment bank. With all that has happened in the global economy over the past year this has proven to be a very challenging environment, though it must be said with never a dull moment! I have found that my time studying science at UCL has equipped me with the logical approach and problem solving skills that are so crucial to doing well in my chosen career.

I had an interest in astronomy from a young age, and my study of Astronomy and Physics at UCL was the culmination of this interest. I had originally envisaged that I would spend my life in research, though my career ended up taking a different path. I decided that if I wasn't to have a career in science, then I would find a way to pursue my own interests in the subject. So I became actively involved in the UK and Global amateur astronomy scene through the British Astronomical Association. I was largely interested in finding ways to contribute to scientific research and so I became a member of the Variable Star Section. My main area of interest over the past few years has been monitoring active galaxies. I have been part of a collaboration of amateur and professional astronomers who study the binary black hole OJ+287. The amateurs have provided long time series brightness measurements of the black holes (both visual and CCD) giving the professionals a wealth of data to analyse. This has resulted in 2 scientific papers, the most recent of which was in Nature; 'A massive binary black hole system in OJ 287 and a test of general relativity', Valtonen *et al*, Nature, 452, 851-853, (2008). This analysed the orbit of the black holes showing evidence of energy loss through gravitational radiation, one of the last remaining tests of Einstein's General Theory of Relativity.

At present I am working on a database project with the British Astronomical Association Variable Star Section. This will put their 2 million plus observations dating back to the 1890's online for amateurs and professionals to access for their research.

I've continued my academic studies through maths courses at the Open University. I have found this very rewarding, though I cannot study every year due to work and life commitments.

2008 has been an especially busy year for me. It has seen the completion of an observatory in my back garden equipped with a 14" telescope. Another highlight has been my visit to China in July and August to see a total eclipse of the Sun from the Gobi desert.

Orsola De Marco and Nic Fulton

Orsola and Nic met while at UCL, Orsola was a Physics Undergraduate and Nic was studying for his PhD. Orsola and Nic are now married with two children. While Orsola continues to work in academia, Nic works for Thomson Reuters.

Nic Fulton

Chief Scientist, Reuters Media (BSc Physics with Electronics 1991, PhD Physics 1995)

My time as an undergraduate at UCL in the Physics Dept. was probably about as normal as anyone else's. Too much beer in the Union, late nights in clubs and house parties, and all nighters during the week trying to finish coursework and cram for exams. I remember it fondly, if bleary eyed. I made it through in the end, a 2:1 in Physics, Electronics and Computing.

With the prospect of graduating into a recession facing me I looked around for other options and found a PhD studentship with **Jonathan Tennyson**. I was, frankly, out of my depth in molecular spectroscopy, but managed to bluff the first couple of years by being a dab hand at programming and computer graphics for visualizing complex functions. But it was hard work.

A low point being a trip to a conference in Riccione, Italy - where I saved money by camping – only to discover my work on Na_3 was bogus because I'd forgot some (obscure) effect called the Berry phase.

On other sides of life things were quite different. To help pay my rent I took on a job as a lab assistant for the first-year practical physics course. This meant being an annoyance to the undergrads (I think they called me patronizing – right Gary?), but with one great upside – face to face with the new intake of female students. After having avoided departmental functions as an undergrad, I realized that a long weekend away in Winsor Park for the Cumberland Lodge retreat would be a good chance to cement my friendship with these young faces, in particular the Italian with a Scottish accent.

The weekend was great, I thoroughly enjoyed the talks, entertainment, and the lie-in (after beer and music) that the end of BST gave us. But best of all, I was in love. Orsola had come over to chat when I was sitting under a tree. She was smart and pretty and a keen, experienced sailor – I too had sailed all my life as my dad was a navy officer. We talked for hours.

My work improved, and I got into some wonderful research on classical/quantum correspondence, inspired by Gonzalo, a student from Madrid who was visiting for a summer – and now a very successful academic in his own right. After successfully completing my PhD in Oct 1994, I decided that academia wasn't for me, and I joined Reuters doing technical research work – specifically modeling financial markets using Neural Networks.

Orsola started her PhD studying Planetary Nebulae.

A year later we got married. Reuters worked out very well for me. Because of UCL sys admin work I'd got into Web stuff just as it was beginning in business so at Reuters the 'new thing' to them was something I was familiar with. Orsola's PhD went well and she finished in 1997.

Orsola had post-doc offers from a few places, but the one in Zürich put us right in a major banking centre, and hence work for me. We moved there for two years. Initially fun, but ultimately boring – yes, the stereotype is true – and then returned to London for a year before moving to New York City

Now it's eight years later. We've had our ups and downs and now have two lovely kids to show for it (excuse the pun). We spend summers out sailing on the Long Island sounds in our 30' Catalina and our children Elliot (4) and Chiara (2.5) have got their sea-legs. But we're not content to sit still, so in early 2009 we're off to Australia.

Orsola De Marco

Reader at Macquarie University (BSc Astrophysics 1994, PhD Astrophysics 1997)

As Nic crossed the first year undergraduate physics lab I thought he was cute.

The year was 1991, and I was an UCL Physics and Astronomy undergraduate while Nic had just started his PhD in the same department.

While waiting to depart for Cumberland Lodge, where the Department still has its start of year retreat, I hoped that Nic would be there and was very happy when I saw him joining us on the bus. The next day, I was taking a walk in Windsor Great Park, where the Lodge is located, and I spotted Nic sitting under a tree, all by himself. Luck has it that I went to say hi, and ended up sitting with him for couple of hours, talking. Under that tree, on a grey November afternoon, I found the love of my life.

We got married 4 years later, when I was a first year PhD student. When I finished my PhD we moved to Zürich where I took up a position as a post-doc and later, after a brief return to London, we moved to New York- where I work in research at the American Museum of Natural History.

In 2004 our son Elliot was born and a short time later our daughter Chiara.

Today, our family is about to start on a new adventure; we are moving to Sydney, where I am taking up a Readership at Macquarie University. We have come a long way from the days at UCL, but our life together is rooted in those days. We still consider our anniversary the first weekend of November.

NEWS HIGHLIGHTS

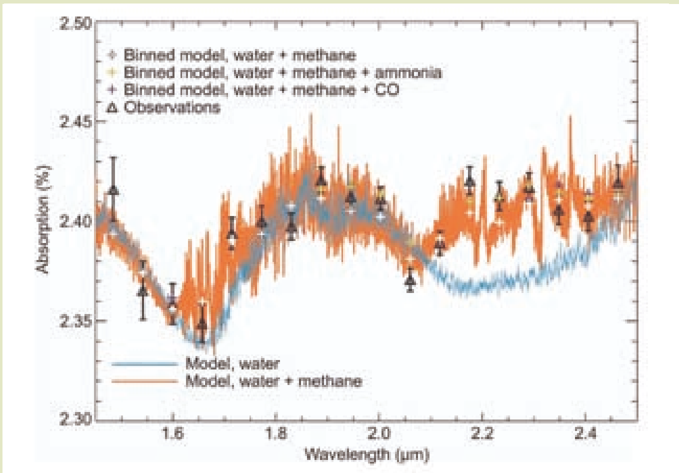
The Presence of Methane in the Atmosphere of an Extrasolar Planet

Mark R. Swain, Gautam Vasisht, **Giovanna Tinetti**

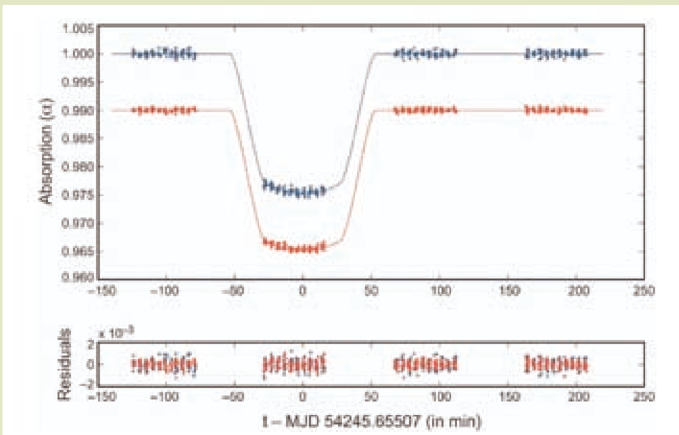
Nature 452, 329 – 331 (2008)

Work in the Department on Extrasolar Planets took another leap forward in March when **Giovanna Tinetti** was amongst the authors of an article in Nature describing the first detection of methane on a planet outside our solar system. Methane is made of carbon and hydrogen and so is an important simple organic molecule - important in that it can take part in prebiotic chemistry, the first steps in the chemistry of life.

The planet on which it was found – the tongue-twistingly named HD189733b – is unlikely to support life as it is a Gas Giant (like Jupiter) very close to its star. However the fact that methane has been found on another world increases our confidence that it may also be abundant on planets with a more equable environment – and illustrates that it is practically possible to detect methane at these distances.



Data compared to modelling results for HD189733b: The black dots are data and all other curves are models which conclusively demonstrate the presence of methane and water.



The Transit Light Curve for HD189733b: These curves show the observations from Hubble in two different frequencies of the transit of the planet – that is a small amount of star-light is cut off as it passes in front of the star.

Staff Highlights and News

Promotions

Promotion to Professor

Professor Mark Lancaster

Professor Ferruccio Renzoni

Professor Linda Smith

Promotion to Reader

Dr Sarah Bridle

Dr Robert Thorne

Dr David Waters

New Appointments

The following academic members of staff started on 1 January 2009.

Dr Nguyen Thanh

Reader in CMMP, associated with the Royal Institution and holder of a Royal Society University Research fellowship. From Liverpoool University.

Dr Giorgio Savini

Lecturer in Astrophysical Instrumentation.
From Cardiff University.

Retirements

Professor Mike Dworetsky

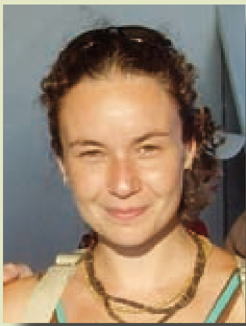
Professor John Finney

Resignations

Dr Jochen Weller left to take up a Professorship at the University of Munich.

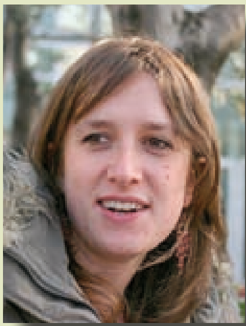
FELLOWSHIPS

The following people won prestigious fellowships during 2008 which they will hold in the Department.



Dr Barbara Ercolano

STFC Advanced Fellowship



Dr Emily Nurse

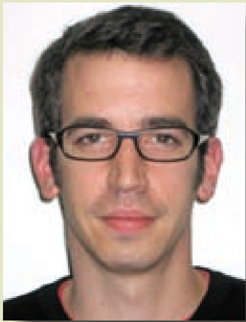
Royal Society University Research Fellowship

Dr Alexandra Olaya-Castro

EPSRC Career Acceleration Fellowship

Professor Chris Pickard

EPSRC Leadership Fellowship



Dr Cristian Ruegg

Royal Society University Research Fellowship

Dr Peter Sushko

Royal Society University Research Fellowship

Dr Giovanna Tinetti

Royal Society University Research Fellowship

Alumni Matters

Professor Tegid Wyn Jones

Dr Joseph William 'Bill' Fox

Alumni who graduated before 1983 will surely remember **Bill Fox** who sadly died on 1st October 2008.

