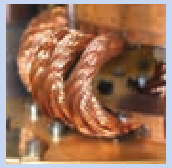
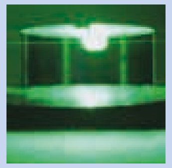
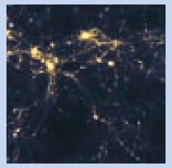
UCL DEPARTMENT OF PHYSICS AND ASTRONOMY

PHYSICS AND ASTRONOMY

ANNUAL REVIEW 2014–15

Contents



Cover image:
The ANITA-3 experiment, being launched in Antarctica.
Credit: Brian Hill (University of Hawaii-Manoa)

Image page 2:
Credit: UCL Media Services.

Image page 5:
Credit: Twinkle Consortium

Image page 11:
Credit: Oli Usher

Image page 17:
Credit: James Millen

Image page 28:
Credit: Andrew Pontzen and Fabio Governato

Review edited by **Olli Usher**, o.usher@ucl.ac.uk
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Welcome

The year 2014 ended with the announcement of the Research Excellence Framework results, an important exercise in which all UK universities are assessed on their research activities, and on which funding allocations are then based. The Department formed the bulk of UCL's 'Physics' submission, with major contributions also from our colleagues in the London Centre for Nanotechnology and in the Mullard Space Science Laboratory.

"…the department is strong and confident. We will meet these challenges together, and continue to prosper."

It is possible to make all kinds of different league tables from the results, but the ones that count most are those which correlate closely with the funding. On all of these, UCL Physics was in the top five nationally, and on my favourite – "research intensity", or average grade per academic – we were second (to Cambridge, so well done them too). These results are of course based primarily on the great research being carried out in the department, and you will find many examples of that throughout the review.

Another success, prepared in 2014 but announced in February 2015, was our receipt of the Institute of Physics Juno (and subsequently Athena Swan) award. These schemes are aimed at addressing the systematic gender imbalance in physics, which is a very important issue for the field. However, I found the lessons they teach about transparency and clarity of organisation, and improving the working environment for all, very generally applicable. I believe our department will be fairer, more pleasant and more successful as a result, to the benefit of all of us. Winning recognition for our efforts is nice, but it the process continues and there is still much work to be done.

The tragic death of Bruce Swinyard in May 2015 was a great loss, and our thoughts are with his family. A full obituary appears on page 13.

Several members of the department received prizes in 2014: Benjamin Joachimi and Ofer Lahav won awards from the Royal Astronomical society, as did the Herschel and Cassini teams which have several UCL members. David Walker won the IoP Optics and Photonics prize, Angela Occhiogrosso and Jennifer Chan won the faculty postgraduate research and taught course prizes, respectively. Steve Fossey won the UCL Communications and Culture award (remember the supernova discovery in Messier 82 from the last review!). Matthew Wing won the Friedrich Wilhelm Bessel Research Award from the Humboldt Foundation, Gerhard Materlik won the IoP Glazebrook medal, and Ian Robinson won the Aminoff Prize.

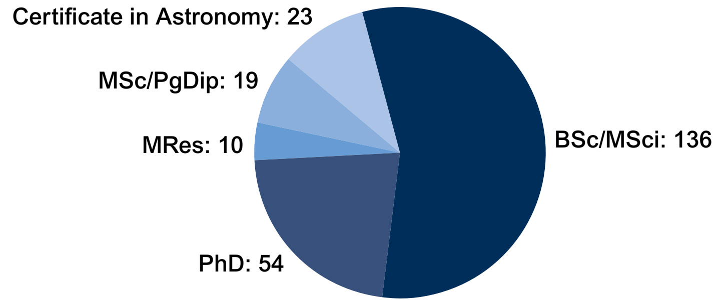
We are surrounded by major estates works, in the Physics Yard and the Kathleen Lonsdale Building; the astrophysics group are currently working in temporary accommodation in Hampstead Road. The financial environment in UCL is also challenging at present, as the university tries to build up a sustainable surplus to reinvest in the future. However, the department is strong and confident. We will meet these challenges together, and continue to prosper.

Professor Jonathan Butterworth
Head of Department

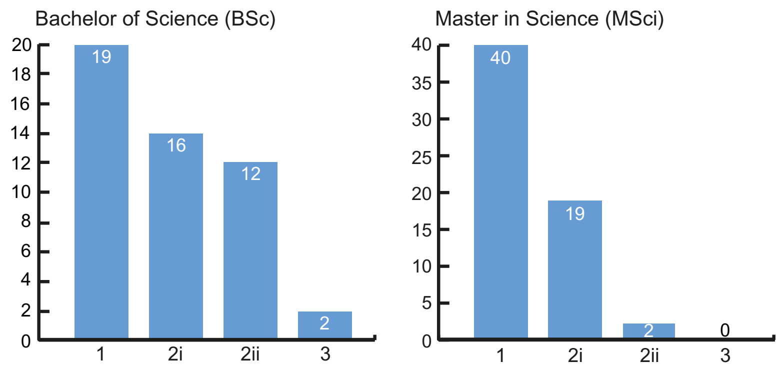
Community Focus

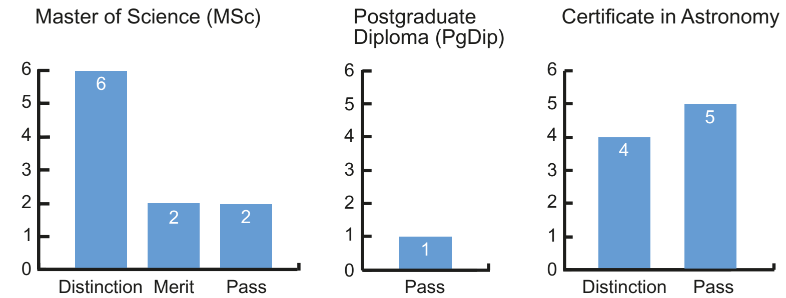
Teaching Lowdown

Intake



Awards





Training the next generation of physics teachers

An important development for the Department's teaching programme has been a new collaboration with the Institute of Education (IOE) to setup a Physics (BSc) plus Qualified Teacher Status (QTS) degree. All BSc students in our Department (including Physics, Theoretical Physics and Astrophysics) will from 2016/17 be able to opt-in for the QTS pathway during Year 3 of their BSc, and spend an extra year on the IOE run QTS qualification.

As a taster of physics education and teaching, a 5-day summer experience will be open to all Year 1 and Year 2 students in June/July 2016, at the IOE and with days in a partnership secondary school.

The UCL Physics plus QTS degree will be supported by bursaries and other maintenance allowances. We anticipate that this exciting new opportunity will lead to several students taking up careers as physics teachers in school each year.

By Raman Prinja

Headline Research

Quantum mechanics explains efficiency of photosynthesis

Light-gathering chromophores in plant cells transfer energy by taking advantage of molecular vibrations whose physical descriptions have no equivalents in classical physics, according to research by physicists in UCL's AMOPP group.

Molecular vibrations are periodic motions of the atoms in a molecule. When the energy of a collective vibration of two chromophores matches the energy difference between the electronic transitions of these chromophores a resonance occurs and efficient energy exchange between electronic and vibrational degrees of freedom takes place.

Providing that the energy associated to the vibration is higher than the temperature scale, only a discrete unit or quantum of energy is exchanged. Consequently, as energy is transferred from one chromophore to the other, the collective vibration displays properties that have no classical counterpart.

The team found the signature of non-classicality is given by a negative joint probability of finding the chromophores with certain relative positions and momenta, something impossible in classical physics.

Published by E. O'Reilly and A. Olaya-Castro, Non-classicality of the molecular vibrations assisting exciton energy transfer at room temperature. Nature Communications, 5 (2014)

Image credit: Thangaraj Kumaravel

Student Accolades

Undergraduate Awards

Departmental Awards

Oliver Lodge Prize
Best performance first year physics
Jakub Mrozek

Halley Prize
Best performance first year astronomy
Anusha Gupta

C.A.R. Tayler Prize
Best performance in Communication Skills (based on aggregate of first and second year marks)
Kate Macleod

Wood Prize
Best performance second year physics
Alan Suganuma

Huggins Prize
Best performance second year astronomy
Claudio Arena

David Pointer Prize
Most improved performance first and second year
Adam Suhaj

Sydney Corrigan Prize
Best performance in second year experimental work
Bhavin Patel

Best Performance Prize
Third year Physics
Martin Buettner

Best Performance Prize
Third year Astrophysics
Felix Priestley

Sessional Prize for Merit
First or Second year
Luke Yeo

Sessional Prize for Merit
Third year
Mitchell Watts

Burhop Prize
Best performance fourth year Physics
Stefan Blesneag

Herschel Prize
Best performance fourth year Astrophysics
Sandor Kruk

Brian Duff Memorial Prize
Best fourth year project
Anita Subbaraj

William Bragg Prize
Best overall undergraduate
Harapan Ong

Tessella Prize for Software
Best use of software in final year projects
Theo Le Bret

Physics and Astronomy prize winners 2014

Postgraduate Awards

Harrie Massey Prize
Best overall MSc student (Joint Award)
Jens Tiebert & Lerh Feng Low

Carey Foster Prize
Outstanding postgraduate physics research in AMOPP
Hugh Price

HEP Prize
Outstanding postgraduate physics research in HEP (Joint Award)
James Mott, Rebecca Chislett and Luke Lambourne

Marshall Stoneham Prize
Outstanding postgraduate physics research in CMMP (Joint Award)
Cristina Blanco Andujar and Szymon Daraszewicz

Jon Darius Memorial Prize
Outstanding postgraduate physics research in Astrophysics
Roser Juanola-Parramon

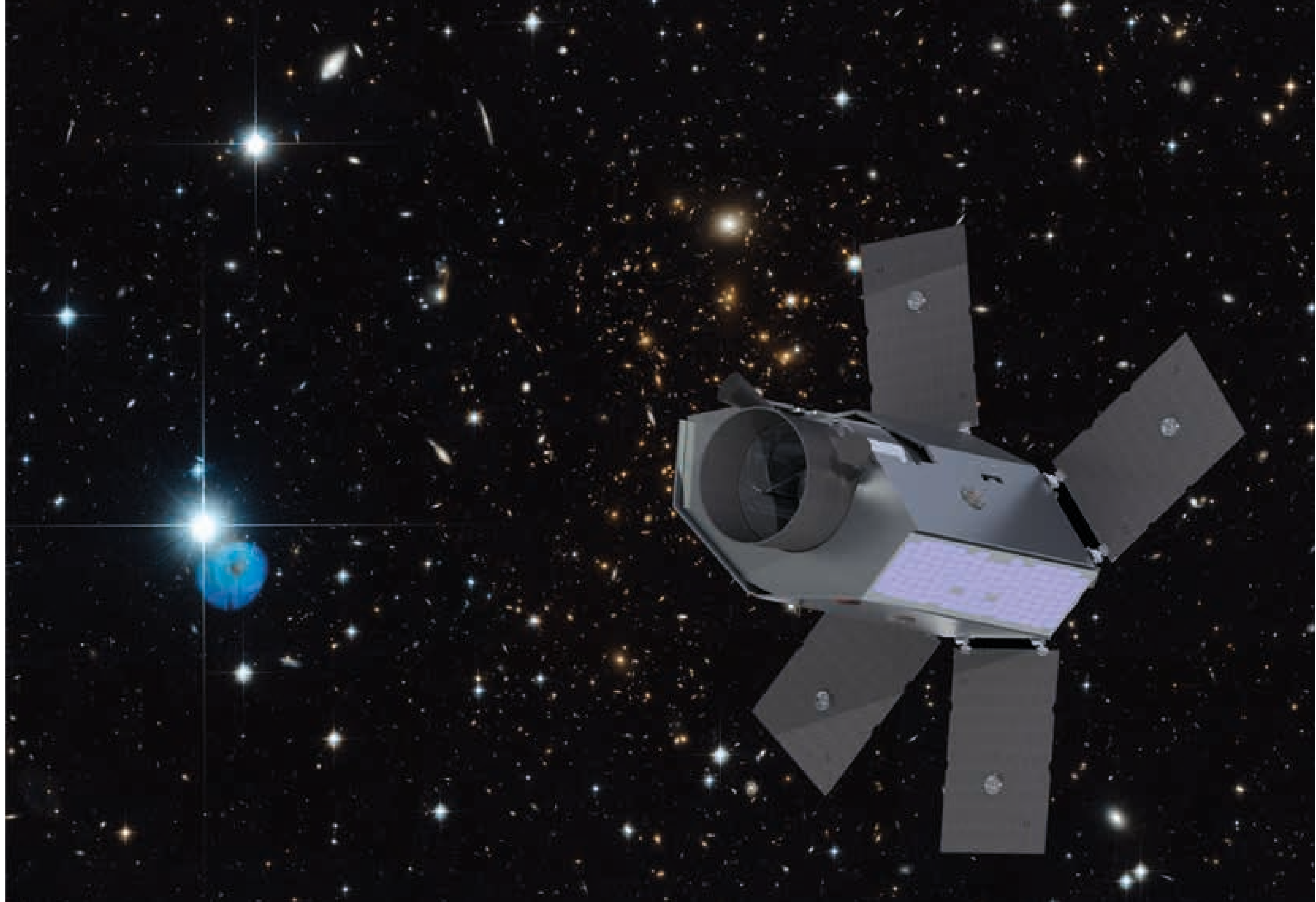
Christopher Skinner Prize
Outstanding postgraduate physics research in Astronomy
Emma Chapman

Twinkle: a new mission to study exoplanets

A new satellite for observing extrasolar planets could be in orbit within four years, under plans drawn up by UCL and Surrey Satellite Technology Limited (SSTL). The Twinkle satellite, pictured below, will observe the light of distant stars with planets orbiting them.