Bill came to the Department in 1937 and graduated in 1940 after the Department had been evacuated to Bangor, North Wales. Together with the Head of Department, **Professor E. N. da C. Andrade** and lecturer **Dr F. A. Vick**, he joined the war effort and worked on anti tank mines and their countermeasures. At the end of the war he returned to UCL and obtained his PhD in 1948 under Andrade's supervision.

From 1950 onwards following **Professor H.S.W. Massey's** appointment as Head of Department, Bill gradually acquired responsibility for all undergraduate matters including admissions.

By the mid sixties he was towering figure in the Department for undergraduate students and young lecturers such as myself. There was indeed considerably more bark than bite in his manner. I gratefully recall his help and encouragement along with his wise and sympathetic approach to students with personal difficulties.

Tony Smith, **Don Davis** and **Colin Wilkin** have commemorated his long and productive life in a fine obituary which you can find at: **www.ucl.uk/phys/department/history/bill_fox**

In the history directory of the Physics and Astronomy website you can also find a valuable history of the Department written by Bill Fox himself.

Alumni Dinner

The annual dinner of the Physics and Astronomy Alumni took place on Friday 9 May 2008.

About forty alumni responded to the invitation sent out with last year's Annual Review and I am pleased to report that it was again a thoroughly enjoyable event.

My 'after dinner speech' was an innovation this year. I am told it was in English and caused some amusement, although following all the retirement speeches I have made in the last few years I can recall only another occasion to become incoherent!

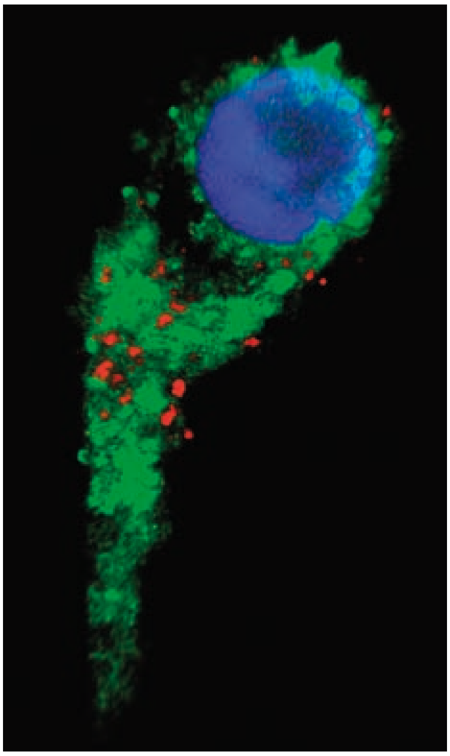
This year the annual dinner will take place on 8 May 2009 and the 'after dinner speech' will be by **Professor Jonathan Tennyson**, the Head of Department who along with **Professor Nella Laricchia**, led us to the success of the Research Assessment Exercise.

Professor Quentin Pankhurst heads new Davy-Faraday Research Laboratory

Following its two and a half year closure for an extensive £22 million renovation, **Quentin Pankhurst** has been appointed the new Director of the Davy-Faraday Research Laboratory (DFRL). Quentin was previously Deputy Director of the London Centre for Nanotechnology at UCL and has been appointed to undertake research in Healthcare Biomagnetics – the application of magnetic materials to healthcare. Quentin also retains a 10% appointment in the Department.

Quentin took up this post on 1 May 2008 and will lead an ambitious collaborative research programme to build a new DFRL team of 15 resident scientists, engineers, medics and technologists to tackle major challenges in the field of Healthcare Biomagnetics. In addition, the RI-UCL programme will see at least another 35 scientists making direct use of the new DFRL facilities.

(Left to right) Quentin Pankhurst, Susan Greenfield and Malcolm Grant



Magnetically Labelled Stem Cell

Quentin and his team will be working to make a difference for patients the world over by perfecting new ways to sense, move and heat magnets which can be safely and conveniently introduced into the human body in the form of a magnetic 'ink'.

Examples of on-going projects include the development of:

- a hand-held scanner that helps cancer surgeons determine the progression of cancer in a patient,
- a treatment method for atherosclerosis using a patient's own healing cells through the use of targeted magnetic force, and
- a method for targeting and activating magnetic particles to cause selective localised heating and destruction of cancer cells.

A defining tenet of the RI is that it should be actively engaged in innovative research undertaken by its own resident scientists.

The DFRL has a long and distinguished 200 year history, including the award of 14 Nobel Prizes, the discovery of 10 elements of the periodic table and the invention of the electric generator.

The Healthcare Biomagnetics programme at the DFRL are jointly funded by a £2.35 million commitment from the RI and a commitment of £1.36 million from UCL for the period April 2008 until March 2013.

Deep-Inelastic Scattering and Related Subjects (DIS 2008) Workshop in UCL

Spring 2008 saw the 'XVI International Workshop on Deep-Inelastic Scattering and Related Subjects' (DIS 2008) held at UCL, jointly organised by the High Energy Particle Physics Groups of the University of Oxford and UCL. The workshop ran from Monday 7 April to Friday 11 April and consisted of a multitude of subjects with around 270 talks and 300 participants. Not only was there a vibrant scientific programme, but also an extensive list of social events enjoyed by all.

The first day, opened in the Cruciform building by the Provost and President **Professor Malcolm Grant**, contained mainly plenary talks with speakers detailing recent experimental and theoretical highlights and prospects in the areas of the strong force and high energy colliders such as the electron-proton collider, HERA, in Hamburg; the proton-antiproton collider, Tevatron, in Chicago, and the proton-proton collider, Large Hadron Collider (LHC), which was turned on this year in Geneva (see page 19).

The main subject of the DIS workshop series, the structure of the proton, has seen tremendous advances recently with the combination of data from two experiments, H1 and ZEUS at HERA. Leading to a much increased precision, significantly better than the simple effect of doubling the statistics. Taking advantage of the very different detectors and their systematic uncertainties, the measurements from H1 and ZEUS effectively 'cross-calibrate' and lead to uncertainties of 1–2% for a large fraction of the 500 data points. All of the results are crucial inputs to our understanding of quantum chromodynamics (QCD) and in particular the structure of the proton which is needed as the starting point for most physics at the LHC.

Several social events were included in the workshop programme. A welcome reception of beer and cheese, held in the North Cloisters in UCL and a brilliant concert by Jack Liebeck (violin) and Katya Apekisheva (piano) at Queen Elizabeth Hall.

The social highlight of the Workshop was the dinner held at Lord's Cricket Ground – the home of cricket. After a tour of the ground and champagne in the museum, an excellent dinner was served, followed by a speech from Norman McCubbin (STFC/RAL) entitled, "The scattering of balls: an English obsession". Norman explained the delights of this English game, such as the length of the game, the many and complicated options on when tea can be taken and the history of Lord's. All supported by props and how the game relates to physics and specifically deep inelastic scattering.

The contributions from our many sponsors was much appreciated, in particular the MAPS Faculty who very generously supported the event. Finally I would like to thank all members of the Local Organising Committee, in particular **Christine Johnston** who quietly and efficiently carried most of the administrative burden and the student helpers who made the conference such a great success.

Matthew Wing

Co-chair of the Local Organising Committee for DIS 2008.

The DIS 2008 quorum in the UCL front quad

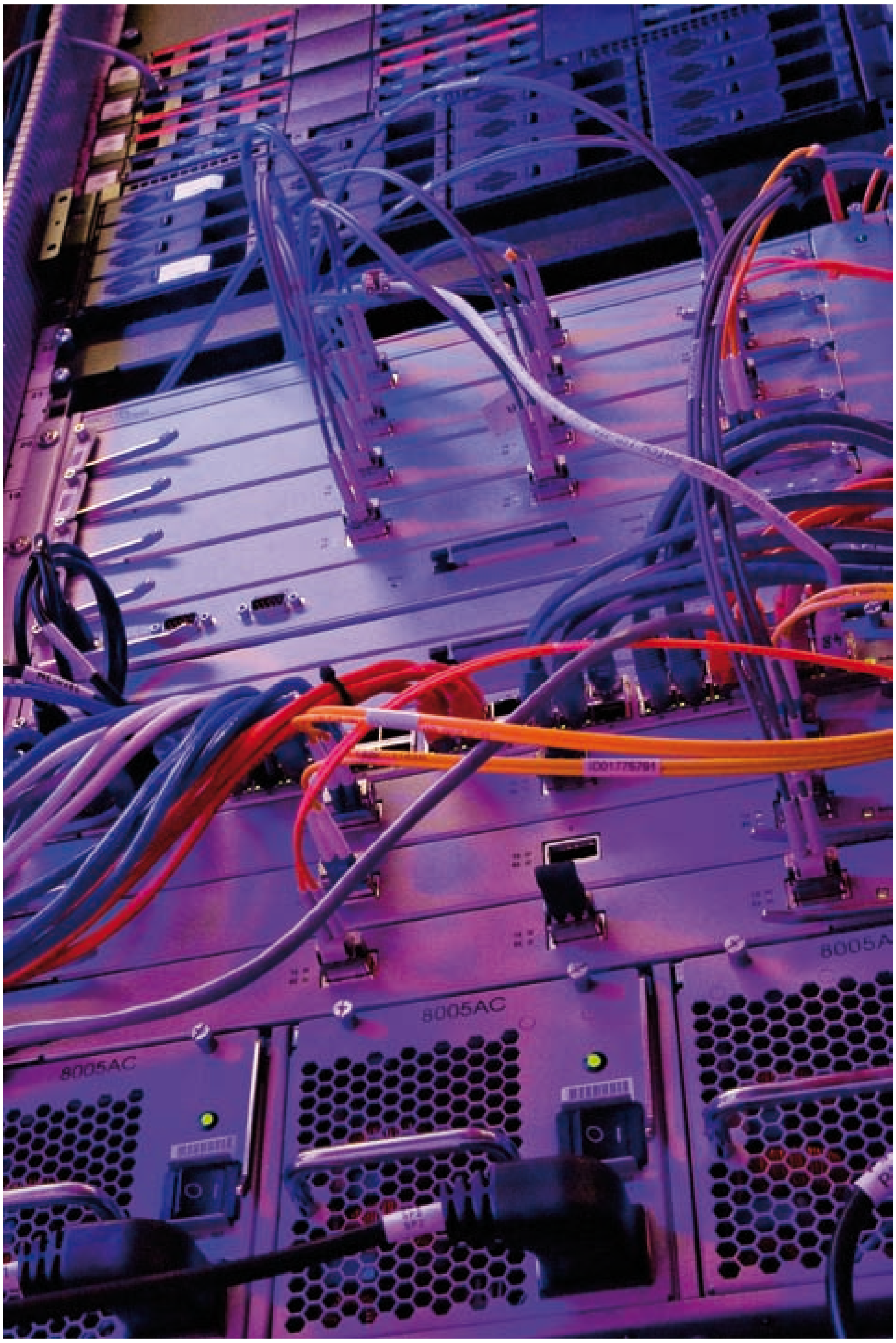
Research Computing – Introducing Legion

November 2008 saw the launch of a major new computational facility for UCL researchers. Legion is arguably the most powerful university based supercomputer in the UK, rivalling even the national supercomputing services in its ability to handle certain types of computational problem.

The main Legion cluster comprises 2560 processor cores, each offering 4GB RAM. The large amount of on-chip memory makes Legion unique in its ability to accommodate a wide variety of computational tasks from across the UCL Faculties. A 192TB high-performance file system ensures I/O speeds that match the demands of today's data intensive applications.