As a planet passes between the star and Twinkle's telescope, a small amount of the light passes through its atmosphere, imprinting on it the chemical signature of its atmosphere. This technique has been used by Hubble to analyse the atmospheres of a handful of exoplanets, but the Twinkle team hopes to probe at least 100 during the spacecraft's mission.

Giovanna Tinetti is the lead scientist in a consortium of UK institutes who will construct Twinkle's scientific instrumentation, a highly precise infrared spectrometer which can tease out the faint signature of the planetary atmospheres from the starlight.



Students in action

Engineering without borders: Physics student in UCL News

Gabriela May Lagunes, an undergraduate student in Physics and Astronomy, has used her skills to help improve quality of life in poor communities in Mexico. She is a member of UCL's branch of Engineers Without Borders (EWB), an international organisation that creates change by empowering engineering students to work in international development.

Gabriela coordinated a project that installed and repaired 13 rainwater-harvesting systems in the schools and clinics of eleven different communities in the Mexican city of San Miguel dee Allende last summer.

"*The project was very important as the levels of fluoride and arsenic in this particular area are between five and ten times higher than the international norm, often leading to health issues such as fluorosis, renal insufficiency and cancer from an early age,*" she says.

> "Gabriela coordinated a project that installed and repaired 13 rainwater-harvesting systems in the schools and clinics of 11 different communities"

Systems that aimed to provide secure, drinkable water were initially installed by a non-governmental organisation, IRRI Mexico, in 2007 (led by current UCL Teaching Fellow Ilan Adler, of UCL Civil, Environmental & Geomatic Engineering). However due to a lack of engagement between the local authorities and the local community, most of these had been abandoned by 2012.

So in 2013, UCL EWB put together a new team, in collaboration with IRRI Mexico and Ilan Adler, to revisit the project.

More than 450 people now have access to secure, drinkable water thanks to the work, and the team is now working towards more long-term goals. A documentary film, Harvesting Water for the Future, has been produced about the group's work.

Headline Research

What is the mass of the neutrino? UCL physicists weigh in

Do neutrinos have mass? And if so, how much? This apparently simple question has no simple answer and has been the subject of debate, controversy and confusion in the world of physics in recent years.

The consensus among physicists is that the standard model of particle physics is incomplete – but identifying what is missing from it is a complex issue.

Cosmologists are currently trying to get to the bottom of this question, with sometimes quite radical solutions. Boris Leistedt and Hiranya Peiris, two UCL researchers, have recently ruled out one of these eye-catching theories, the idea that neutrinos have a relatively high mass.

They look at this apparent evidence for high-mass neutrinos from two different angles:

- First, if the neutrino is indeed heavy, what would that imply about the universe around us (and does it fit with what we see)?
- Second, if it is not, what else could explain the discrepancies in the data?

On both fronts, their analysis points firmly at a significantly lighter neutrino, in line with previous estimates. They argue that the distribution of galaxies in the universe is only compatible with a low-mass neutrino, and that the discrepancies in the data that hinted at high-mass neutrinos are down to imprecise measurements of galaxy clusters.

Published by B. Leistedt, H. Peiris and L. Verde, No New Cosmological Concordance with Massive Sterile Neutrinos, Physical Review Letters, 113 (2014).

Clustering of galaxies, such as in this Hubble image, would be much less pronounced if neutrinos had a high mass. Credit: NASA, ESA, HST Frontier Fields

Bioengineering for everyone

A startup led by two astrophysics PhD students is making waves in the world of biotechnology. Tom Catling and Oli Coles are co-chief technology officers of Bento Bio (previously known as Darwin Toolbox), which is developing a lab-in-a-box for DIY science projects. The kit, currently undergoing testing, is a safe, affordable and easy portable biology laboratory, including a centrifuge and DNA analysis kit.

Their work has been recognised with a win in the London Entrepreneurs Challenge and UCL Bright Ideas award, as well as a runner-up place in the Royal Academy of Engineering's Enterprise Hub scheme. They've also been covered on BBC Radio and in technology magazine Wired.

They now have their own CNC machine and are building up a nice collection of tools, as well as securing a loan from UCL to rent a workshop.

Plans for the immediate future are to produce more prototype boxes and distribute them around the community to get some feedback on how people use them. They hope soon to start outsourcing construction.

The team are also keen on public engagement, travelling to the Green Man Festival to present their 'bacterial art', and won £2000 thanks to an audience vote at UCL Public Engagement Unit's Focus on the Positive competition.

Headline Research

Revealed: how bacteria drill into our cells and kill them

A team of scientists, including members of the lab of Bart Hoogenboom (BioP) at UCL, has revealed how certain harmful bacteria drill into our cells to kill them. Their study shows how bacterial 'nanodrills' assemble themselves on the outer surfaces of our cells, and includes the first movie of how they then punch holes in the cells' outer membranes.

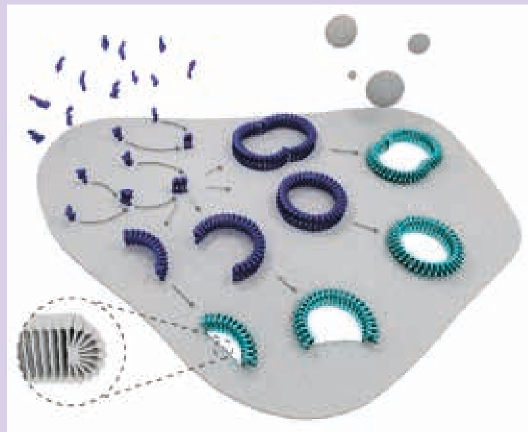
The research supports the development of new drugs that target this mechanism, which is implicated in serious diseases.

Unlike drills from a DIY kit, which twist and grind their way through a surface, bacterial nanodrills do not contain rotating parts. Rather, they are ring-like structures (similar to an eyelet) built out of self-assembling toxin molecules. Once assembled, the toxins deploy a blade around the ring's inside edge that slices down into the cell membrane, forming a hole.

A big surprise for the team was that complete rings aren't needed to pierce the cell membrane: even relatively short fragments are still able to cut holes, albeit smaller ones, and hold them open, allowing bacteria to feed on the cell's contents.

The discovery supports the development of new drugs that can target bacterial nanodrills and help treat the diseases in which they are implicated. These include pneumonia, meningitis and septicaemia.

B. Hoogenboom et al, 'Stepwise visualisation of membrane pore formation by suilysin, a bacterial cholesterol-dependent cytolysin', eLife (2014)



Bacterial nanodrills self-assembling on a cell membrane. Credit: eLife

Career Profile

Clara Sousa Silva

I have wanted to work with extra-solar planets (now simply known as exoplanets) ever since I knew they existed.

From the age of eleven I have been trying to understand these planets, but it was only at university that I realised how sophisticated a challenge this was. During my undergraduate and masters in Astrophysics at the University of Edinburgh I followed the development of exoplanetary research as it progressed from the youngest field in astrophysics to the fastest growing source of public fascination with space.

After graduating, I worked as a chemist at the Joseph Stefan Institute in Ljubljana, where I became interested in learning how to remotely study the atmospheres of exoplanets throughout the galaxy by analysing their light. I contacted Giovanna Tinnetti regarding my desire to work at UCL, knowing she was doing extraordinary work into exploring far away worlds with these exact techniques.

Giovanna suggested that I contact Jonathan Tennyson, then the head of the Department of Physics & Astronomy, to discuss joining his team who were pioneering the modelling of molecules in space. As a result, in 2011 I joined his ExoMol project as a PhD student.

With a talented multidisciplinary team of chemists, physicists, astronomers and computer scientists, ExoMol is creating a comprehensive molecular database for the atmospheric characterisation of exoplanets. My PhD focused on simulating molecular spectra for phosphine, which will enable the remote identification of this molecule on exoplanets. Due to its biogenic origins, phosphine is a potential marker for extinct or existing extraterrestrial life.

On Earth, it also happens to be an unintentional marker for crystal meth labs.

While writing up my PhD, I joined Researchers In Schools - a new teacher training programme for post-doctorate scientists aiming to bring exciting new research in to secondary schools. With the support of the programme's organisation, the Brilliant Club, and my business sponsor Goldman Sachs, I have taught science in several London schools and currently work part-time at Highams Park School.

In early 2015 I joined Twinkle; a new space mission dedicated to the study of the atmospheres of extraterrestrial worlds, led by Giovanna Tinetti. Given my interests in outreach and astrophysics, I became the coordinator for the mission's educational programme, EduTwinkle. It aims to bring space exploration into schools and improve the uptake of STEM subjects amongst women and other underrepresented groups.

> "I have wanted to work with extra-solar planets ever since I knew they existed."

I'm currently organising a EduTwinkle project where young astrophysicists supervise A-level students so they can produce original, publishable research alongside their studies. Many more projects for all age groups are being developed and these will continue until after the spacecraft launch in late 2018.

My research with phosphine and other molecules has been published at several leading astrophysics journals and I have spoken at major scientific conferences and educational events, most recently at the Royal Astronomy Society and Downing Street.

By Clara Sousa Silva

Alumni Matters

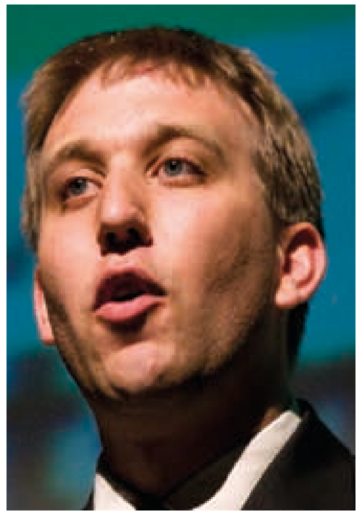
The second Physics and Astronomy Gala Dinner was held on the 24th of October 2014, in the nearby Ambassador Hotel (as the Wilkins Building is undergoing extensive refurbishment). Some 30 undergraduate and postgraduate prize winners and their guests, 18 members of staff and 57 alumni – an unprecedented number – came together to meet at the reception. Over dinner, they heard about our students' achievements in the award ceremony, and then heard the traditional after dinner speech.

Chris Lintott (UCL PhD 2006) gave this year's speech. Fresh from being appointed to his professorship in Astrophysics and Citizen Science at Oxford, Chris is famous as one of the presenters on BBC Sky at Night.

Chris related the previous January's discovery of the supernova in Messier 82 by four of our undergraduates assisted by Steve Fossey, comparing it to perhaps the first example of large scale public participation in the history of astronomy: when the total eclipse of the sun was observed and reported by many citizens across England and Wales in 1715. Edmund Halley had predicted the path of the total eclipse across the country (Phil. Trans. R. Soc. Lond. April 1715) but did not live long enough to check his predictions when the eclipse occurred again in 1724.

Following a stellar career at Oxford, Durham, Cambridge and Caltech, Prof Richard S Ellis CBE FRS is returning to his Alma Mater at UCL. I am proud to announce that he will be the After Dinner Speaker at the third Gala Dinner and Prize Giving to be held on Friday 23rd October 2015.

By Professor Tegid Wyn Jones



Prof Chris Lintott

Prof Richard S Ellis CBE FRS

Headline Research

A hiding place for the Earth's missing xenon

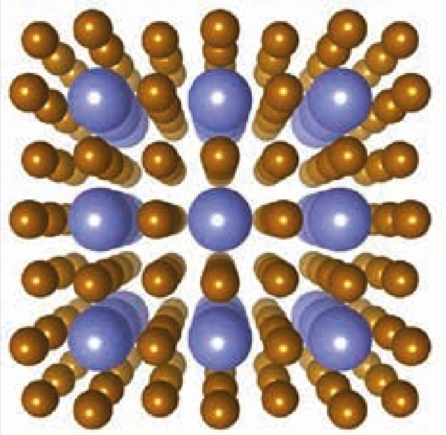
A collaboration between researchers in Jilin, China and University College London, including Professor Chris Pickard (then of the CMMP group), has identified a possible resting place for the Earth's elusive store of the noble gas xenon.