Legion has already generated publishable results for a number of experienced users who have been given early access to the system. For example in Physics and Astronomy, Legion has been used to support three Grand Challenge projects in the areas of molecular physics and cosmology. **Professor Jonathan Tennyson** and **Dr Lorenzo Lodi** are currently calculating the most accurate potential energy surface of the water molecule to then compute the most accurate dipole of water (see page 21 for further details of this project). **Dr Sergey Yurchenko** and **Dr Bob Barber** are calculating the first linelist of hot ammonia for use in climate and planetary atmosphere simulations and in industrial applications.

Additionally **Dr Sarah Bridle** has used Legion to compute UCL's entry in the GREAT08 PASCAL Challenge (see page 17). This focuses on a problem that is of crucial importance for future observations in cosmology; using the shapes of distant galaxies to determine the properties of dark energy and the nature of gravity. This involves analysing the shapes of 300 million galaxies at extremely high accuracy.



For further information about Legion see **www.ucl.ac.uk/research-computing**

Opening of the ν-Building at Mullard Space Science Laboratory (MSSL)

The ν Clean Room

The morning of Wednesday 30 April was wet, cold and miserable. Not an auspicious start for the beginning of one of the most important developments for the capability of the High Energy Physics (HEP) group at UCL. Fortunately the weather brightened as guests arrived for the official opening of the ν-building at MSSL, a collaborative project between HEP and MSSL.

The project was conceived four years ago when **Professor Jenny Thomas** (HEP) and **Professor Keith Mason** (then Director of MSSL) persuaded UCL's Provost and the PPARC CEO to fund the development of a new building to enhance UCL's capabilities to lead large construction projects in Particle Physics and Space Science. That was the easy part – the project then had to be approved by the Deputy Prime Minister's Office and the Local Councils. **Jenny Thomas** and **Professor Alan Smith** who succeeded **Keith Mason** as head of MSSL successfully steered the plans through the authorities and construction began in 2006.

The underlying science of MSSL and the HEP group are surprisingly connected. Particle Physics studies the evolution of the universe in the first micro-second which created the conditions for stars to form. Space scientists study the life cycle and properties of these stars and galaxies. The most interesting synergy lies in the study of the neutrino, given the Greek symbol, ν, pronounced 'new'. Large numbers of neutrinos are emitted by stars such as our sun and in super-nova explosions such as the explosion of SN1987A observed in 1987. The neutrino also potentially holds the key as to why our universe is dominated by matter and why all the anti-matter disappeared within a few minutes of its creation in the Big Bang. The neutrino however only interacts very weakly with matter and its observation requires large sophisticated detectors which will be built in the ν Building.

Guests began to arrive at 2pm and included local dignitaries, the chairpersons of the two local parish councils, Abinger and Ewhurst, and the local MP Sir Paul Beresford as well as prominent members of the research community. First they were taken on a tour of the ν Building and then **Jenny Thomas** and **Alan Smith** each gave a presentation explaining their vision for the future and the desire of the two groups to work closely together and how closely aligned this was to the 'Institute of Origins' which is a recent Faculty initiative (see page 15).

The opening ceremony was then carried out by the Provost.

The ν Building is a fantastic facility – nearly half of it is taken up with a new clean room which is approximately 12m square and 7m high (above). Its inaugural project will be the construction of detectors for the SuperNEMO experiment. SuperNEMO will search for a very rare process, neutrinoless double beta decay. If it is observed it will confirm a long held view that neutrinos are their own antiparticle and will allow physicists to determine the mass of the neutrino which at present is unknown.

The day concluded with the time honored consumption of wine and champagne.

(Left to right) Alan Smith, Jenny Thomas and Malcolm Grant unveiling the new laboratory.

Staff Profile

Professor John Humberston

John has been a long-standing and immensely popular member of the department for nearly 50 years. Indicative of his popularity was the award of the Departmental Teaching Prize in 2008. Additionally, although John officially retired five years ago, the department was loath to lose such a popular teacher and so managed to persuade him to continue teaching classical mechanics for a further five years. All bribery methods exhausted, sadly John decided to relinquish the course in 2008. He is now looking forward to a peaceful and exam-free retirement.

John joined UCL in October 1959 as a PhD student working under the supervision of **Sir Harrie Massey**. After he obtained his PhD, John was appointed to a lectureship at UCL in 1966 and, with the exception of spending a couple of years working at different institutions in North America, he has been at UCL ever since.

John is both a keen researcher and teacher and has successfully managed to balance both the teaching and research aspects of his academic career. On the research side he is part of the AMOPP group and is involved in the theoretical aspects of positron-atom collisions. One particularly significant piece of research in which John was involved was the theory of positron-helium scattering. Scientists were then able to use his theoretical results to justify and explain the experimental results, thus serving to prove the viability of positron scattering. In addition to this, John, in collaboration with **Michael Charlton** (ex- UCL, currently EPSRC Senior Fellow at Swansea University) has written one of the only comprehensive texts on Positron Physics, published in 2001, aptly titled 'Positron Physics'.

On the teaching side, John has taught classical mechanics in the department for at least ten years and is famous both with the students and staff for his ingenious use of demonstrations (see image below).

John uses simple apparatus in practical examples to illustrate important basic principles in classical mechanics.

So what are John's plans for the future? When talking to John one can't help but notice a real love for teaching and academia and luckily for us he plans to retain ties with the department by giving a weekly tutorial to a group of second year undergraduates. His research will also continue but the majority of his time will be taken up concentrating on family life with his two grandchildren.

John Humberston *demonstrating the conservation of angular momentum in the Harrie Massey Lecture Theatre with undergraduate student* ***Aiden Dunne****. Aiden is standing on a turntable holding a spinning wheel; when he tilts the wheel in one direction the turntable will turn Aiden round in such a direction that total angular momentum is conserved. If he tilts the wheel in the other direction, the direction of the turntable will also change.*

Institute of Origins

The Institute of Origins has been recently established to promote world leading research in topics related to the Origins and Evolution of the Universe. The institute embraces the work carried out in at least four UCL departments covering Astrophysics, High Energy Physics, Solar System Physics and Mathematics. The Institute had its formal launch event on 27 February 2009 with keynote speeches from **Sir Paul Nurse**, Nobel Prize winner in Physiology or Medicine 2001 (President of Rockerfeller University, New York) and **Professor John Ellis** (CERN).

Initially funded as a special initiative in fundamental physical science by the Provost's special fund, the institute will in due course look for external funding to ensure the continuation of its multidisciplinary activity.

Astronomy Colloquium

The UCL Astronomy Colloquia was started in 1979 by **Professor Sir Robert Wilson** and **Professor Allan Willis**, based on a 3-day meeting on a selected Astrophysical topic. The format has remained largely unchanged for the past 30 years with a meeting roughly 2 years out of 3. A key aspect being informality and UCL hospitality including complementary wine and bar – much appreciated by participants. The theme of this year's colloquium was 'Exploration of the Solar System'.

Participants at the Astronomy Colloquium 7–10 July 2008.

NEWS HIGHLIGHTS

Quantum Delocalization Behaviour of Molecular Hydrogen in Potassium-Graphite

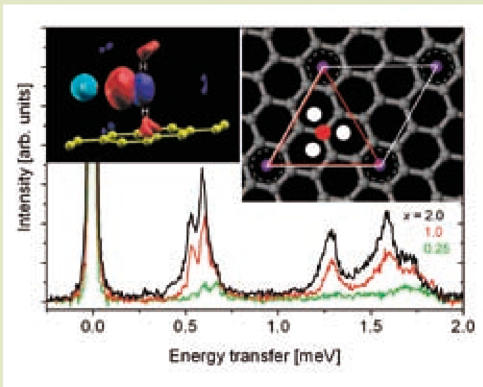
Arthur Lovell, **Felix Fernandez-Alonso**, **Neal T Skipper**, Keith Refson, **Stephen M Bennington**, and Stewart F Parker

Phys. Rev. Lett. 101, 126101 (2008)

Understanding how molecular hydrogen (H_2) binds to materials is crucial to designing a new generation of hydrogen storage media for 'clean' fuel cell vehicles. By combining neutron scattering studies with first-principles (DFT) calculations, new insight into H_2 binding sites in the layered potassium-graphite intercalate KC_{24} has been gained.

The inelastic neutron spectra show features consistent with a single adsorption site, unlike in the similar compound CsC_{24}. Further, H_2 is strongly pinned along a single quantization axis and the H_2-substrate interaction is characterized by rotational barriers ~100 times greater than in pure graphite.

First-principles calculations suggest hydrogen is sited close to potassium ions but fail to account for the underlying symmetry of the experimental H_2 orientational potential. This discrepancy disappears once the H_2 position is averaged over three positions close to separate ions in each adsorption site, naturally leading to the well-known saturation coverage of ~$2H_2$ per metal atom in this material. Our results imply that H_2 storage in metal-doped carbon substrates can be severely affected by quantum-mechanical delocalisation effects extracted from a single copy.



Inelastic neutron spectra of $KC_2(H_2)x$.

Left inset: *calculated electron density difference (red = gain, blue = loss) showing strong charge interaction between H_2 and K.*

Right inset: *vicinal hydrogen sites (white circles) in the KC_{24} unit cell (white lines).*

Outreach

Many members of the department have continued with their public and school outreach during 2008, in anticipation to the International Year of Astronomy (IYA2009).

***Steve Fossey** (ULO) is assisted by UCL students **Michaela Musilova** (red jacket) and **Cherry Ng** in setting up a 7-in maksutov telescope at the Alexandra Park School for an observing session with Year 7 student members of the science and engineering club. Photo: Rogan Macdonald*

The dark universe has been a major public topic, one very brief example of this is **Professor Ofer Lahav** talking on the Radio 4 Today programme discussing dark matter.

School outreach work has included **Dr Steve Fossey** continuing to work with the Alexandra Park School. This collaboration between the School and UCL was recognised by the London Education Partnership Awards with an award in the category 'Excellent Professional Practice in Curriculum and Student Support in science, technology, engineering and mathematics'.

Steve's work has also been complemented with practical observation sessions with portable telescopes. Hundreds of school children have enjoyed visits to the University of London Observatory and use of the National Schools Observatory via the internet to obtain observational data.

Finally STFC science society fellows, **Dr Maggie Aderin** and **Dr Francisco Diego** have been very active lecturing to schools, science festivals and collaborating with the media. Maggie was recently was made a Member of the Order of the British Empire (MBE) for services to science. Whilst Francisco has visited China and successfully recorded the total solar eclipse of 1 August 2008 and the material is now being used in popular lectures.

The website for his fellowship is **www.ucl.ac.uk/themindoftheuniverse.**

Composite of 10 pictures of the solar corona seen from Yiwu, China during the total eclipse on the 1 August 2008. The star on the right is 3.9V delta Cancri. The corona shows streamers diverging from the magnetic poles, typical of periods of minimum solar activity. Photo: Francisco Diego

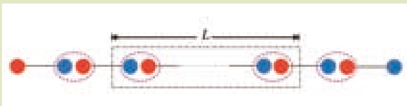
NEWS HIGHLIGHTS

Single-copy Entanglement in a Gapped Quantum Spin Chain

Christopher Hadley
Phys. Rev. Lett. 100, 177202 (2008)

In recent years, the field of quantum information theory has blossomed, promising super-powerful machines solving classically-intractable problems, perfectly secure communication, and providing new insight into quantum mechanics. The resource underlying the power of such quantum computers is 'entanglement', a stronger-than-classical correlation between particles. Entangled particles, in some sense, lose their individual identities and only truly exist as part of a pair or group.

Entanglement occurs naturally in most physical systems; the amount is often given as an indication of how powerful a system would be as a quantum computer. The standard measures of entanglement used at present are a little artificial, in as much as they measure the amount of entanglement that can be extracted from a system if one has an infinite number of copies of the system – the so-called 'asymptotic limit'.