The atmosphere of the Earth contains far less xenon (the second heaviest noble gas) than expected. It is one of the enduring mysteries of the planetary sciences and is often referred to as the 'missing xenon paradox'.

Combining advanced structure prediction techniques, and high quality quantum mechanical calculations, the research team have shown that at the pressures found in the Earth's core both iron and nickel (its main constituents) react readily with xenon to form a variety of thermodynamically stable compounds – most importantly the cubic Fe3Xe (see Figure). Using diamond anvil cells, the conditions at the centre of the Earth can be reproduced in the laboratory. Experiments which have tried to make iron xenon compounds have never been successful, and earlier calculations made assumptions about the likely structures and found no bonding. It had been concluded that iron and xenon do not react in the Earth's core.

Advances in structure prediction (such as ab initio random structure searching, developed by Prof Chris Pickard, and swarm based approaches pioneered by Jilin researcher Prof Yanming Ma) allow the unbiased discovery of unsuspected materials. New, more stable, xenon iron compounds were found in the current study, and the earlier conclusion overturned. Awaiting experimental confirmation of the result, their article published in Nature Chemistry proposes that the Earth's core is a natural hiding place for the missing xenon.

C. Pickard et al, 'Reactions of xenon with iron and nickel are predicted in the Earth's inner core', Nature Chemistry, 6, 2014



Cubic Fe3Xe. At sufficiently high pressure (around those found in the Earth's inner and outer cores) the normally inert xenon reacts readily with iron and nickel.

Science in action

This year the department has employed an Outreach coordinator for the first time. This is to coordinate all of the outreach currently being done by members of the department, but also to build better relationships with nearby schools by forming Physics Partnerships, and to invigorate and improve the outreach program offered through the University of London Observatory (ULO).

Since beginning my role at the very end of July, a day after leaving my previous role as a physics teacher, I have been investigating various ways in which I can help make the outreach that the department conducts more sustainable. At the top of this list is building partnerships with schools, where we offer more than just appearances at one-off events. So far this program is shaping up to include lunchtime lectures from undergraduate students, CPD training for teachers, teaching internships for undergraduate students, and talks from academics on a wide range of topics from careers to the more inaccessible areas of the A-level curriculum.

Dr Sarah Hutton demonstrating how stars are formed during the pop-up Astronomy event in the Main Quad.

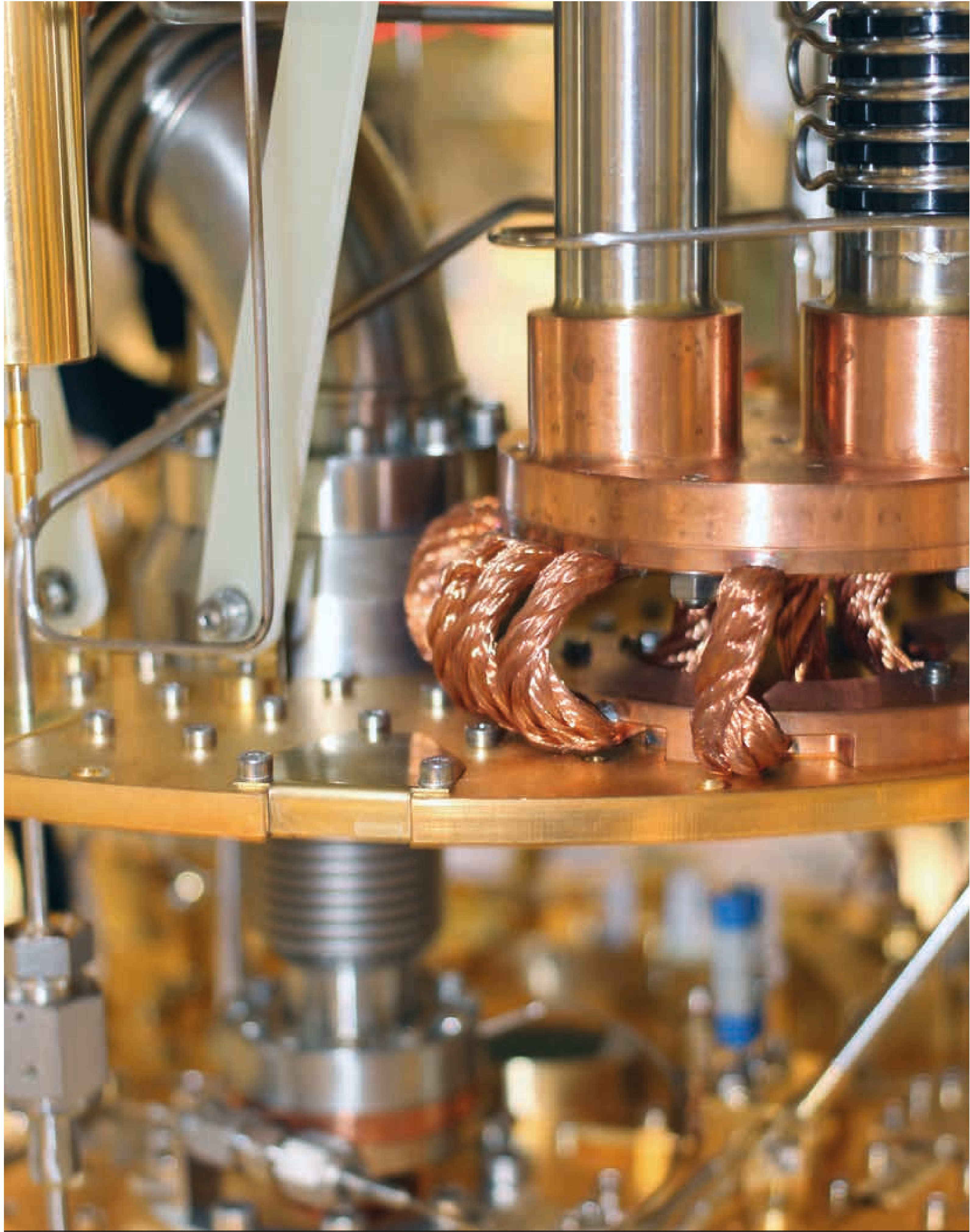
Dr Steve Fossey shows the Sun to interested UCL undergraduates and members of the public through the solarscope.

With regards to ULO I have begun to learn how the current system of school and public tours operate and to see how we can deliver the largest impact. Combining my astronomy and teaching backgrounds I am exploring different methods that we can use to deliver our Schools Programme. One such option is for the department to invest in a mobile planetarium that can be taken into schools for children of all ages to experience the wonder and amazement that only comes from viewing a completely dark night sky – a nearly impossible task for the thousands of schoolchildren who live in central London!

We have also been working hard to raise the profile of ULO on the UCL campus. We arranged a display of astronomical images taken at ULO in the South Cloisters complete with an information board describing the history of the Mill Hill site. The images cover a wide range of celestial objects including the Type Ia Supernova SN2014J discovered by undergraduates and Dr Steve Fossey during an evening observing session.

We also held a pop-up event out of the Northern Dome in the main quad with the aid of UCL Museums and Mathematical & Physical Sciences Faculty staff. Over 250 visitors enjoyed observing the sun through a solar scope, viewing Lunar Orbiter, Viking and Mariner archive images of the Moon and Mars taken during the 1960s and 1970s, and learning about the advancements in astronomical images from the Palomar Sky Survey in the 1950s to the Hubble Space Telescope images taken today.

By Sarah Hutton



Academic Showcase

Staff News

Academic Appointments

Recruitment is a two way process, and a measure of the continuing success of the Department can be evidenced through the ability to attract highly esteemed academic members of staff. Each member of staff compliments and enhances the high-profile research portfolios of both the individual research groups and the Department as a whole.

Promotions

Promotion to Professor

Prof. Peter Doel (Astro)
Professor of Astronomical Instrumentation

Promotion to Reader

Dr David Cassidy (AMOPP)
Reader in Physics

Dr Stephen Hogan (AMOPP)
Reader in Atomic and Molecular Physics

Dr Emily Nurse (HEP)
Reader in Physics

Dr Marzena Szymanska (AMOPP)
Reader in Physics

Promotion to Principal Teaching Fellow

Mr Paul Bartlett
Principal Teaching Fellow

Retirements

Dr Mark Ellerby (CMMP)

New academic members of staff

F Kruger (CMMP) Lecturer

Headline Research

LHC may falsify Leptogenesis

From experiments we know that there is an asymmetry of matter and anti-matter in our universe: The excess of baryons over anti-baryons (e.g. protons over anti-protons) could be triggered by a mechanism called leptogenesis, which is currently the most favourite explanation for many particle physicists.

Already in 1967 Sakharov defined three conditions which such models have to fulfil. One of them is the departure from thermal equilibrium. This is a crucial condition as in thermal equilibrium any net baryon asymmetry produced by a specific process would be immediately destroyed by the inverse process. This is usually called "wash-out".

Now Frank Deppisch and Julia Harz (HEP group) have demonstrated that it is possible to draw conclusions from observations at the LHC on the evolution of the universe: observing a process which violates lepton number at the LHC is equivalent to establishing a lower limit on the washout factor for the lepton number in the early universe.

If the primordial lepton number asymmetry is originally generated above the lepton number violating scale observed at the LHC, the resulting washout will reduce the asymmetry exponentially, rendering leptogenesis ineffective. Thus, the LHC may offer a unique way to rule out leptogenesis.

F. Deppisch, J. Harz et al, 'Falsifying High-Scale Leptogenesis at the LHC', Physical Review Letters, 112 (2014)

The LHC tunnel. Credit: CERN

Obituary

In memoriam
Bruce Swinyard

The department has lost a dear friend and colleague.

Bruce Swinyard joined the Department of Physics & Astronomy's Astrophysics Group in the summer of 2010, as a joint appointment between UCL and STFC's Rutherford Appleton Laboratory, spending half his time at UCL and half at RAL's Space Science and Technology Department, where he was Leader of the Astronomy Group.

Bruce played an outstanding role in the successful development of a series of state-of-the-art scientific instruments for important space missions. He was Calibration Scientist for the Long Wavelength Spectrometer for ESA's Infrared Space Observatory, which flew between 1995 and 1998. From 1999 he designed and oversaw the technical development of the SPIRE imager and spectrometer for ESA's Herschel Space Observatory, to its launch in 2009 and the completion of its ground-breaking mission in April 2013. He was deeply involved in the use of the SPIRE instrument in orbit and devised a number of innovative observing techniques that successfully stretched its capabilities. In particular he recognised before launch the potential power of using Herschel's two multi-wavelength imaging instruments (SPIRE and PACS) as effectively a single `fourth instrument' when operated in 'parallel mode'. This enabled a number of high impact observing programmes, including deep surveys for extragalactic sources and the HiGAL survey of the plane of the entire Milky Way.

From 2001 until 2005. Bruce acted as European Project Scientist for the James Webb Space Telescope's MIRI instrument. He then stepped down from that project in order to concentrate on his role as the European Principal Investigator for the Japanese-led SPICA infrared mission, in particular leading the design of the proposed European SAFARI instrument. Bruce then led the conceptual design and modelling of the integrated payloads for the proposed EChO, Ariel and Twinkle exoplanetary transit spectroscopy missions. He was one of the leaders of an initiative to involve industry in the design and implementation of innovative receiver technology in space, which led to the recent funding of the LOCUS supra-THz limb sounding instrument to measure atomic oxygen and other species in the Earth's upper atmosphere.

Bruce was first diagnosed with cancer nearly four years ago but continued to work normally and in his usual optimistic way, continuing to generate many new ideas for instruments and missions. Unfortunately Bruce's health began to decline rapidly earlier this year, and he passed away on 22 May 2015.

Bruce was an inspiration to the many colleagues and students that he worked with. He was an incredibly brave and talented person and his death represents a major loss to the Astrophysics Group and to the Department of Physics and Astronomy.

Our thoughts are with his wife Margaret and his two daughters.

Colleagues watch as the UCL flag is lowered in honour of Bruce Swinyard in a ceremony in July

Staff Accolades


Ian Robinson

Royal Swedish Academy of Sciences: Gregori Aminoff Prize in Crystallography

Awarded to **Professor Ian Robinson**

For his contribution in areas concerned with the dynamics of the formation and dissolution of crystal structures, specifically his pioneering contributions in the field of X-ray diffraction.

Institute of Physics: Glazebrook Medal

Awarded to **Professor Gerhard Materlik**

For his outstanding leadership in establishing a world-leading laboratory at the Diamond Light Source and for his innovations in X-ray diffraction physics.


Gerhard Materlik


Matthew Wing

Humboldt Foundation: Friedrich Wilhelm Bessel Research Award

Awarded to **Professor Matthew Wing**

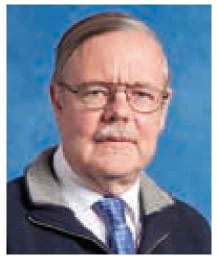
For outstanding research as a scholar internationally renowned in his field who is expected to continue producing cutting-edge achievements which him have a seminal influence on [his] immediate discipline beyond [his] immediate field of work.

UCL Communication & Culture Awards: Media communicator of the year

Awarded to **Dr Steve Fossey**

For his numerous media appearances surrounding his discovery of Supernova 2014J in Messier 82.


Steve Fossey


David Walker

Institute of Physics: Optics and Photonics Prize

Awarded to **Professor David Walker** (jointly of UCL and Glyndwr University)

For his work on astronomical optics, and for commercialising his university research to help produce an international optics-based manufacturing company.

Royal Astronomical Society: Winton Capital Award

Awarded to **Dr Benjamin Joachimi**

For establishing himself as a world leader in the subject of galaxy intrinsic alignments, whose effect would ruin the promise of lensing for cosmology if ignored.


Benjamin Joachimi


Ofer Lahav

Royal Astronomical Society: Gerald Whitrow Lecture

Awarded to **Professor Ofer Lahav**

For having made pioneering contributions to cosmology by using novel statistical techniques to exploit galaxy survey data, and playing influential leadership roles in observational cosmology.

UCL: Provost's Teaching Award (early career staff)

Awarded to **Dr Daven Armoogum**

For outstanding teaching of undergraduate students in Physics & Astronomy.

UCL Physics & Astronomy Teaching Prize

Awarded to **Dr Robert Thorne**

For inspirational and dedicated teaching of advanced modules.


Daven Armoogum


Robert Thorne

In addition, UCL physicists were members of teams recognised in the Royal Astronomical Society's group awards.

Royal Astronomical Society: Geophysics Group Achievement Award

Awarded to the Cassini Magnetometer Team, including **Dr Nick Achilleos**

Royal Astronomical Society: Astronomy Group Achievement Ward

Awarded to the Herschel-SPIRE consortium, including **Professor Bruce Swinyard**, **Dr Giorgio Savini** and **Professor Mike Barlow**.

Portrait of…

Dr Gillian Peach

Having just completed a maths degree she began her postgraduate work with very little prior knowledge of atomic physics. She started out by performing numerical calculations using a Monroe electrically powered desk machine, which clattered so loudly she couldn't work more than a few hours at a stretch. Today, more than fifty years later, Gillian Peach is still doing science, using UCL's Legion cluster to carry out her research.

Gillian Peach has been a familiar face at UCL for decades. She first came to UCL in 1960 as a postdoc in what was then the Department of Physics headed by Sir Harrie Massey, before becoming the Department's first woman lecturer in 1966. Aside from a year at the University of Maryland, she has been at UCL ever since.

She has seen at first-hand the enormous changes – in the College, the department, and also in women's place in science – that have occurred during that half century. UCL is in many respects barely recognisable, with vastly expanded student numbers and new buildings all over campus. From an almost entirely male environment, the department has become far more diverse – even if there is still work to do.

> "…the department is still recognisably the one Harrie Massey shaped over 60 years ago."

The department has also expanded into new areas in that time, merging with the former Department of Astronomy in 1972 and more recently with the establishment of the CMMP group. And yet, she says, the department is still recognisably the one Harrie Massey shaped over 60 years ago.

During her career, Gillian has worked on a number of areas in theoretical atomic physics.

Two major areas relate to the analysis of astronomical and laboratory spectra. She has studied photoionisation (in which photons knock electrons out of atoms and atomic ions) and has developed general formulae that astrophysicists have used extensively in their analysis of the structure of stars. While in the plasma physics group at the University of Maryland she first became interested in the problems of spectral line broadening (subtle changes in the spectral properties of atoms that depend on conditions such as temperature and particle density).

She has also worked extensively on ultra-cold atomic collisions. This follows on from research by others into Bose-Einstein condensation in gases, a state of matter previously predicted theoretically and first confirmed experimentally in the mid-1990s. People working in this area at the time knew very little about the theory of atom-atom collisions and at these super-low temperatures atoms move very slowly, but collisions are still important. Gillian has used her extensive experience of atomic collisions at higher temperatures to bring new perspectives and fresh clarity to this work.

Gillian retired in 2001 and is now an emeritus reader. She is still an active researcher and supervises students for their final year undergraduate projects.

Research Degrees

January – December 2014

Samer Al-Kilani
Electrical tests of the ATLAS Phase-II Strip Tracker Upgrade
(Supervisor: Professor M. A. Lancaster)

Hussain Anwar
Towards fault-tolerant quantum computation with higher-dimensional systems
(Supervisor: Dr D. E. Browne)

Cristina Blanco-Andujar
Sodium carbonate mediated synthesis of iron oxide nanoparticles to improve magnetic hyperthermia efficiency and induce apoptosis
(Supervisor: Professor T. T. K. Nguyen)

Emma Chapman
Seeing the first light: a study of the Dark and Dim Ages
(Supervisor: Dr F. B. Abdalla)

Rebecca Chislett
Studies of hadronic decays of high transverse momentum W and Z bosons with the ATLAS detector at the LHC
(Supervisor: Dr M. Campanelli)

Samuel Cook
Characterisation of the MuSIC muon beam and design of the Eu-XFEL LPD/CCC interface firmware
(Supervisor: Prof M. Wing)

Camilla Danielski
Optimal extraction of planetary signal out of instrumental and astrophysical noise
(Supervisor: Dr G. Tinetti)

Jonathan Davies
A search for cosmogenic neutrinos with the Askaryan Radio Array
(Supervisor: Dr R. J. Nichol)

Harpreet Dhanoa
The pressure-driven fragmentation of clouds at high redshift
(Supervisor: Professor J. M. C. Rawlings)

Michael Down
Assignment of trace atmospheric species
(Supervisor: Professor J. Tennyson)

Alexandros Gerakis
Controlling and probing molecular motion with optical lattices
(Supervisor: Professor P. Barker)

Luke Green
Synthesis and characterisation of FePt magnetic nanoparticles
(Supervisor: Professor T. T. K. Nguyen)

Christian Gutschow
First observation of electroweak Z boson plus two jet production
(Supervisor: Dr E. L. Nurse)

Morgan Hollis
Characterisation of extrasolar planets
(Supervisor: Dr G. Tinetti)

Roser Juanola-Parramon
A far-infrared spectro-spatial space infererometer. Instrument simulator and testbed implementation
(Supervisor: Dr G. Savini)

Christopher Kirkham
Bi and Mn nanostructures on the Si(001) surface
(Supervisor: Professor D. R. Bowler)

Luke Lambourne
Boosted bb decays with the ATLAS experiment at the LHC
(Supervisor: Prof N. Konstantinidis)

Boris Leistedt
Accurate cosmology with galaxy and quasar surveys
(Supervisor: Professor H. V. Pieris)

James Mott
Search for double beta decay of 82Se with the NEMO-3 detector and development of apparatus for low-level radon measurements for the SuperNEMO experiment
(Supervisor: Professor R. Saakyan)

Edward O'Reilly
Quantum traits in the dynamics of biomolecular systems
(Supervisor: Dr A. Olaya-Castro)

Dino Osmanovic
Polymer theory applied to the nuclear pore complex
(Supervisor: Professor I. J. Ford)

Luke Peck
Technical development and scientific preparation for the e-Merlin Cygnus OB2 radio survey
(Supervisor: Professor R. K. Prinja)

Hugh Price
Multi-electron ionisation in driven atoms and molecules
(Supervisor: Dr A. Emmanouilidou)

Alexander Radovic
Measuring the disappearance of muon neutrinos with the MINOS detectors
(Supervisor: Professor J. A. Thomas)

Nico Seidler
Polythiophene nanofibres for optoelectronic applications
(Supervisor: Professor F. Cacialli)

Laura Shemilt
Coherent diffraction imaging and ptychography of human metaphase chromosomes
(Supervisor: Professor I. K. Robinson)

Marcell Tessenyi
A theoretical framework to understand the diversity of exoplanet atmospheres with current and future observatories
(Supervisor: Dr G. Tinetti)

Cristovao Vilela
Search for double-beta decay of 48Ca in NEMO-3 and commissioning of the tracker for the SuperNEMO experiment
(Supervisor: Professor D. S. Waters)

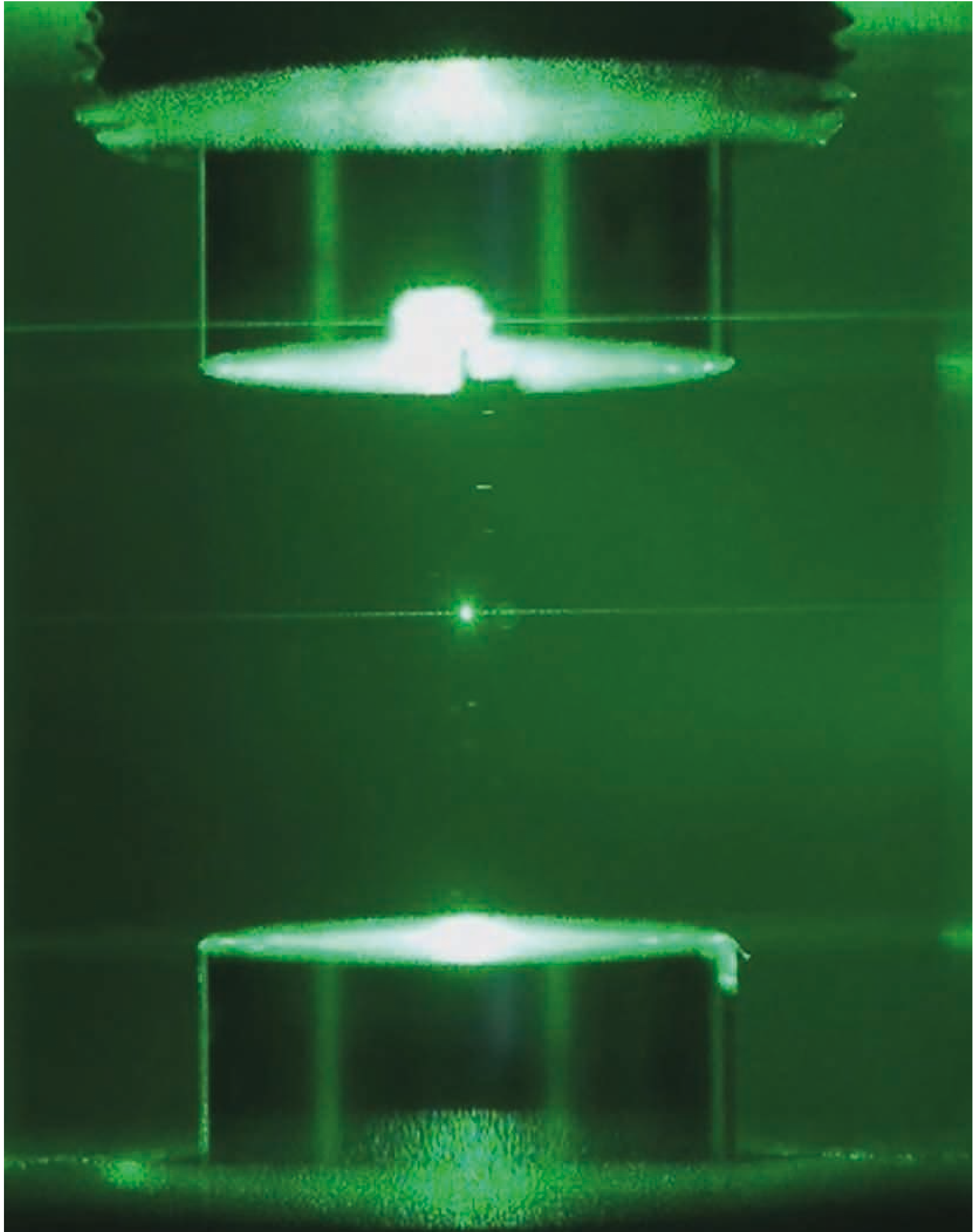
Ben Warner
Engineering the properties of magnetic molecules through the interaction with the surface
(Supervisor: Dr C. F. Hirjibehedin)

Benjamin Watt
Investigations into the effect of Hadron Collider data on MSTW Parton Distribution Functions
(Supervisor: Professor R.S. Thorne)

Laura Wolz
Cosmology with future radio surveys
(Supervisor: Dr F. B. Abdalla)

Jie Wu
Novel orbit-based approaches for matter in strong laser fields
(Supervisor: Dr C. Figueira De Morisson Faria)

Ho-Ching Yiu
High latitude thermosphere meso-scale studies and long-term database investigations with the new scanning doppler imager and Fabry-Perot interferometers
(Supervisor: Dr A. L. Aruliah)



Research Spotlight

Condensed Matter and Materials Physics (CMMP)

The Condensed Matter and Materials Physics group works on a wide spectrum of subjects including quantum computing, organic electronics, superconductivity, and biomagnetism. Many of the group's members hold joint appointments with the London Centre for Nanotechnology, including professors Des McMorrow (whose research focuses on understanding how electrons organise themselves in solids), and Neal Skipper (who focuses on atomic-scale modelling of how materials are made up).