A far more realistic measure is given by the 'single copy entanglement'

In this paper, Hadley gives the first indication that for a particular class of systems (those with a finite gap between the energies of the ground state and the first-excited state), the single copy entanglement is equal to the asymptotic amount. This means that all the entanglement present can be extracted from a single copy of the system, and that the presence of many copies of the system does not convey any advantage. Previously, it was known that for systems that have no energy gap, only half the entanglement present may be extracted from a single copy.

Astrophysics

The Astrophysics group at UCL is one of the largest and most active in the UK. The group's current activities cover an impressive range of research topics, which include atmospheric physics of the Earth and other planets; circumstellar and interstellar environments; galaxies and cosmology; massive stars and clusters; optical instrumentation; star formation; astrochemistry, and recent pioneering studies of the environments of extra-solar planets. Some of the highlights of the group's research in these areas during 2008 are described below by **Dr Sarah Bridle.**

The Great Cosmological Challenge

In October 2008 cosmologists launched a challenge to the world. The challenge is to solve a compelling statistical problem, which will bring us closer to understanding the nature of dark matter and energy which makes up 95 per cent of the 'missing' universe. The GRavitational lEnsing Accuracy Testing 2008 (GREAT08) PASCAL Challenge is led by **Dr Sarah Bridle** in collaboration with **Professor John Shawe-Taylor**, Director of the UCL Centre for Computational Statistics and Machine Learning. The challenge is set by 38 scientists across 19 international institutions, with the aim of enticing other researchers to crack it by 30 April 2009.

The GREAT08 PASCAL Challenge will help us answer the biggest question in cosmology today: what is the dark energy that seems to make up most of the universe? The gravitational lensing community realised that solving their image processing problem does not require knowledge of astronomy, so they are reaching out to attract novel approaches from other disciplines.

Twenty per cent of our universe seems to be made of dark matter, an unknown substance that is fundamentally different to the material making up our known world. Seventy-five per cent of the universe appears to be made of a completely mysterious substance dubbed dark energy. One possible explanation for these surprising observations is that Einstein's law of gravity is wrong.

The method with the greatest potential to discover the nature of dark energy is gravitational lensing, in which the shapes of distant galaxies are distorted by the gravity of the intervening dark matter. Streetlamps appear distorted by the glass in a bathroom window and these distortions could be used to learn about the varying thickness of the glass. In the same way, we can learn about the distribution of the dark matter by looking at the shapes of distant galaxies. The observed galaxy images appear distorted and their shapes must be precisely disentangled from observational effects of sampling, convolution and noise. The problem being set, to measure these image distortions, involves image analysis and is ideally matched to experts in statistical inference, inverse problems and computational learning, amongst other scientific fields.

Cosmologists are gearing up for an exciting few years interpreting the results of new experiments designed to uncover the nature of dark energy, including the ground-based Dark Energy Survey (DES) in Chile and Pan-STARRS in Hawaii, and space missions by the European Space Agency (Euclid) and by NASA and the US Department of Energy (JDEM). Methods developed to solve the GREAT08 Challenge will help the analysis of this new data.

The GREAT08 Challenge contains 200 GB of simulated images, containing 30 million galaxy images. For the main competition, participants are asked to extract 5400 numbers from 170 GB of data. UCL's Legion computer has already been used to compute our entry into the competition (see page 22). The competition can be accessed via the website **www.great08challenge.info**

Huge Lenses to Observe Cosmic Dark Energy

Professor Ofer Lahav leads the UK Dark Energy Consortium (DES). A major DES project in 2008 has been the construction of one of the largest ever cameras to detect the mysterious dark energy component of the Universe. Pieces of glass for the five unique lenses of the DES camera have been shipped from the US to France to be shaped and polished into their final form. The largest of the five lenses is one meter in diameter, making it one of the largest in the world.

Each milestone in the completion of this sophisticated camera brings us closer to detecting the mysterious and invisible matter. The DES camera will map 300 million galaxies using the Blanco 4-meter telescope – a large telescope with new advanced optics at Chile's Cerro Tololo Inter-American Observatory.

Fig 1. *The largest of the five Dark Energy Survey camera lenses.*

***Fig 2**. **Peter Doel**, leader of the Optical Science Laboratory (left) and **Ofer Lahav** (right), Head of the Astrophysics Group, inspecting one of the DES lenses at Heathrow. The five lenses will be assembled at UCL, before being shipped to the telescope in Chile.*

The vast DES galaxy map will enable the astronomers to measure dark energy far more precisely than current observations.

The glass for the five lenses was manufactured in the US before being shipped to France where the lenses will be polished to a smoothness level of one millionth of a centimetre. The polishing and assembly of the five DES lenses will be a major technological achievement. This level of polishing across such large lenses is far more demanding than for normal eye glasses. The lenses will then be sent to the Optical Science Laboratory at UCL for assembly into the camera and from there to the telescope in Chile, where observations will start in 2011 and will continue until 2016.

The DES collaboration involves over 100 scientists from the US, UK, Spain and Brazil.

Sweet Molecule Could Lead Us To Alien Life

In November 2008 scientists detected an organic sugar molecule, glycolaldehyde in a massive star forming region of our galaxy where habitable planets could exist. This is an important discovery as glycolaldehyde is directly linked to the origin of life.

An international team of researchers, including **Dr Serena Viti**, used the IRAM radio telescope in France to detect the molecule in a massive star forming region of space, some 26000 light years from Earth.

The sugar molecule has previously only been detected towards the centre of our galaxy where conditions are extreme compared to the rest of the galaxy. This new discovery, in an area far from the galactic centre, also suggests that the production of this key ingredient for life could be common throughout the galaxy. This is good news in our search for alien life, as a wide spread of the molecule improves the chances of it existing along side other molecules vital to life and in regions where Earth-like planets may exist.

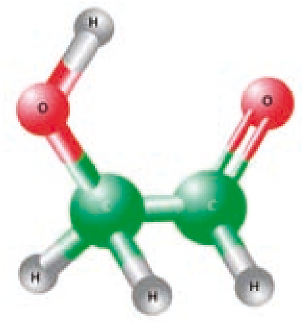


Image courtesy: IRAM ©

***Fig 4.** Model of the glycolaldehyde molecule.*

Glycolaldehyde, the simplest of the monosaccharide sugars, can react with the substance propenal to form ribose, a central constituent of Ribonucleic acid (RNA), thought to be the central molecule in the origin of life.

The team were able to detect glycolaldehyde by using the IRAM telescope (Fig. 3) to observe the region with high-angular resolution and at different wavelengths. The observations confirmed the presence of three lines of glycolaldegyde towards the most central part of the core of the region.

Image courtesy: IRAM/Rebus©

***Fig 3**. The IRAM Plateau de Bure Interferometer.*

High Energy Physics

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.
As well as challenging our theories, experiments capable of reaching these extremes of energy and size pose significant technical problems. The challenges include devising precision detectors which can operate in hostile environments, particle accelerators which can achieve high energy collisions, super-sensitive detectors capable of identifying very rare decays with very small 'background noise', high-speed electronics which can read out millions of pieces of information per second, and robust, flexible software which can analyse the data in a distributed computing system all over the world. The UCL group has expertise and works in all of these areas.

Activities in the group include particle phenomenology, analysis of data from the HERA electron-proton collider (which ran at DESY in Hamburg until 2007) and the Tevatron proton-antiproton collider (currently running at Fermilab in Chicago). We also have several projects investigating the mysterious neutrino, including the MINOS experiment at Fermilab, the ANITA balloon experiment at the South Pole, and super-sensitive underground experiments (NEMO III, SuperNEMO) searching for rare neutrinoless double-beta decay processes which might show that the neutrino is its own antiparticle and measure its mass for the first time.

Large Hadron Collider (LHC)

Even if you were visiting Mars at the time, you probably noticed that in September 2008 the LHC at CERN, in Geneva, opened for business.
Its 'business' is colliding protons at super-high energies to study what matter is, fundamentally, and what the forces of physics are at the shortest distances.

In doing so it will effectively glimpse back in time, to the physics of the early universe, since the energies of the colliding particles mimic the energies all particles had in the first moments after the Big Bang.

Professor Jon Butterworth leads the UK part of the collaboration responsible for building and running ATLAS, and UCL has built significant hardware and software components of the detector, one of four big detectors at the LHC. These are the 'eyes' of the LHC, built to record what happens when the protons collide. The UCL ATLAS group consists of about 35 people. UCL staff and PhD students work on several aspects of the experiment. We were involved in engineering and electronics for the ATLAS Silicon Central Tracker, as well as working on the 'trigger' which decides which collisions are interesting enough to record.

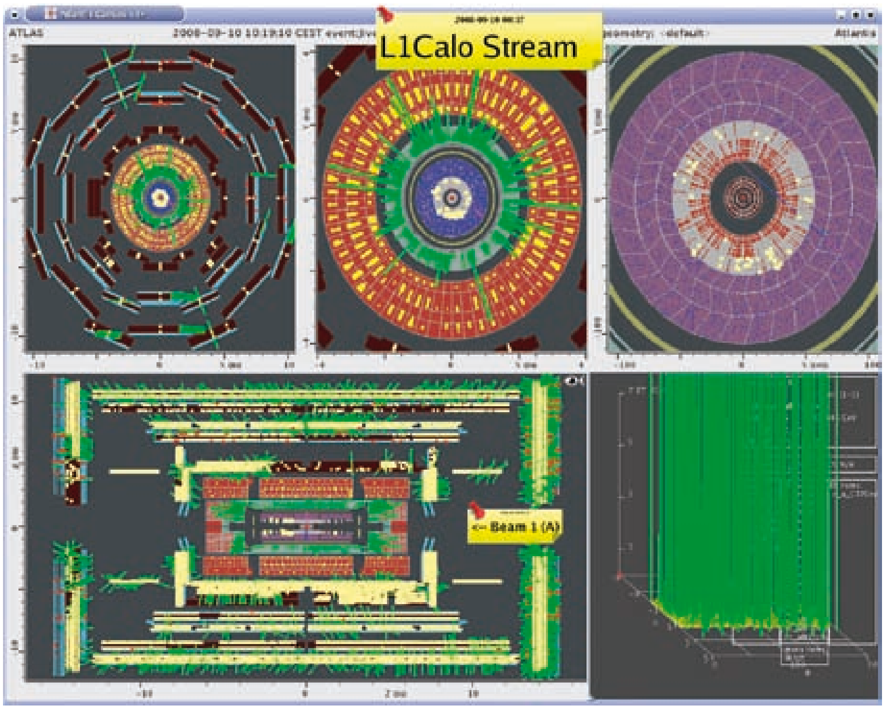


***Fig 2**. The first signs of the LHC beam seen by ATLAS.*

We also write and run key bits of the complex software and computing environment needed to analyse the data – in fact the first time ATLAS saw the LHC beam, the event pictures which flashed around the world were displayed by the ATLANTIS event display, a project led by **Dr Nikos Konstantindis** and his team at UCL. The UCL Legion computing cluster is part of the LHC computing 'grid'

The Higgs Boson

Aside from all the publicity surrounding the start of this enormous and inspiring experiment, it is worth stepping back and asking why physicists are so excited at the prospect of studying collisions at the LHC. When the protons collide, at energies 7 times higher than previously possible, they will open up a new landscape of physics. Any new territory is exciting, especially when it is the closest we have yet seen to the Big Bang. However, there is a special reason to be sure the LHC will rewrite the textbooks on particle physics. The 'Standard Model', which does so well at predicting what we have measured so far at high energy colliders, requires a new particle called the Higgs boson to exist, otherwise the other particles are not allowed to have mass!
The Higgs 'sticks' to heavy particles, giving them their inertia. If the Standard Model Higgs boson is to do its job properly, it must be in range of the LHC. So the LHC will either find the Higgs – or prove the Standard Model wrong!

One thing the Higgs does is give mass to the W and Z particles, carriers of the weak nuclear force, which drives the sun. It is because they have mass (unlike the photon, which does not) that the force is weaker than electromagnetism. It is already known that the weak force and the electromagnetic force are very similar in strength at high enough energies.
In a sense they are 'unified', there is a symmetry between them which is broken at everyday energies but restored at high energies. The LHC is the first experiment to operate in the region where this symmetry is present. If the Higgs exists, it provides the mechanism to break the symmetry. But if not, nature must have chosen another way to break it, and the LHC will give us the first clue what this might be.

An example of the kind of work going on to exploit the huge potential of ATLAS is a new technique developed by the group to search for the Higgs boson. The search at energies around 120 GeV, which is the most favoured region from a theoretical point of view, is very challenging, because the Higgs decays to bottom quarks, which produce jets of hadrons, and the backgrounds are very large. It was widely considered that WH and ZH production were poor search channels at the LHC for this reason.

UCL physicists showed that at high transverse momenta, employing state-of-the-art jet reconstruction and decomposition techniques, these processes can be recovered as promising search channels for the standard model Higgs boson around 120 GeV in mass. Not only might this be the best way of finding a Higgs in this mass region, but it also provides the only way at the LHC to measure the ratio of the WH and ZH couplings, which is important in proving you have actually got a standard model Higgs (or not!). Figure 3 shows two simulated peaks in the mass distribution. The lower (green) peak is from the Z boson at 90 GeV, the higher (blue) peak from a Higgs at 120 GeV reconstructed using our new technique.

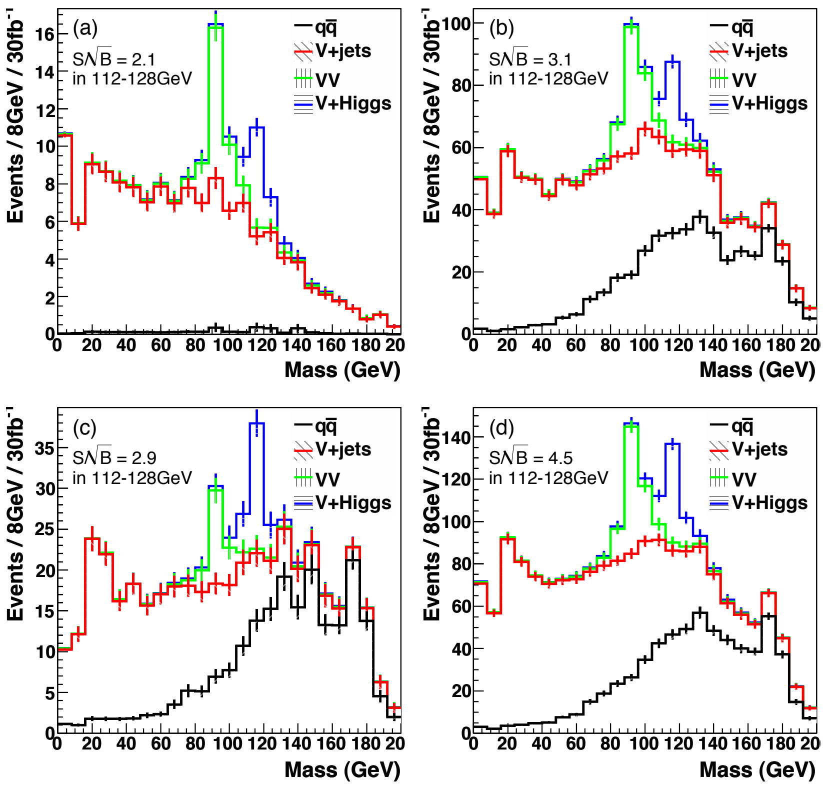


Fig 3. Two simulated peaks in the mass distribution of LHC events. The lower (green) peak is from the Z boson at 90 GeV, the higher (blue) peak from a Higgs at 120 GeV reconstructed using the new technique developed at UCL and Paris.

Atomic, Molecular, Optical and Position Physics

The atomic, molecular, optical and positron physics group is engaged in experimental and theoretical research that covers a wide breadth in this very active field.

Their research spans from the fundamental to the applied and encompasses the following broad topics: positron, positronium and electron collisions, ultracold gases, quantum chaos and statistical physics, ultrafast laser spectroscopy and strong laser interactions, biological physics and optical tweezers, atomic and molecular spectroscopy, and quantum information.

The group comprises 15 members of academic staff almost equally divided between theory and experiment.

Recent decades have seen a pronounced shift in research by traditional 'atomic physics' groups to work much more on problems involving molecules. At UCL the work on molecular physics is underpinned by a very active theoretical molecular physics group whose leader, **Professor Jonathan Tennyson**, summarises some of the group's recent activities.

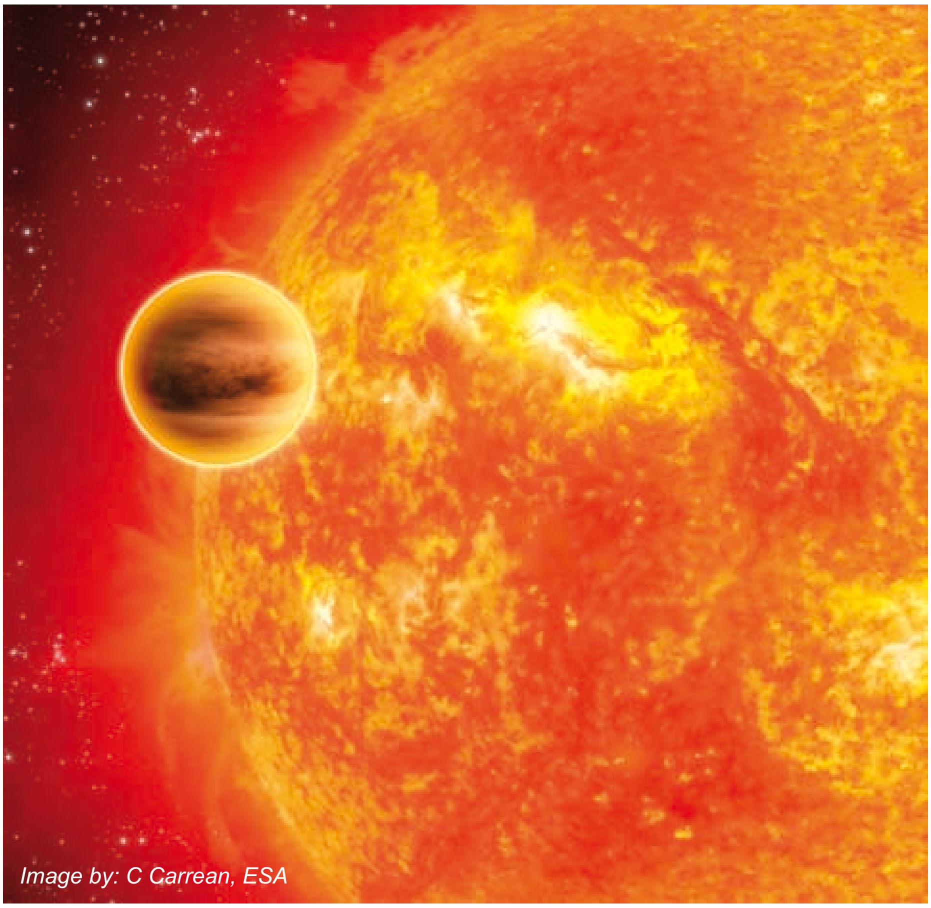


Image by: C Carrean, ESA

***Figure 1**. Artists impression of extrasolar planet HD189733b orbitting its central star. Water was detected in the atmosphere of this planet, the first molecule found in a planet outside our solar system, on the basis of calculated water spectra.*

Quantum Theory

Seventy years ago British Noble prize laureate Paul Dirac famously said that "the underlying physical laws necessary for the mathematical theory for a large part of physics and the whole of chemistry are…completely known" before adding the important rider that "the difficulty is only that the exact application of these laws leads to equations much too complicated to be soluble". The laws of non-relativistic quantum mechanics have remained essentially unchanged since Dirac's day, what has however changed is the advent of ever faster computers which have led to a revolution in our ability to perform useful calculations on problems of interest. The theoretical molecular physics group aims to find quantum mechanical solutions to problems of current scientific or technological interest. To do this end we study not only the quantum mechanical fundamentals of molecules, but also the application these principles to practical calculations in areas ranging from atmospheric physics through astrophysics to the etching of silicon wafers, the process that makes microchips and hence drives much of the modern economy.

Water Vapour

The way water vapour absorbs and emits light is of fundamental importance for our planet where water is the both the largest absorber of incoming sunlight and the dominant greenhouse gas, it is vital for many areas of astrophysics as water is the third most abundant molecule in the Universe (after hydrogen and carbon monoxide), and is key to understanding many other processes. Despite huge effort in the laboratory, much of the information needed to interpret and model the interaction of water vapour with light is either not available or not determined accurately enough. In a multifaceted project we have, over a number of years, developed the most advanced theoretical model of the water molecule demonstrating, for example that a fully quantitative treatment needs to move beyond non-relativistic quantum mechanics and allow for not only relativistic effects on the motion of the electrons but even for effects of quantum electrodynamics.

This model has formed the basis for systematic calculations by **Dr Bob Barber** which characterise precisely how strongly water vapour absorbs light as a function of both temperature and wavelength. That this problem is solved computationally is not surprising as Bob's calculations led to no less than 500 million distinct wavelengths (or colours) at which a water molecule might absorb; assembling this quantity of data by direct wavelength-by-wavelength direct measurements in the laboratory is unthinkable. In practice about 100,000 of these wavelengths have been measured in the laboratory and provide an excellent benchmark to compare our calculations with.

These calculations on water, and earlier similar ones, have led to some remarkable results such as the characterisation of water in sunspots by **Dr Oleg Polyansky**, the identification of water on extrasolar planet HD189733b (Figure 1) by **Dr Giovanna Tinetti** and significant changes in the treatment of absorption by water vapour in our own atmosphere. In particular we were able to show that much of the absorption of sunlight known to be missing from standard atmospheric models was due to weak water absorptions missing from available data compilations.

There remain major issues to do with unexplained absorption of sunlight in the earth's atmosphere. This absorption, which is apparent at all wavelengths, is usually called the water continuum.