Prof Ian Robinson, a member of the group, was awarded the Gregori Aminoff prize in September 2014, in recognition of his work in crystallography.

Below, **Dr Pierre Thibault** explains some of the group's work in the field of X-ray imaging.

High resolution X-ray phase contrast

The ability of X-rays to penetrate materials is a property that has been exploited since their discovery.

X-rays are high-energy electromagnetic waves. They are attenuated when they penetrate a material, producing the contrast exploited for hospital imaging. X-rays are also refracted by matter, an effect unfortunately much harder to observe by conventional means. Experimental set-ups designed to detect X-ray refraction produce phase-contrast images – since refraction is the result of a phase shift in the incident wave caused by the sample. The phase shift produced by most objects is a useful signal that provides information complementary – and sometimes superior in quality – to the conventional attenuation signal. Better X-ray phase contrast has therefore been a goal of the X-ray imaging community for decades.

The central problem with phase contrast imaging is that phase cannot be measured directly. To obtain phase information the wave must interfere with itself.

The oldest type of X-ray interferometry is X-ray crystallography. In a crystal diffraction experiment, the distortions of the incident wave field caused by the atoms are amplified in specific directions by constructive interference. The effect of minute phase modulations produced by electrons in the crystal creates an intensity signal, which lets you reconstruct a high resolution three-dimensional map of the electron density of the molecules in the crystal.

Imaging with coherent X-rays

A range of techniques has been developed over the years for obtaining phase contrast from larger, non-crystalline samples.

Phase contrast techniques need the incident X-ray wave to have the capacity to interfere, a property described by the concept of coherence. Coherence is a statistical description of a wave field: the greater the coherence, the more stable the field. In quantum terms, a perfectly coherent wave is made of photons that all occupy precisely the same state, as in a laser. Unlike traditional X-ray tubes, synchrotron facilities like Diamond Light source produce highly coherent X-rays and have transformed the field.

Ptychography

Beyond phase contrast, reaching the highest resolution when producing two- and three-dimensional images is a key objective for X-ray science. While X-rays' sub-nanometre wavelength offers potential for atomic resolution, many hurdles stand in the way. There is no simple X-ray equivalent to the lenses used in optical microscopes. This situation has led to the development of lens-less imaging, which uses an algorithmic lens instead. Because these techniques rely heavily on the high degree of coherence of the incident X-ray wave, they are called coherent diffractive imaging (CDI).

> "One of the latest successful steps in this translation is the demonstration of speckle-tracking imaging using a high-brilliance laboratory source."

Among CDI techniques, ptychography (from the Greek word for folding) stands out. The technique combines far-field diffraction patterns produced by the interaction of a small (about 1 μm) X-ray spot with an extended sample. Numerous data points are collected as the spot is scanned across the sample. A computer then reconstructs both the X-ray wave field profile and the sample transmission function (which itself includes both its absorption and phase shifting properties).

The experimental set-up for ptychography (see figure 1) requires only a coherent X-ray beam, a sample on a high-precision translation stage and a large pixel-array detector.

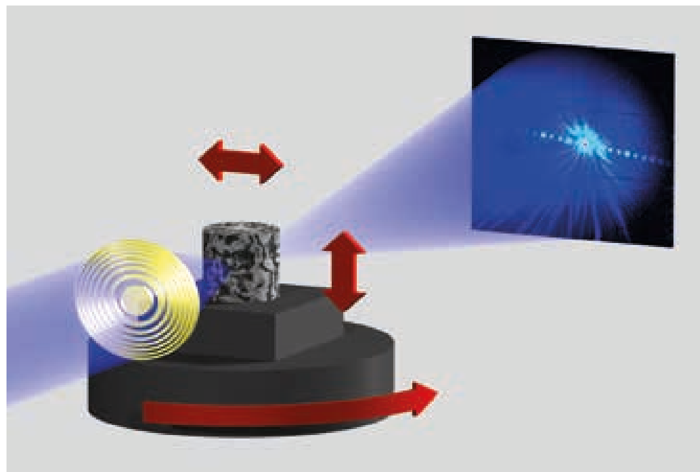


Figure 1.
Schematic of a ptychography experimental set-up. The incident X-ray beam is focused onto a sample mounted on translation and rotation stages and the scattered wave is collected further downstream with a pixel-array detector.

Both experimental conditions and reconstruction algorithms have progressed tremendously in recent years. Ptychography is now being used as a routine technique in synchrotron facilities, and has delivered some of the best X-ray images. Two recent examples of bone samples are shown in figure 2.

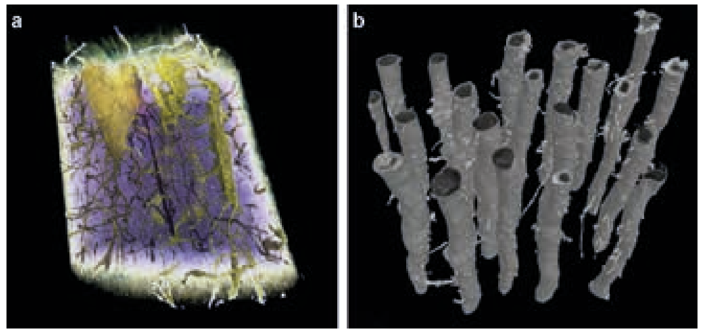


Figure 2.
Examples of 3D ptychographic reconstructions. (a) Murine bone sample, showing one lacuna and the small channels (down to below 200 nm in diameter) forming the canalicular network (b) Tubules in the dentine of a human tooth. Each tubule has a diameter of about 1.2 μm. In both cases, data was collected at the Paul Scherrer Institut (Switzerland).

Near-field coherent imaging

Holography, also commonly used with X-rays, exploits interference effects in monochromatic waves, just as its far-field diffraction counterparts. Holography has its own phase problem. The algorithms developed for far-field ptychography have been shown to work fine also in this near-field geometry. A recent image obtained at the European Synchrotron Radiation Facility is shown in figure 4. One benefit of working with shorter propagation distances (this is roughly what "near-field" means) is the weaker coherence requirement. As a direct consequence, adapting synchrotron-based imaging techniques to work in the lab is a real possibility.

One of the latest successful steps in this translation is the demonstration of speckle-tracking imaging using a high-brilliance laboratory source. While the apparatus needed for this technique is nearly identical to the one for ptychography, the data analysis is radically simpler: the absorption and refraction caused by the sample are extracted from the measurement by detecting minute changes in a reference speckle frame. Figure 5 shows a rendering of such a speckle intensity field, and the phase-contrast images it can produce. Speckle tracking does not reach the spatial resolutions achieved by ptychography, but an extra imaging channel, called dark field, provides a quantitative estimate of features in a sample that are too small to image and merely scatter X-rays as they travel through it.

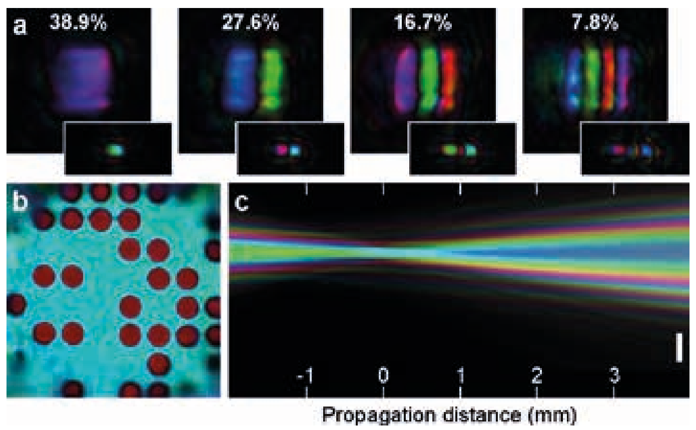


Figure 3.
Recent results in X-ray wave field reconstructions. (a) Four dominant modes of a partially coherence incident wave. (b) The reconstruction of the test sample used to retrieve the wave. (c) Numerical propagation of the wave field around the point of interaction with the sample. The scale bar is 1 μm. Data collected at the Paul Scherrer Institut (Switzerland).

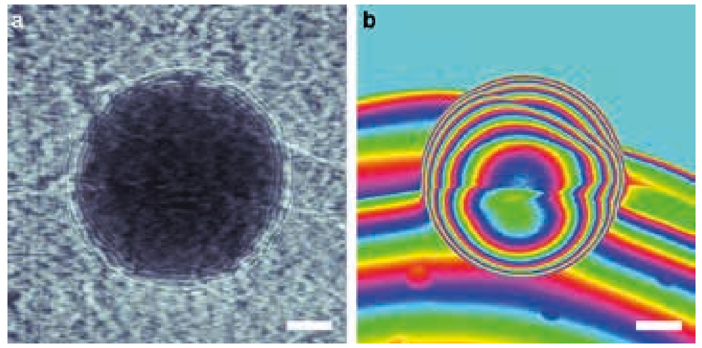


Figure 4.
Results from one of the first near-field ptychography experiments. (a) One of the raw frames, showing the speckle structure induced by the phase modulator introduced in the beam, and the strong scattering and absorption caused by a uranium sphere. (b) The phase image reconstructed from this dataset. The colors indicate that the sample induces a phase shift of many times 2π. Both scale bars are 10 μm long. Data collected at the European Synchrotron Radiation Facility (France).

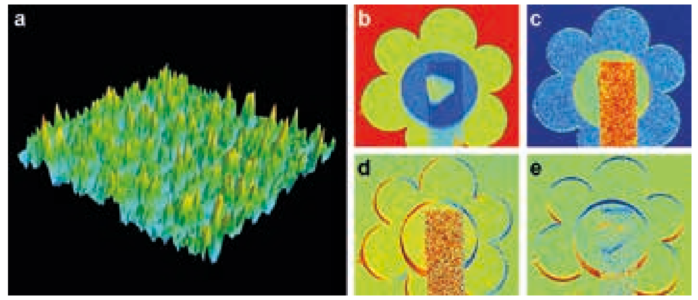


Figure 5.
Speckle tracking demonstration experiment using a liquid-target laboratory X-ray source. (a) A surface rendering of a portion of the measured speckle pattern caused by a piece of sandpaper placed in the beam. (b-e) Reconstructions of the absorption, dark field, differential phase contrast in x, and differential phase contrast in y, respectively, from a test sample (a plastic flower fixed on a wooden holder). Data collected at the KTH Royal Institute of Technology (Sweden).

A bright future

The momentum of coherence-based imaging has been building up for decades, thanks to increasing computing power and improved reconstruction strategies. Improved detectors, better optics and sample environments have helped too. In addition the apparition of the first X-ray free-electron lasers, which provide essentially fully coherent X-rays in pulses of a few femtoseconds, has already started to transform X-ray science. In the laboratory, after nearly a century of rather slow progress, new high-brilliance sources are now making their entry, clearing the way for a much wider availability of phase-contrast inspection of materials.

Atomic, Molecular, Optical and Positron Physics (AMOPP)

ExoMol: molecules in faraway worlds

Sergey Yurchenko reports on research from the Atomic, Molecular, Optical and Positron Physics (AMOPP) group, which is helping astronomers understand the spectrographic data they are collecting from extrasolar planets.

We now know that the galaxy is full of planets. Pretty much every star supports its own planetary system. These planets are being discovered in large numbers, a process that will only accelerate as new space-borne and ground-based planetary search missions come on line.

But what are these new worlds like?

There are already many surprises with most planetary systems looking quite unlike our own solar system. “Hot Jupiters”, large gas giants orbiting very close to their host stars, and “super Earths”, rocky planets significantly bigger Earth, Venus or Mars, both seem to be common. “Lava planets”, rocky planets that orbit so close to their star that the rock must be substantially molten, form another unanticipated find.

> “We need to understand how the atmospheres of these planets absorb and emit light.”

These planets give rise to intriguing questions: What are they made of? How did they form? And, of course, are any of them capable of support life?

Answers to these questions require new measurements. We need to understand how the atmospheres of these planets absorb and emit light. Interpreting these faint signals requires a detailed understanding of the physical processes involved. Given that most planets we can observe are hot, this means a detailed understanding of how hot molecules interact with light. The answer to this question turns out to be complicated.

The ExoMol project, led by Prof Jonathan Tennyson and Dr Sergey Yurchenko, uses the equations of quantum mechanics to compute how every molecule that is likely to be important in the atmospheres of planets absorbs and emits light.

This challenging undertaking is funded by an Advanced Investigator Grant Award from the European Research Council. While ExoMol has studied the behaviour of many molecules: it is the work on methane that caught the headlines in the last year.

Yurchenko and Tennyson developed a new and much more complete model for methane, the simplest organic molecule, widely acknowledged to be a sign of potential life. This model extended our understanding of this molecule to much higher temperatures: 1200 C. To do this involved computing almost 10 billion wavelengths where methane can absorb light and the associated probability for each wavelength that the light will be absorbed. The resulting list transition frequencies and transition probabilities is known as 10to10.

Tennyson says:

“*Current models of methane are incomplete, leading to a severe underestimation of methane levels on planets. We anticipate our new model will have a big impact on the future study of planets and ‘cool’ stars external to our solar system, potentially helping scientists identify signs of extraterrestrial life.*”

This comprehensive spectrum has only been possible thanks to the astonishing power of modern supercomputers, which are needed for the billions of lines required for the modelling. They limited the temperature threshold to 1250 C to fit the capacity available, so more research could be done to expand the model to higher temperatures still. The calculations required about 3 million CPU (central processing unit) hours alone; processing power only accessible through the Science and Technology Facilities Council (STFC)-funded national DiRAC integrated supercomputing facility.

Yurchenko says:

“*We are thrilled to have used this technology to significantly advance beyond previous models available for researchers studying potential life on astronomical objects, and we are eager to see what our new spectrum helps them discover.*”

> “Current models of methane are incomplete, leading to a severe underestimation of methane levels on planets.”

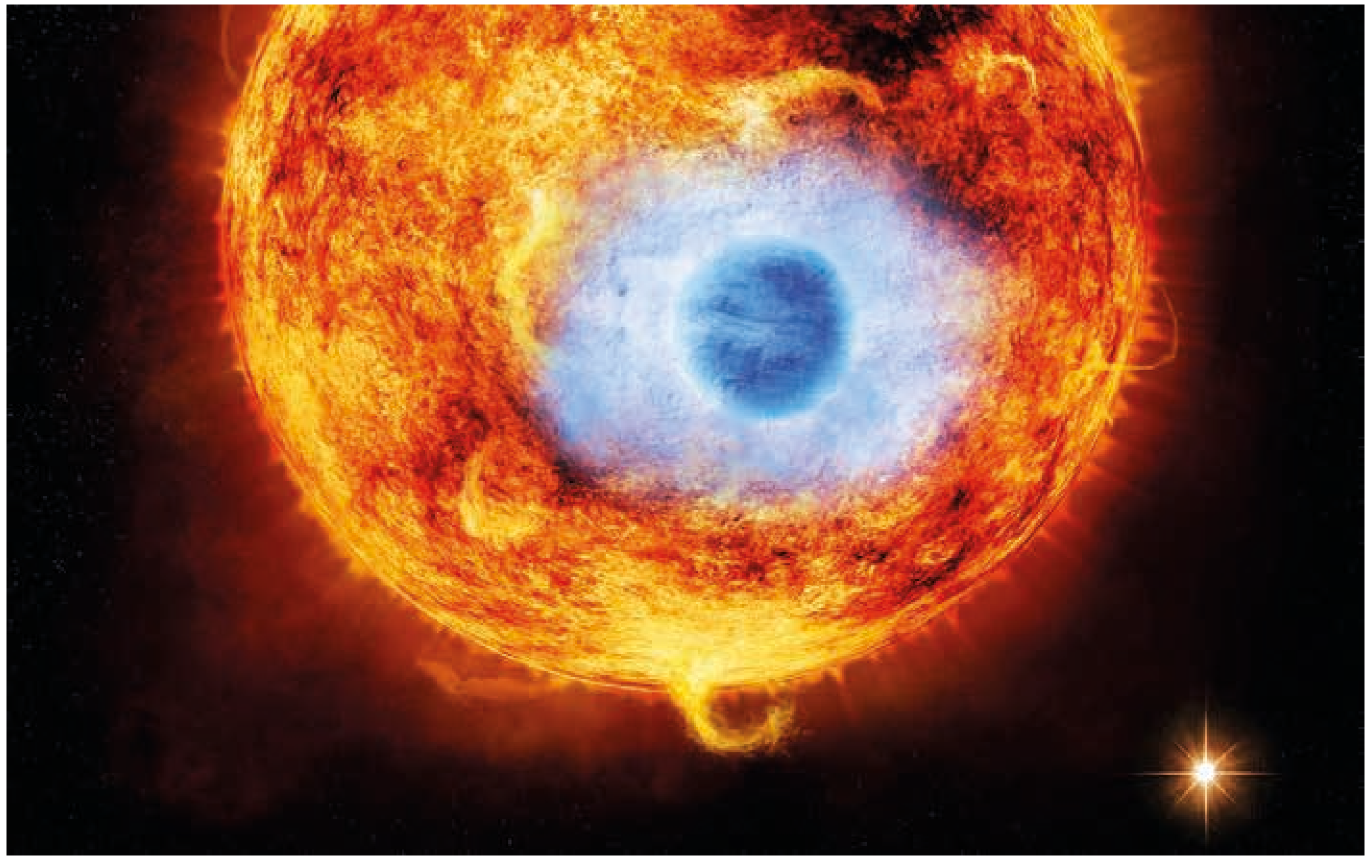
The new model has been tested and verified in collaboration with Prof Jeremy Bailey (University of New South Wales) by successfully reproducing in detail the way in which the methane in failed stars, called brown dwarfs, absorbs light, something previous models had all failed to do (see figure).

Similar studies are being performed with the group of Prof Giovanna Tinnetti where Dr Ingo Waldmann has developed a special computer code, TauRex, to study how light travels through exoplanetary atmospheres. The 10to10 methane line list forms part of the core input for TauRex where it is being used both to interpret current observations of exoplanets and to plan for future observational missions such as Twinkle (see page 5).

So far ExoMol has produced comprehensive lists of transitions for 15 molecules, all of them large but generally a little smaller than the 10to10 methane transitions list. Similar lists for about another 15 molecules are currently being constructed.

The stated aim of ExoMol is to provide comprehensive data for the study of the atmospheres of astronomical bodies such as exoplanets, brown dwarfs and stars cooler than our Sun. However these data also have use in a variety of environments somewhat closer to home.

For example, power stations and waste combustion produce hot exhaust gases which need to be monitored for environmental reasons. Designing suitable detectors to do this by trial and error in the laboratory is time consuming and expensive. ExoMol data are being used to optimise sensors that will be fitted to flue exhausts to ensure that the gas releases are kept within allowed limits.



High Energy Physics (HEP)

Probing the fundamental laws of nature requires a variety of dedicated experiments. High energy colliders such as the CERN Large Hadron Collider (LHC) push the energy frontier to search for heavy particles whereas precision measurements at lower energies constitute the intensity frontier.

The UCL HEP group is involved in many of these efforts, and in its phenomenology research it interprets the experimental results in the context of theoretical models. **Dr Frank Deppisch** has been a member of the UCL HEP group since 2011. He describes below the interplay between UCL's theoretical and experimental HEP research aiming for a better understanding of the standard model of particle physics and the 'new physics' that lies beyond.

Precision Calculations for the LHC

The LHC is probing the properties of matter by colliding protons head-on at very high energies. This produces a shower of particles, recorded by detectors intersecting the LHC ring. The immense amount of data from the billions of collisions per second is compared with theoretical predictions in order to discover new particles and to precisely determine the properties of known particles.

Most prominently, this led to the discovery of the Higgs boson in 2012 – the final building block of the standard model.

The technical and experimental efforts behind the LHC have to be matched by the theoretical calculations used to predict the outcome of a collision. In addition to participating in the ATLAS experiment, the HEP group is engaged in two related theory projects.

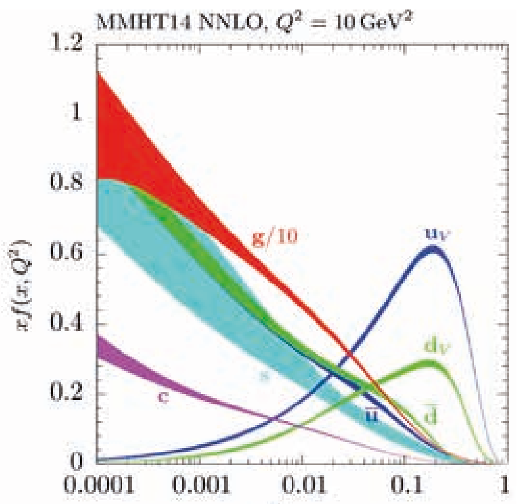


Figure 1.
Parton distribution functions showing the probability to find a given quark or gluon species (collectively called partons) inside the proton at an energy scale Q, as a function of the fraction x of the proton energy carried by the parton.

Protons are ideal bullets for the LHC. Their large mass means they can be accelerated to very high energies. Their use also complicates things, though, as they are not fundamental particles. To first approximation they are made up of three quarks, but due to quantum effects it is possible to 'hit' other sea quarks or gluons in a collision.

Parton distribution functions (PDFs) describe the probability of finding a given quark or gluon (collectively called partons) inside a proton (Figure 1). PDFs are a crucial ingredient to precisely predict the different processes and they form a basis for all searches at the LHC. Without PDFs the Higgs discovery would not have been possible. With efforts led by Professor Robert Thorne, the HEP group is largely responsible for one of the most precise PDF sets used by particle physicists. The previous major version resulted in the most highly cited theory paper in purely particle physics since 2009 and the PDFs have recently been updated.

While PDFs describe the colliding quarks and gluons, UCL is also involved in the theoretical modelling of the reactions that follow. The main technique incorporates Monte Carlo (MC) simulations. These combine intricate theoretical calculations of a process (such as Higgs production at the LHC) with a random 'rolling of dice' to generate hypothetical LHC collisions. With efforts led by Dr Keith Hamilton, UCL is engaged in the development of MC simulations and the theoretical work that will take them to the even greater accuracy.

Last year, UCL co-developed not only the world's most accurate simulation of Higgs boson production but also the most accurate simulation of any collider process. It will play a central role in determining the properties of the Higgs boson and in probing new physics effects.

Neutrinos and Muons

Not all particles and fundamental laws can be dissected at the high energies of the LHC. Most prominently, neutrinos are so light and weakly interacting that they require dedicated experiments.

Neutrinos exhibit 'flavour' oscillations: the three types discovered so far transform between each other as they travel through space. Moreover, they appear to have masses which are much smaller than that of the other matter particles such as electrons. Oscillation experiments already provide detailed information on neutrinos, but unknowns remain. The HEP group participates in related experiments such as the planned Long-Baseline Neutrino Experiment (LBNE) and the development of state-of-the-art detectors (Figure 2) to observe these elusive particles. These efforts aim to ascertain the mass order of the three neutrinos and whether there is a source of matter-antimatter asymmetry in the neutrino sector.

Not all neutrino properties can be determined through oscillations as they depend on the slight difference between the masses of the three neutrino states rather than their absolute masses. It is also not possible to test whether a neutrino is different from its anti-particle or identical to it. The most sensitive probe for both the absolute mass and the character of neutrinos is the neutrinoless double beta decay (Figure 3).

UCL is involved in the next generation experiment SuperNEMO (Figure 4), which will search for this process. Its discovery would prove the existence of another way of generating mass beyond the Higgs mechanism.

In the unbroken Standard Model (at sufficiently high energies that the Higgs mechanism does not take effect), neutrinos and left-handedly spinning charged leptons (electron, muon and tau) behave almost identically. Experiments involving muons have proven useful to exploit this relation and probe new physics models.

Figure 2.
The prototype of a new type of Cherenkov detector is being deployed in the flooded Wentworth mine pit (Northern Minnesota) in summer 2014. It is part of the CHIPS (Cherenkov Detectors In mine PitS) project which aims to develop highly sensitive but cost-effective neutrino detectors.