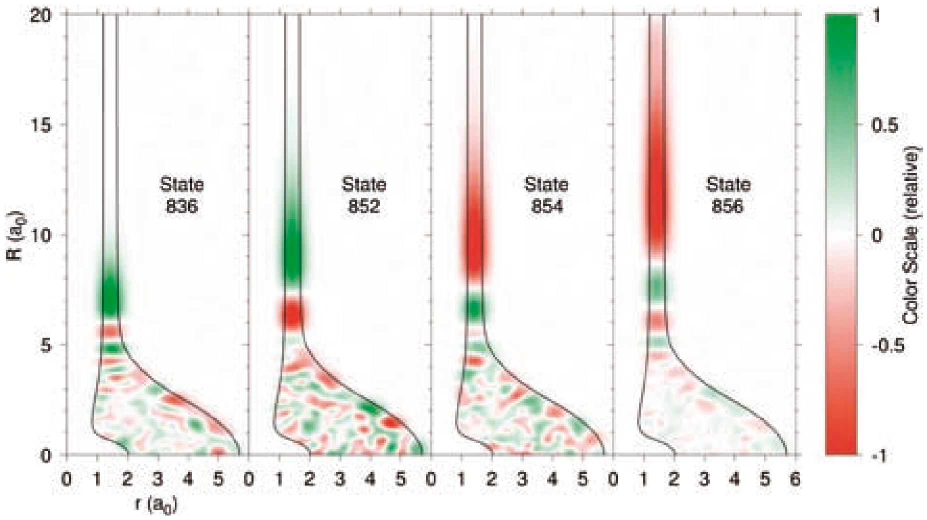


***Figure 2**. Wavefunctions of four asymptotic vibrational states of the H_3^+ molecular ion. The black contours enclose the region where each wavefunction is energetically allowed by classical mechanics. These states lie above the classical dissociation limit for the system (given by R becoming very large) which means that classically the molecule should break-up into H^+ + H_2; however quantum mechanically this does not happen since there is not enough energy in the system to populate the lowest state of H_2 due its quantum mechanical zero-point energy.*

This continuum absorption is certainly observed but its physical origin remains a matter for conjecture, something that makes accurate climate change predictions unreliable. **Dr Ross Kelly** and **Matt Barber** are working on this problem as part of a UK consortium 'CAVIAR' (Continuum Absorption at Visible and Infrared wavelengths and its Atmospheric Relevance). Our aim is to find and model from first principle quantum mechanics the physical basis for this extra absorption.

To this end we are pursuing the idea that the absorption is due to the pairs of water molecules sticking together to form dimers.

An international project to construct the definitive data compilation of absorption and emission by the water molecule is being led from UCL. In addition **Dr Lorenzo Lodi** has just started a new project aimed at replacing all experimental measurements of the probability of water absorption at a particular wavelength with our own calculated values. We believe these will be more accurate than the current measured values given the many difficulties making these measurements in the laboratory. This last project has relied on the multi-core Legion supercomputer (see page 12) which has allowed us to complete 20 single-processor-years of calculations in about 3 months.

Asymptotic Vibrational States

This work on water is now being extended to look at how the molecule behaves as it breaks up.

This project already led to the discovery, as part of his PhD studies, by **Dr James Munro** of a new class of molecular states. These states, one of which is featured in figure 2, display very extended wavefunctions and we coined the phrase Asymptotic Vibrational States to describe them. These extended states are a direct result of quantum mechanics: energetically the molecule can all but break up but it cannot actually completely dissociate because there is insufficient energy in the system for the quantum mechanical zero point energy of the molecular fragments. We anticipate such states will be ubiquitous for molecules with more than two atoms.

Stars cooler than the sun are much the commonest in our galaxy even if they are not always easy to see because they do not shine as brightly as hotter stars. Small molecules form in the outer layers of these cool stars and strongly influence their behaviour and properties by the degree they absorb light generated from the hot stellar interior. To understand this process it is necessary to model how very hot molecules absorb the light – cool stars have temperatures similar to the centre of an oxy-acetylene torch. This was the original motivation for our studies on water and we now have extensively databases for several other species. In particular **Dr Bob Barber** is currently working in collaboration with Dr Sergei Yurchenko (from Dresden) on calculations on ammonia for which the power of the Legion supercomputer is also required. Additionally we have an Italian visitor, **Dr Andrea Urru** who is performing similar calculations for acetylene. This work is beginning to find significant application outside astrophysics as the data can be used to characterise or study a variety of processes involving hot molecules such as those involved in combustion.

Low Energy Collisions

Physics often involves study of collisions. Collisions of electrons with molecules are important for a whole variety of processes from natural phenomena such the earth's aurora and lightning bolts to key technological processes such the spark plugs that fire internal combustion engines or electric lighting. We have led the long-running development of a method for treating electron-molecules collisions based on the so-called R-matrix method which involves doing a detailed treatment in an inner region, where the scattering electron has to be treated as indistinguishable from those in the molecular target, and a much simpler treatment in the outer region, where this electron is well separated from the target. A major advantage of this approach is the energy of the scattering electron needs only to be explicitly considered in the outer region where repeating many calculations is cheap. The codes to perform these calculations are large and rather difficult to run.

However, a recent UCL spin-out company called Quantemol (**www.quantemol.com**), have developed an expert system, known as Quantemol-N, for running the R-matrix codes with the aim of making them generally accessible. As a major application of these codes is to plasma etching problems, **Dr James Munro** has also developed a second expert system, Quantemol-P. This uses physical data from Quantemol-N and elsewhere to build up detailed chemical models of the etching gas to allow the etching process to be optimized.

This work builds on the fact that the molecular R-matrix codes are now capable of giving excellent results for electron collisions with small molecules such as water or the fluorocarbons found in etching plasmas. The European Space Agency (ESA) has recently contracted us to perform a series of calculations aimed at characterising electron-molecule collisions important for modeling spacecraft re-entry. This work is largely being performed by Professor K L Baluja, a visitor from the University of Delhi.

In addition, **Dr Amar Dora** is applying the R-matrix codes the to problem of electron collisions with biological molecules. The main aim of this work is to aid the understanding and modeling of radiation damage in living systems. Collisions with low-energy electrons are the key to understanding this process since it is now realised that virtually all forms of damaging radiation are harmful because they release showers of low-energy electrons which then disrupt DNA.

The positron is the anti-particle of the electron whose existence was originally postulated by Dirac on the basis of the quantum mechanical equations he derived.

UCL has one of the worlds major experimental positron physics group (Figure 3) led by **Professor Gaetana Laricchia**. It was therefore a natural step to adapt the R-matrix methodology described above to studies of positron physics. Theoretically positron collisions are actually harder to model than electron collisions. **Dr Jan Franz** and **Rui Zhang** are exploring two methods to adequately account for low-energy collisions of positrons with small molecules: a high class procedure based on explicit allowance the for positron—electron interaction coordinate in the calculation and a computational brute force procedure based on the inclusion of very many 'pseudo-states' in the calculation. So far the brute force is triumphing as it has been shown to give excellent results for these low energy collision models.

Ultracold Collisions

Access to ultracold temperatures, just above absolute zero, has led a revolution in atomic physics. This revolution is just spreading to molecular physics where methods to prepare ultracold molecules are rapidly being developed. Many of

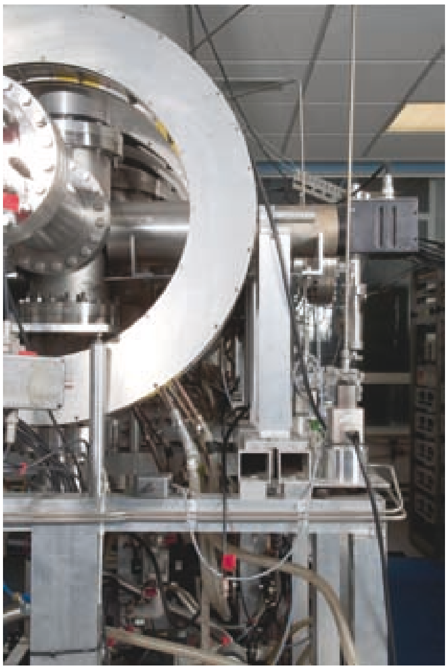


***Figure 3**. Positronium is the ‘atom’ formed by a positron and electron. Pictured is the world’s only positronium beam which is in* **Professor Gaetana Laricchia’s** *Laboratory at UCL.*

these methods only work for a few specific species but **Professor Peter Barker** has pioneered a method of cooling rather general and therefore chemically interesting molecules. However a second step is required to make these molecules ultracold. He proposes to do this using a ‘chill wind’ of ultracold rare gas atoms such as helium or argon. Before spending considerable time, money and effort setting up such an experiment it is good to be confident that it should work. **Dr Paolo Barletta** has performed a series of such calculations, so far focusing on molecular hydrogen and benzene.

These studies show that this so-called sympathetic cooling should be very efficient and potential loses of trapped cold gases by collisions which excite the molecule in question should be too infrequent to worry about. The experiments are now being built.

The Katrin Collaboration

Finally what is the mass of a neutrino? Well know it has a mass and we know that it is small but so far its value has defied measurement. Attempts to do this in the laboratory have proved extraordinarily difficult but a new collaboration called KATRIN (Karlsruhe Tritium Neutrino experiment) have determined to do this. KATRIN aims to achieve this by measuring the decays from a huge tank of molecular tritium, the radioactive form of hydrogen, (Figure 4). To remove systematic errors which plagued previous attempts at such lab studies, **Dr Natasha Doss** performed a series of detailed studies on the molecular processes that arises after the spontaneous radioactive decay of a T_2 molecule. Measurements are due to start early in the next decade and we hope these calculations will help weigh these light, elusive but very common fundamental particles.

***Figure 4**. The main spectrometer for the KATRIN experiment on the final part of its journey to the Forschungszentrum Karlsruhe, Germany where the experiment will be performed.*

Condensed Matter and Materials Physics

The work of the group covers an enormous range of activities, both experimental and theoretical, in the physics of condensed matter. In the examples below **Dr Christian Ruegg** describes fundamental studies of quantum phase transitions, and **Dr Maria Sushko** demonstrates the impact of physical theory on biological problems.

Quantum Phase Transitions in One Dimension

Phase transitions are familiar from our everyday experience, such as water molecules forming a gas, liquid, or solid depending on temperature and pressure. Physicists are interested in finding model systems to understand similar transitions that do not involve changes in the form of the material being studied, but in its internal properties. In a solid material, containing magnetic copper atoms for example, phase transitions and exotic quantum behaviour can be studied at the most fundamental level. In particular, the states of pairs of magnetic moments (dimers) in so-called quantum magnets can be tuned and closely monitored by different experimental techniques. As part of an international collaboration, UCL physicists **Dr Christian Rüegg** and **Professor Des McMorrow** study exciting fundamental properties of matter in novel model materials at temperatures close to absolute zero.

Classical magnets have typically a characteristic temperature, where the magnetic moments (or spins) of the individual atoms align. But there are systems where formation of an ordered state can be impossible, even at the lowest possible temperature, due to quantum fluctuations. The spins remain then in a quantum-disordered, liquid-like state. Such behaviour is frequently observed when the individual magnetic moments are small, and when the spins are coupled to form low-dimensional structures.

An ordered state is then eventually recovered at a new type of phase transition when not the temperature, but a different parameter like a magnetic field, exceeds a critical value. The transition is then called a quantum phase transition and occurs at absolute zero temperature. But even beyond this field-driven transition, dimerised spins do not behave like those in classical magnets below the ordering temperature. Their quantum mechanical nature is still important. The new phase is characterised more accurately by a mixture between classical and quantum behaviour, and can be described as a Bose-Einstein condensate (or BEC). Such condensates are now extensively studied in many areas of physics.

The BEC is one example of a phase which dimers can enter at absolute zero temperature and in a magnetic field of sufficient strength. By contrast, quantum (phase) fluctuations are even stronger and preclude the formation of long-ranged order or BEC, if the pairs of spins are arranged in a one-dimensional structure, for example as rungs on a ladder. At UCL we have focussed especially on such one-dimensional quantum spin ladders. Nature provides us with a prototypical realisation of this geometry in the material piperidinium copper bromide $(C_5H_{12}N)_2CuBr_4$, which has the large ring-like organic molecules $C_5H_{12}N$ isolating the magnetic ladders from each other (inset Figure 1).

In this case the spins completely refuse to behave like their classical analogues, even after a first quantum phase transition in a magnetic field.

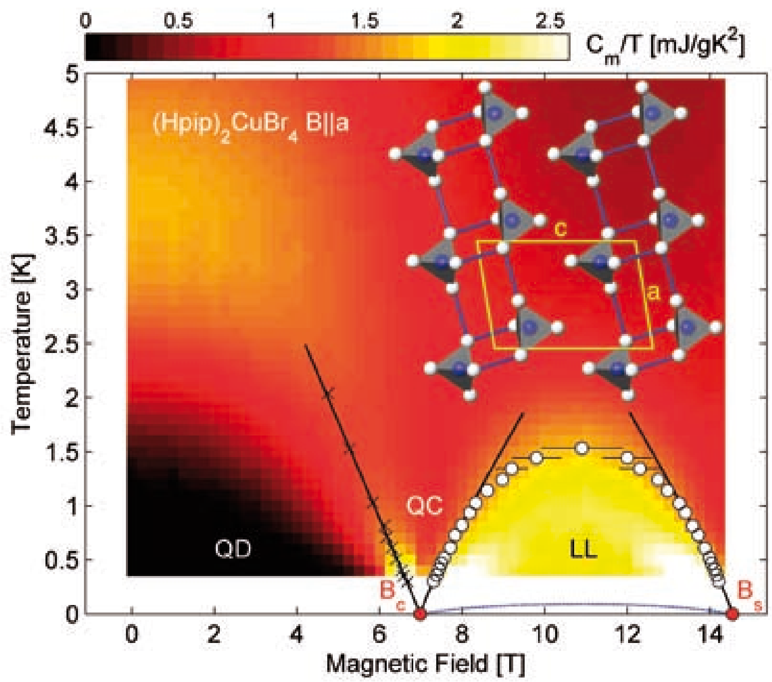


Figure 1. *Magnetic field-temperature phase diagram of the spin-ladder compound $(C_5H_{12}N)_2CuBr_4$, showing quantum disordered (QD), quantum critical (QC), and spin Luttinger liquid (LL) phases. Quantum phase transitions occur at B_c (closing of spin triplet gap) and B_s (spin system fully polarized). Inset: lattice structure of $(C_5H_{12}N)_2CuBr_4$ in projection along the b-axis, with Cu atoms blue and Br white.*

They remain in a fascinating state called a spin Luttinger liquid, until a very strong magnetic field forces them to align completely parallel like in a ferromagnet (Figure 1). The spin Luttinger liquid is another fundamental phase, which has its origin in the quantum properties of the individual magnetic moments.

These quantum phases, which have fascinated physicists for decades, can be studied in detail in quantum magnets by measuring their magnetic response and characteristic excitation spectrum as a function of the external parameters using extremely sensitive magnetometers in the laboratory and high-resolution neutron spectroscopy. The results contribute directly to the fundamental understanding of the states of matter and interactions between magnetic moments, which are of interest for people working on quantum theory and similar physical effects in ultra-cold atoms and semiconductors. They have also direct implications for future applications of magnetism in technology like the miniaturisation of storage devices and even quantum computers.

Nanomechanical Biosensing

There are many places in the natural world where chemical energy is transformed into mechanical work and back again. Examples include an enzyme sliding along a DNA strand to copy it, the passing of messages through the membranes that surround cells, and the way in which molecules called myosins cause muscles to work.The mechanical stress can be either a driving force or a consequence of chemical transformations, and in the latter case can serve as a measurable quantity for characterization of these processes.

The macroscopic devices for measuring stresses in thin films are simple beams of uniform material fixed on one side. For example, one can take a flexible ruler fixing one end on the table to make a cantilever sensor. If one of the surfaces of the cantilever beam is then coated with a thin film of another material, the curvature of the beam will change due to strains and stresses at the interface. This change in curvature can be measured and it characterizes the mechanical properties of two materials.

The development of nanotechnology provided the tools for scaling-down cantilever sensors to micron and nanoscale. This allowed pushing their sensitivity up to the detection of molecular processes, such as chemical reactions and subtle physical transformations on the surface of the sensor. These technological advances stipulated application of cantilever sensors to the detection of a variety of chemical and biological processes such as DNA hybridization reactions, protein recognition and cell adhesion.

In these nano-sensors very thin silicon strips are coated on one side with biomolecules, which then use very specific recognition reactions to fish out their complementary molecules from complex mixtures. For example, if the active layer is a monolayer of single-stranded DNA molecules with the same sequence, only complementary genes will react with the sensor forming double-stranded DNAs (Figure 1). Therefore, this technology may prove to be invaluable for detecting signature genes of various diseases in medical diagnostics.

However, before these devices can be used clinically the sensitivity and reproducibility of the signal have to be considerably improved. Both these goals are impossible to achieve without fundamental understanding of the origin of the signal, which till recently remained elusive.

The scientific breakthrough made by UCL's **Dr Maria Sushko** was to combine beam mechanics, mesoscopic soft-matter theory and modelling at the atomic level to develop a unified quantitative theoretical model of nanomechanical sensing. This complemented experimental studies made by other UCL scientists. This new truly multiscale model, which crosses the boundaries of materials science, physics and chemistry, reveals new fundamental physics at the nanoscale. It can be used for engineering devices with significantly improved reproducibility and detection sensitivity in silico, i.e. on a computer.

The first example of the application of this new model is the theoretical prediction of the parameters of the DNA sensor required for 10- to 100-fold increase of its sensitivity compared to that reported in literature. These theoretical predictions were confirmed experimentally by a team of scientists from McGill University in Canada. This first success story showed that the fundamental advances made by UCL and overseas scientists are a major step towards the transition from the proof-of-concept experiments to cantilever-based devices for routine medical diagnostics.

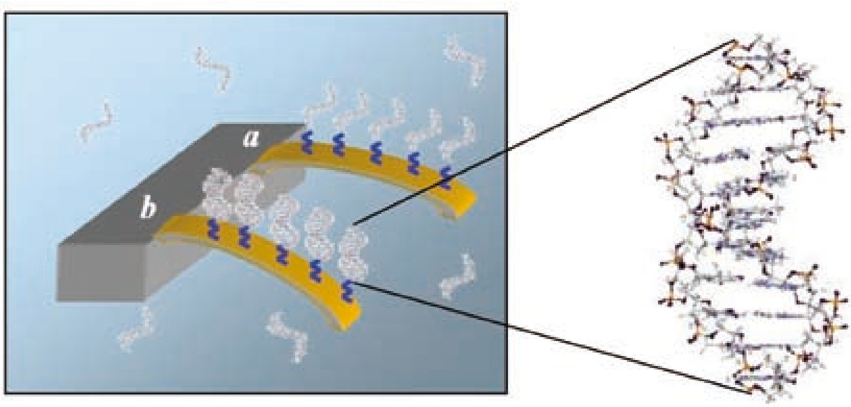


Figure 2. *Cantilever Bio-sensor. Cantilever 'a' is coated with single-stranded DNA molecules and represents the initial state of the sensor. Cantilever 'b' represents the final state of the sensor after DNA hybridization reaction with complementary single-stranded DNAs from solution.*

Active Grants and Contracts (Jan 2008 – Dec 2008)

Astrophysics

The next generation of cosmological surveys (Leverhulme Trust)
£42,000 PI: F Abdalla

Studies of the thermospheres and ionospheres: From the earth to the stars (STFC)
£1,570,463 PI: A Aylward

Modelling and observations of planetary atmospheres: The solar system and beyond (STFC)
£266,136 PI: A Aylward

SWARM: Modelling inonspheric currents for improved magnetic and electronic field analysis for SWARM (ESA)
£18,934 PI: A Aylward

The dust enrichment of galaxies: supernovae and evolved stars (STFC)
£184,226 PI M Barlow

Formation of massive star clusters and cluster complexes in galaxies (STFC)
£250,170 PI: N Bastian

Cosmic vision Euclid Briding Grant (STFC)
£10,087 PI: S Bridle

Constraining and testing cosmological models (Royal Society)
£205,823 PI: S Bridle

Measuring cosmic shear (STFC)
£186,144 PI: S Bridle

University Research F/Ship – Renewal: Quantifying the dark universe using cosmic gravitational lensing (Royal Society)
£135,482 PI: S Bridle

The nature of dark matter from cosmic gravitational lensing (Royal Society)
£2,010 PI: S Bridle

The mind of the universe: A series of school/public lectures communicating the excitement of cosmic discovery (astronomy, astrophysics cosmology) (STFC)
£33,727 PI: F Diego

Smart X-ray optics (EPSRC)
£3,072,089 PI: P Doel

Dark energy survey design work (University of Chicago)
£10,072 PI: P Doel

Zonal biomorph deformable mirror feasibility study (STFC)
£19,640 PI: P Doel

DES Consortium: Purchase of glass blanks (University of Chicago)
£93,023 PI: P Doel

DES Consortium: Purchase of glass blanks (University of Portsmouth)
£251,500 PI: P Doel

DES Consortium: Purchase of glass blanks (University of Michigan)
£69,767 PI: P Doel

Large ultra-thin lightweight, carbon-fibre adaptive mirrors for ELTs (STFC)
£347,447 PI: P Doel

DES Consortium: Purchase of glass blanks (University of Pennsylvania)
£139,535 PI: P Doel

WFMOS Design Study (STFC)
£18,319 PI: P Doel

Astronomy in the classroom: School and observatory visits for KS2, KS3, KS and A Level (STFC)
£5,600 PI: M M Dworetsky

Astronomy in the classroom: School and observatory visits (STFC)
£13,354 PI: M M Dworetsky

Astronomy in the classroom: School and observatory visits (STFC)
£8,200 PI: M M Dworetsky

Effects of radiation feedback on star and planet formation: Advanced Fellowship (STFC)
£410,178 PI: B Ercolano

System management support for the UCL astrophysics group (STFC)
£96,530 PI: I Howarth

PATT Support (STFC)
£52,013 PI: I Howarth

Cosmology with the new generation of photometric redshift surveys (STFC)
£186,144 PI O Lahav

Astrogrid 2 (STFC)
£22,113 PI O Lahav

A wide-field corrector for the dark energy survey (STFC)
£1,762,660 PI: O Lahav

Cosmology: from galaxy surveys to dark matter and dark energy (STFC)
£839,172 PI: O Lahav

Wolfson Research Merit Award: Observing dark energy (Royal Society)
£100,000 PI: O Lahav

Modelling the universe: From atomic to large scale structures (STFC)
£246,803 PI: S Miller

The e-MERLIN radio astronomy revolution: developing the science support tool (Leverhulme Trust)
£124,272 PI: R Prinja

UCL astrophysics short term visitor programme 2006-2009 (STFC)
£25,661 PI: R Prinja

Star formation and its relationship with the interstellar mediums (STFC)
£164,006 PI: J Rawlings

PATT linked grant to sponsor use of ground based telescopes (STFC)
£81,164 PI: L J Smith

Massive stars, starbursts and feedback into the environmental galaxies (STFC)
£164,230 PI: L J Smith

Clusters, starbursts and feedback into the environments of galaxies (STFC)
£499,485 L J Smith

Exploring extra-solar worlds: from terrestrial planets to gas giants (Royal Society)
£413, 232 PI: G Tinetti

Detecting biosignatures for extrasolar worlds (STFC)
£274,039 PI: G Tinetti

Mapping cosmic evolution with high-redshift clusters (STFC)
£251,250 PI: C Van Breukelen

Chemistry as a probe of physical evolution in the interstellar medium (Royal Society)
£9,930 PI: S Viti