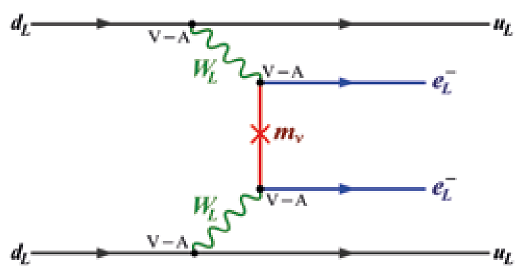


Figure 3.
Underlying process responsible for neutrinoless double beta decay of a nuclear isotope, used to probe the absolute mass scale and Majorana character (particle and anti-particle are identical) of neutrinos. The two down (d) quarks on the left are each part of a neutron in the decaying nuclear core and they are transformed to up (u) quarks, thereby producing two protons. Two electrons (e) are emitted and can be detected.

The UCL group is part of two related collaborations: The COMET experiment at J-PARC (Japan) will search for processes that include the transmutation of a muon into an electron, whereas the g-2 experiment (Figure 5) will measure the anomalous magnetic moment of the muon to a precision of 0.1 parts per million, the highest ever achieved at a particle accelerator.

In UCL's phenomenological research on 'beyond the Standard Model' physics, headed by Dr Frank Deppisch, the group explores the consequences of experiments and what they tell us about possible deeper laws of physics. The HEP group focuses on models of light neutrino mass generation, in which all the above experiments are related and can contribute to the discovery of deeper structures. For example, the team has constructed models connecting the light neutrino masses with a potential dark matter particle. It has also shown that the discovery of lepton number violating processes at the LHC (similar to neutrinoless double beta decay) would rule out a large class of models that try to explain why there is any matter in the universe after all.

Figure 4.
The first detector section of the SuperNEMO experiment was completed at the UCL Mullard Space Science Laboratory. It will be installed in 2015 within the underground LSM (Laboratoire Souterrain de Modane) facility under the French Alps. The SuperNEMO experiment will search for the exotic neutrinoless double beta decay process.

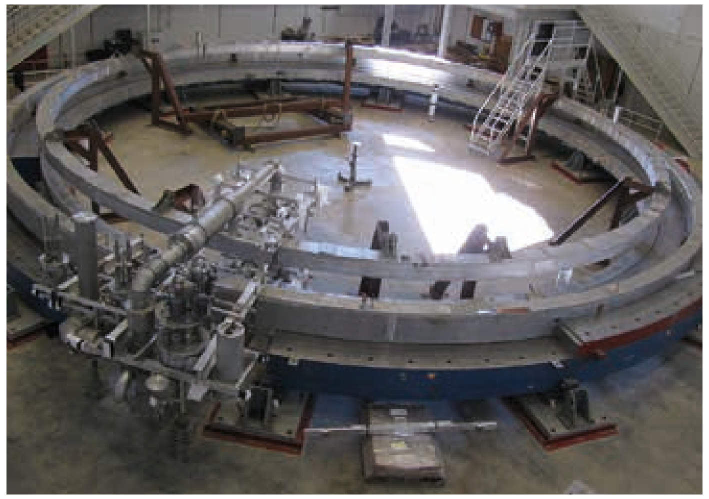


Figure 5.
Muon storage ring of the upcoming g-2 experiment intended to measure the anomalous magnetic moment of the muon with unprecedented precision. The UCL group is building the electronics that will readout the signals produced when the positrons from the decaying (positive) muons pass through the tracking detectors. These detectors will be tested in 2015 and installed at Fermilab in 2016.

Astrophysics

Herschel and ALMA Observations of Molecules and Dust in Supernova Remnants

Prof Mike Barlow, head of the Astrophysics Group, reports on two important recent papers on supernova remnantssupernova remnants.

Discovery of a noble gas molecule in the Crab Nebula

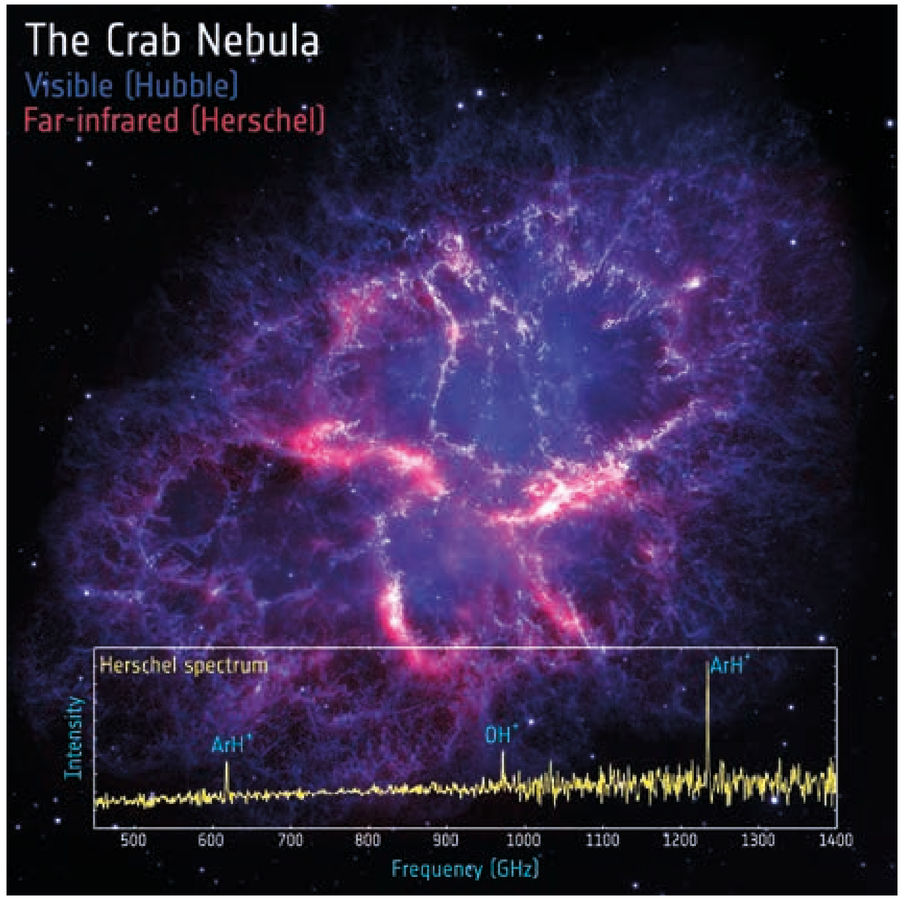
UCL-led research has made the first detection of a noble gas molecule in space. The team used ESA's Herschel Space Observatory to study regions of cold gas and dust in the Crab Nebula, the cloud of debris left by a core-collapse supernova in 1054 AD. These observations them to the serendipitous discovery of the spectroscopic fingerprints of argon hydride molecular ions (ArH^+) (see Figure 1).

The observations were taken as part of a Herschel survey to study the properties of the dust that has formed in several bright supernova remnants.

In addition to mapping the dust emission by making far-infrared images of the nebula, the team used Herschel-SPIRE's Fourier Transform Spectrometer to obtain spectroscopic observations of several different regions in the Crab Nebula between frequencies of 450 GHz and 1500 GHz (corresponding to wavelengths between 670 and 200 microns). When they looked at the data the team saw two strong emission lines at frequencies that had never been seen in astronomical spectra before. Although these two lines were unidentified, a third emission line was present at a frequency that had been observed in many other nebulae and which had been attributed to a rotational emission line of the OH^+ molecular ion.

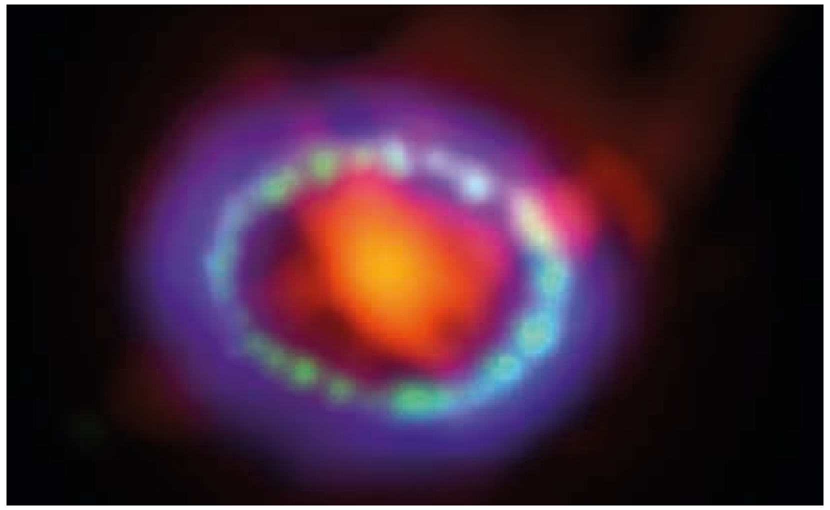
Each sub-region of the Crab where the three lines were seen had its own radial velocity, corresponding to approaching or receding knots with velocities ranging from -1200 km/s to +1200 km/s. So the radial velocities measured from the OH^+ emission line at different positions in the nebula were used to shift the frequencies measured for each of the two unknown lines in the same spectrum to a corrected 'rest frequency'. The resulting mean 'rest' frequencies of the two lines were found to be 1234.786 ± 0.643 GHz and 617.554 ± 0.209 GHz. The ratio of the two frequencies was 1.9995 ± 0.0012, strongly suggesting that the lines were due to the J=2-1 and J=1-0 rotational lines of a simple diatomic molecule. Using databases of laboratory measurements of molecular line frequencies, the team were able to identify the unidentified lines back to the argon-36 isotopic variant of the ArH^+ molecular ion, at 1234.60275 ± 0.00030 GHz and 1234.60275 ± 0.00030 GHz respectively.

Normally when a new molecule is found in space, its signature is weak but unusually in this case the new features were the strongest emission lines in the SPIRE FTS spectra of the Crab. The discovery of a noble gas molecule in the Crab Nebula was particularly unexpected because of the harsh environment inside the Crab Nebula. However, emission from molecular hydrogen (H_2) had previously been found in ground-based near-infrared spectra of the the Crab Nebula and was interpreted as arising from neutral gas filaments within the nebula. It seems likely that the ArH^+ molecules observed in the Herschel-SPIRE spectra have been produced by the exothermic reaction of an Ar^+ ion with a H_2 molecule, to produce an ArH^+ molecule and a H atom.



Credit: Herschel Space Observatory data: ESA/PACS/SPIRE: O. Usher/P. Owen. Hubble Space Telescope data: NASA/ESA.

Figure 1 *A false colour image of the Crab Nebula supernova remnant. The Hubble Space Telescope data (blue) show optical line emission from the supernova ejecta. The Herschel Space Observatory PACS 70-micron data (red) show emission from dust that has condensed in the ejecta. The inset shows the Herschel-SPIRE spectrum (yellow) of one of the nebular knots. Three lines are present in the spectrum – a rotational emission line of OH^+ at 971.8 GHz, along with the newly detected J=1-0 and J=2-1 emission lines of $^{36}ArH^+$, at 617.5 GHz and 1234.6 GHz, respectively.*



Credit: ALMA (ESO/NAOJ/NRAO)/A. Angelich. Visible light image: NASA/ESA Hubble Space Telescope. X-Ray image: NASA Chandra X-Ray Observatory.

Figure 2 *A false colour composite image of Supernova 1987A. The ALMA 450-micron data (orange-red) show the emission from the newly formed ejecta dust. The Chandra data (blue) show X-ray emission from gas in the surrounding circumstellar ring that has been shocked by the expanding outer parts of the supernova ejecta. The Hubble Space Telescope data (green) show optical line emission from the shocked `ring of beads', whose angular diameter is ~1.8 arcseconds).*

Due to their mass differences, ArH^+ rotational lines from the two other stable isotopes of argon, argon-40 and argon-38, are displaced to frequencies nearby to those of $^{36}ArH^+$. Their lines were not detected in the Herschel-SPIRE spectra of the Crab Nebula, consistent with explosive nucleosynthesis calculations for core-collapse supernovae, which predict that following the fusion of two oxygen-16 nuclei into sulphur-32, argon-36 should be formed by alpha-particle capture onto sulphur-32. Argon-38 is then created by the capture of neutrons by argon-36. Models predict that argon-36 should be five times more abundant than argon-38, with negligible amounts of argon-40 predicted. These isotopic ratios should apply throughout most of the cosmos, since supernovae are believed to be the main source of argon in galaxies. On Earth, however, argon-40 is the dominant argon isotope as it is released by the radioactive decay in rocks of potassium-40, which has a half-life of 1.25 billion years. At almost one per cent, argon-40 is the third most abundant gas in the atmosphere of Earth, after nitrogen and oxygen. Along with the other noble gases, argon was discovered at UCL at the end of the 19th century by William Ramsay.