Clumpiness in star forming regions (STFC) £206,257 PI: S Viti

Chemistry in galaxies at high redshifts (Leverhulme Trust)
£112,381 PI: S Viti

Basic technology: Ultra precision surfaces – A new paradigm (accuracy capability of 1 part 10 to the power of 8) (EPSRC)
£1,568,731 PI: D Walker

On-machine metrology for surface fabrication (STFC)
£298,258 PI: D Walker

Integrated knowledge centre in ultra precision and structured surfaces (EPSRC)
£391,853 PI: D Walker

Ultra-precision surfaces – translation grant (EPSRC)
£681,546 PI: D Walker

Distinguishing modifications of gravity from dark energy (Nuffield Foundation)
£4,800 PI: J Weller

Perenatal events in astronomy (STFC)
£4,214 PI: D A Williams

Atomic, Molecular, Optical and Positron Physics

Excited state photoengineering: Virtual crystallography – A new approach to spectroscopy, molecular dynamics and structure (EPSRC)
£625,471 PI: A Bain

Photophysics of fluorescently tagged DNA (EPSRC)
£35,358 PI: A Bain

Trapping and slowing cold molecules in pulsed optical lattices (EPSRC)
£77,277 PI: P Barker

Manipulating molecules with optical fields (EPSRC)
£237,552 PI: P Barker

Creating ultra-cold molecules by sympathetic cooling (EPSRC)
£1,264,848 PI: P Barker

Spin chain connectors, entanglement by measurements and mesoscopic quantum coherence (EPSRC)
£783,478 PI: S Bose

Wolfson Research Merit Award: Quantum information uses of complex systems and limits of the quantum world (Royal Society)
£75,000 PI: S Bose

Quantum information processing interdisciplinary research collaboration (EPSRC)
£87,678 PI: S Bose

Developing coherent states as a resource in quantum technology (EPSRC)
£79,725 PI: S Bose

Quantum information processing interdisciplinary research collaboration (EPSRC)
£91,493 PI: D Browne

Microstirring of complex ionic liquids with optical tweezers (Royal Society)
£12,000 PI: P Jones

Superreserving optical tweezers (Royal Society)
£7,174 PI: P Jones

Theory of producing, detecting and designing molecular Bose-Einstein condensates (Royal Society)
£73,833 PI: T Kohler

Pairing and molecule formation in ultra cold atomic gases (Royal Society)
£261,740 PI: T Kohler

Pairing and molecule formation in cold atomic bose and fermi gases (EPSRC)
£855,268 PI: T Kohler

Positron reaction microscopy (EPSRC)
£604,297 PI: G Laricchia

Alternative S-matrix approaches for matter in strong laser fields (EPSRC)
£310,014 PI: C Faria

Collaborative computational project 2 (EPSRC)
£64,759 PI: T Monteiro

Postdoctoral Fellowship (EPSRC)
£258,549 PI: A Nazir

Exploiting quantum coherent energy transfer in light-harvesting systems: Career Acceleration Fellowship (EPSRC)
£741,637 PI: A Olaya-Castro

Calculation of the accurate linelist for water spectra at disassociation (Royal Society)
£3,814 PI: O Polyansky

Brownian motors, disorder and synchronization an optical lattice (Leverhulme Trust)
£21,600 PI: F Renzoni

New applications of dark states in metrology and quantum control – visiting researcher (EPSRC)
£18,796 PI: F Renzoni

Cooling of atoms in optical cavities by collective dynamics (EPSRC)
£457,631 PI: F Renzoni

Quantum control at the single atom level via adiabatic following of a dark state (Royal Society)
£13,910 PI: F Renzoni

New rectification mechanisms in cold atom ratchets (Royal Society)
£12,000 PI: F Renzoni

Brownian motors, disorder and synchronization an optical lattice
(Leverhulme Trust)
£721,707 PI: F Renzoni

Opacity functions for hot molecules
(Royal Society)
£12,000 PI: J Tennyson

QUASAAR – Quantitive spectroscopy for atmospheric and astrophysical research (European Commission)
£126,788 PI: J Tennyson

A theoretical investigation of positron annihilation in molecules (EPSRC)
£188,424 PI: J Tennyson

WWLC weak weather vapour lines contribution to the absorption of atmospheric radiation
(European Commission)
£109,999 PI: J Tennyson

Dynamic imaging of matter at the attosecond and angstrom scale (EPSRC)
£101,769 PI: J Tennyson

Infrared and visible wavelength absorption by water vapour (NERC)
£130,616 PI: J Tennyson

Low-mass star formation and evolution in the early universe (STFC)
£118,651 PI: J Tennyson

Electron driven processes (Quantemol)
£12,930 PI: J Tennyson

An opacity function for ammonia (Leverhulme Trust)
£59,480 PI: J Tennyson

Positron scattering from molecules at low energies using R-matrix method (Royal Society)
£15,820 PI: J Tennyson

Electron initiated chemistry in biomolecules (EPSRC)
£375,727 PI: J Tennyson

CAVIAR (NERC)
£396,342 PI: J Tennyson

Quantum states of water and dissociation (EPSRC)
£88,697 PI: J Tennyson

Line lists for isotopologues of water (Royal Society)
£4,162 PI: J Tennyson

Quantum etch plasma simulation
(EPSRC) £93,686 PI: J Tennyson

A database for $H_2{}^{16}0$
(Royal Society)
£3,362 PI: J Tennyson

Detailed modelling of quantum electron molecule scattering in radioactive waste (EPSRC)
£26,777 PI J Tennyson

A Database for water transitions (NERC)
£185,336 PI: J Tennyson

Calculation of the accurate linelist for water spectra at dissociation (Royal Society)
£3,814 PI: J Tennyson

Dynamic imaging of matter at the attosecond and angstrom scales (EPSRC)
£70,788 PI: J Underwood

The study and control of condensed phase molecular dynamics via femtosecond laser techniques
(Royal Society)
£14,138 PI: J Underwood

Fundamental issues in the aerothermodynamics of planetary-atmosphere (Re)entry (ESA)
£24,499 PI: J Tennyson

High Energy Physics

CEDAR: Combined EScience data analysis resource for high energy particle physics (STFC)
£326,408 PI: J Butterworth

Development and maintenance of ATLAS run time tester (CCLRC)
£45,000 PI: J Butterworth

MCnet – Monte Carlo event generators for high energy particle physics
(European Commission)
£171,985 PI: J Butterworth

ATLAS e-science – High level trigger software validation
(with Royal Holloway) (STFC)
£26, 315 PI: J Butterworth

Probing the ultra-high energy universe with neutrinos as cosmic messengers (Royal Society)
£121,500 PI: A Connolly

Preparation for and measurement of new physics processes using ATLAS experiment at LHC (STFC)
£459,243 PI: C Gwenlan

Core software development for the physics exploitation of the ATLAS detector at LHC (STFC)
£114,009 PI: N Konstantinidis

Core software development for the physics exploitation of the ATLAS detector at LHC (STFC)
£24,290 PI: N Konstantinidis

ARTEMIS – Investigation of the electroweak symmetry breaking and the origin of mass using the first data of ATLAS detector at LHC
(European Commission)
£228,959 PI: N Konstantinisdis

Experimental high energy particle physics research at UCL (STFC)
£5,724,079 PI: M Lancaster

Energy spectrometer for the ILC
(British Council)
£3,696 PI: A Lyapin

Investigating neutrino oscillations with MINOS and neutrino astronomy with ANITA
(Royal Society)
£438,868 PI: R Nichol

Detection of ultra-high cosmic ray neutrinos with ANITA and investigation of future large scale detectors (STFC)
£281,290 PI: R Nichol

QCD phenomenology at hadron colliders and an improved measurement of the top quark mass (STFC)
£104,555 PI: E L Nurse

University Research Fellowship – Higgs physics at ATLAS (Royal Society)
£244,218 PI: E L Nurse

Measurement of the neutrino mass spectrum with oscillation and double beta decay experiments (STFC)
£236,269 PI: R Saakyan

Design study of the superNEMO experiment (STFC)
£753,999 PI: R Saakyan

Development of the ZEUS global tracking trigger at HERA and the ATLAS level 2 trigger (STFC)
£225,125 PI: M Sutton

ILIAS – Integrated large infrastructures for astroparticle science (European Commission)
£12,096 PI: J Thomas

Construction, calibration and exploitation of the MINOS experiment (STFC)
£9,425 PI: J Thomas

Establishment for a new HEP/SS facility for construction of large HEP and SS projects (STFC)
£251,151 PI: J Thomas

Deputy chair of science board (STFC)
£55,515 PI: J Thomas

Global fits for parton distributions and implications for hadron collider physics (STFC)
£150,675 PI: R Thorne

University research fellowship (Royal Society)
£123,654 PI: R Thorne

GridPP Tier-2 support (STFC)
£42,244 PI: B Waugh

GridPP Tier- 2 support (STFC)
£128,479 PI: B Waugh

The development of acoustic detection, reconstruction and signal processing techniques and their application to the search for ultra-high energy cosmic ray neutrinos (Defence Science and Technology Laboratory)
£12,930 PI: D Waters

Royal Society Fellowship: Electroweak physics and Higgs searches at the CDF experiment (Royal Society)
£159,768 PI: D Waters

CALICE: Calorimetry for the international linear collider (STFC)
£138,596 PI: M Wing

Studentship: Sarah Boutle (Deutsches Elektronen-Synchrotron)
£37,757 PI: M Wing

EUDET: Detector research and development towards the international linear collider (European Commission)
£207,685 PI: M Wing

LC-ABD Collaboration: Work package 9: Cavity BPM energy spectrometer (STFC) £203,957 PI: M Wing

Condensed Matter and Materials Physics

Many CMMP grants are held through the London Centre for Nanotechnology

Modelling charge transport in conducting polymers and biological systems (IRC Cambridge University)
£17,468 PI: D Bowler

New Exploratory Project – Modelling charge transport in conducting polymers and biological systems (IRC Cambridge University)
£127,409 PI: D Bowler

Structure and conduction mechanisms of atomic-scale wires on surfaces (Royal Society)
£172,260 PI: D Bowler

NSF: Quantum frustration (EPSRC)
£72,907 PI: S Bramwell

THREADMILL – Threaded molecular wires as supramolecularly engineered materials (European Commission)
£310,691 PI: F Cacialli

Insulated molecular wires: Supramolecular materials for organic optoelectronics (EPSRC)
£266,560 PI: F Cacialli

British-Italian partnership programme 2007-8 (British Council)
£4,000 PI: F Cacialli

Exploring new graphitic superconductors: Charge transfer, excitations and dimensionality (EPSRC)
£621,904 PI: M Ellerby

Studentship for Andrew Walters (STFC)
£19,821 PI: D McMorrow

Suppressing decohenrence in solid-state quantum information processing – Meeting the materials challenges of nano-CMOS electronics (EPSRC)
£439,638 PI: A Shluger

New Materials for hydrogen storage and large area solar cells (Wolfson Foundation grant) (Royal Society)
£200,000 PI: N Skipper

Development of simultaneous diffraction-conductance measurements at ISIS (CCLRC/STFC)
£29,000 PI: N Skipper

Studentship: T Headon (Schlumberger Cambridge Research)
£6,000 PI: N Skipper

Publications 2008

Astrophysics

1. D. Zhang, D. Rodiguez Sanmartin, T. Button, C. Atkins, P. Doel, C. Dunare, C. Feldman, A. James, A. Michette, W. Parks, S. Pfauntsch, S. Sahraei, T. Stevenson, H. Wang and R. Willingale, **Development of Piezoelectric Actuators for Active X-ray Optics,** Proc. of Electroceramics, XI (2008).

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