The results described above were published in the December 13th 2013 issue of the journal Science (vol. 342, p.1343) in a paper led by Mike Barlow, Bruce Swinyard and Patrick Owen from UCL. Their results are currently being followed up via ground-based near-infrared spectroscopy of the vibrational lines of H_2 and of ArH^+. In addition, Cycle-2 observing time has been allocated on the Atacama Large Millimeter Array (ALMA), to use its very high spatial and spectral resolution to attempt to measure the argon-36 to argon-38 isotope ratio in the Crab Nebula via observations of their ArH^+ J=1-0 rotational lines in the 617 GHz spectral region.

ALMA observations of cold dust in the ejecta of Supernova 1987A

Core-collapse supernovae from massive stars have been proposed to be major factories for the dust that is found in galaxies at high redshifts as well as in the local Universe. Cosmic dust particles help facilitate star formation, with large amounts of dust aggregating to form planetesimals and planets such as the Earth. Searches at mid-infrared wavelengths for warm dust that had formed in the ejecta of supernovae within the first few years after outburst had however found only small quantities of dust (less than 0.001 solar masses of warm dust per supernova) compared to the greater than 0.1 solar masses of dust per supernova estimated to be needed to account for the overall masses of dust found in galaxies. The advent of Herschel in 2009 however allowed sensitive searches for cold dust to be made at far-infrared and submillimetre wavelengths for the first time. Since cold dust emits less efficiently than warm dust, larger masses of cold dust are needed to account for a given observed flux at infrared wavelengths.

One of the early discoveries made by Herschel was the detection in the ejecta of Supernova 1987A of half a solar mass of cold dust (equivalent to 330,000 earth masses of dust) which was emitting at a temperature of about 21 degrees Kelvin. This result was reported in a UCL-led paper published in Science in 2011 (Matsuura et al., vol. 333, p.1258), as described in the 2011–12 Annual Review. However, Herschel's 3.5-metre diameter telescope had insufficient angular resolution to be able to determine whether the location of the cold dust emission was coincident with the compact supernova ejecta at the centre of the 1.8 arcsecond angular diameter nebular ring that surrounds Supernova 1987A.

The Atacama Large Millimeter Array (ALMA) recently came into operation at its Chajnantor site at an altitude of 5000 metres in Chile's northern Atacama region. Its unprecedented angular resolution and sensitivity at submillimetre wavelengths offered us the opportunity to follow up the Herschel far-infrared and submillimetre observations of SN 1987A by obtaining high angular resolution observations with ALMA to establish the position and size of the cold dust emission region. An international consortium was formed and was awarded early Cycle-0 ALMA time to observe Supernova 1987A's ejecta and ring nebula. The resulting ALMA imaging data had an angular resolution of 0.3 arcsec and are shown in Figure 2 in a composite image. They spectacularly confirm that the cold dust emission (coloured orange-red) originates from the supernova ejecta located at the centre of the nebula and confirm that the total dust mass in the ejecta has grown to 0.5 solar masses over a period of 25 years. The ALMA results were published by Indebetouw, Matsuura et al. (2014, ApJ, 782, L2).

Further ALMA time has been awarded for observations of Supernova 1987A during Cycles 1 and 2. For these ALMA will have more antennae and longer observing baselines, conferring higher sensitivity and enhanced angular resolution. The early ALMA observation displayed in Figure 2 show the ejecta emission to be bipolar - the future ALMA observations should be able to resolve the detailed structure of the ejecta. The new ALMA observations will also include a spectroscopic survey of SN 1987A for molecular emission lines, with the aim of measuring isotopic abundance ratios that will probe the explosive nuclear reactions that occurred during the supernova event.

Biological Physics (BioP)

'Seeing without frying' – Low Power Super Resolution Fluorescence Microscopy

Dr Angus Bain

In 2014, the Nobel Prize in Chemistry was awarded for "the development of super-resolved fluorescence microscopy," which brings "optical microscopy into the nanodimension". Super resolution is a means of breaking the fundamental limit at which an optical microscope can resolve (i.e. see) structure in a sample. This length limit L is given by the Abbé criterion as

$$L = \lambda/2NA$$

where λ is the wavelength of light illuminating the object and NA is a number describing the focusing power of the microscope. In state of the art confocal microscopes this value is around 1.2. So for visible light of 600 nm (yellow) the Abbé limit L is 250nm; about 40 times smaller than the diameter of a human hair. With this degree of resolution it is possible to investigate structures within cells and other similarly sized objects. This is impressive but 250nm is around twice the width of a large virus such as HIV.

Breaking the Abbé limit is essential if we want to study structures that exist within cells that are 100nm or smaller (see Figure 1). In order to do this we need to reduce the point spread function (PSF) of the microscope. The PSF can be determined by measuring the dimensions of an object that is significantly smaller than L. We routinely use 100nm diameter (and smaller) spherical beads that contain fluorescent molecules. This fluorescence is created by the absorption of a blue (490nm) pulsed laser focused through the microscope objective onto the sample. The laser is scanned with nanometre precision over the bead and the fluorescence intensity is recorded as a function of position. A typical measurement from a confocal microscope in our laboratory revealing a PSF with a width of 235 nm is shown in Figure 2.

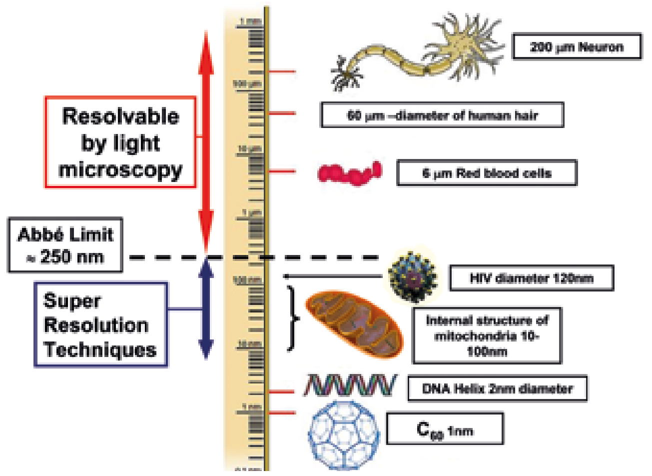
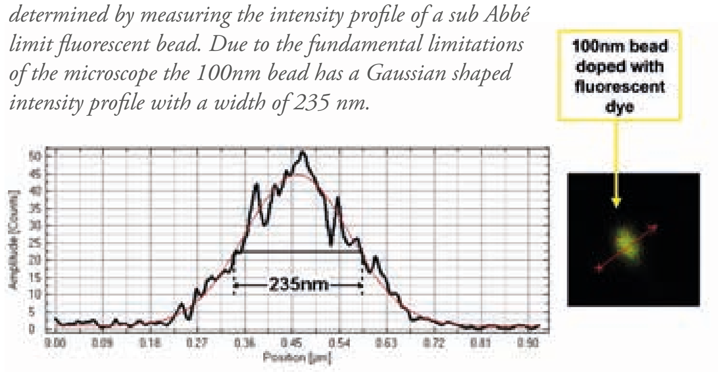


Figure 1
Length scales and objects of interest to the biophysical community.

Figure 2
The point spread function (PSF) of a confocal microscope determined by measuring the intensity profile of a sub Abbé limit fluorescent bead. Due to the fundamental limitations of the microscope the 100nm bead has a Gaussian shaped intensity profile with a width of 235 nm.



One kind of super resolution microscopy that the Nobel Prize recognised involves a technique called Stimulated Emission Depletion (STED). STED employs the same physics as that involved in the laser. A laser operating at a wavelength matching the tail of the emission spectrum of the fluorescent marker molecules in a sample stimulates their emission, effectively switching them off. A smaller PSF in STED is engineered by producing a depleting beam which when focused has a central hole resembling a donut. This overlaps the exciting laser whose intensity profile is similar to the PSF in Figure 2 and the two are scanned over the sample. If the depletion laser intensity is sufficiently high, all the molecules in the ring of the donut are rendered non-fluorescent and a PSF well below 235nm can be obtained.
This has its drawbacks, as the degree of resolution is dependent on the intensity of the depletion (donut) laser. For example, using a continuous wave (CW) laser, on sample depletion powers of around 300mW are needed. When focused into a sub micron region, this corresponds to an intensity of 1.5 TW/m2; around a billion times that of sunlight on the earth's surface. This is a very bright environment indeed and damage to the fluorescent marker molecules and the sample (frying) often results.

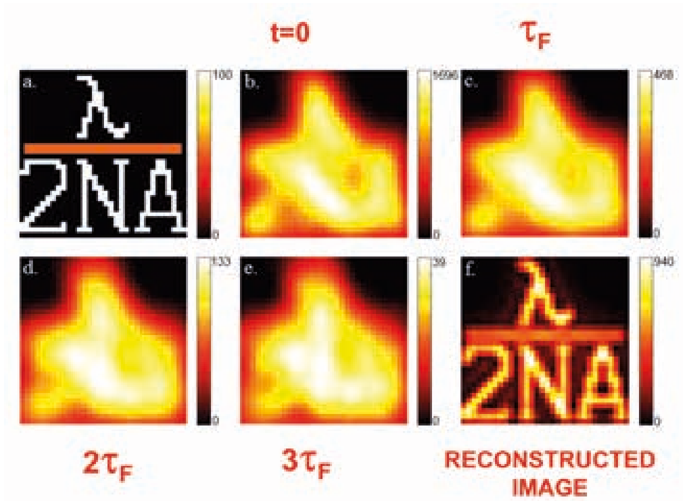


Figure 3
Illustration of the LIR-SR technique. The 'true image' depicting the Abbé relation in (a) is made up of pixels containing fluorescent molecules whose natural lifetime is τ_F (usually in the region of 3–4 nanoseconds). Immediately following excitation by a short laser pulse the image in (b) corresponds to the traditional resolution afforded by a confocal microscope. As the CW depletion beam spatially alters the lifetimes of the molecules the image becomes apparently more blurred. However a linear combination (weighted addition and subtraction of (b) to (e)) yields the image in (f) where the original information is recovered.

We have recently developed a new method of achieving super resolution using a significantly lower power depletion laser (a factor of 40) that has the same focused spatial profile as that of the excitation laser –the donut beam and its complex optics are not required. We use a lifetime imaging microscope that allows us to look at how the fluorescent image created by a picosecond blue excitation pulse (490nm) evolves in time in the presence of the CW depletion laser (ca. 7mW operating at 595nm). Molecules that contribute to the emission at the centre of the PSF have a shorter lifetime due to greater stimulated emission than those giving rise to fluorescence that is detected further at the wings. The time slices of the PSF flatten and finally turn into a donut, if we take linear combinations of these we can find a combination that minimises the PSF. The same linear combination of time slices can be applied to a structure labelled with fluorescent markers.

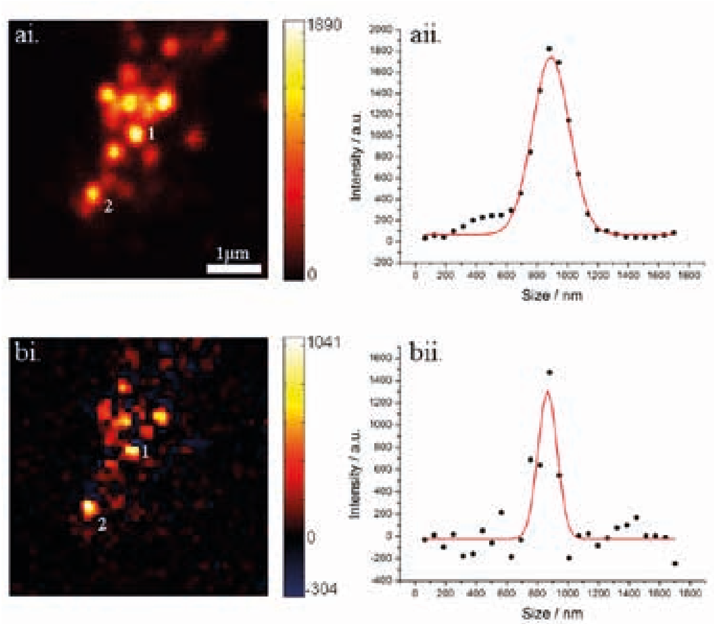


Figure 4
A confocal fluorescence image of a cluster of 20nm nanospheres in a live HEK cell. aii) Profile across nanosphere '1' corresponds to a Gaussian intensity distribution with a width of 284nm. The corresponding width of nanosphere '2' is 292nm. bi) LIR-SR using a linear combination of the time windows with coefficients chosen to minimize the width of nanosphere '1' applied to the whole image. A CW depletion power of c.a. 7.5mW at 595nm was employed. bii) Profile across reconstructed nanosphere '1' and shows a reduced Gaussian width of ≈ 147nm. The width of nanosphere '2' is 158nm.

Reproduced from 'Low Power Super Resolution Fluorescence Microscopy by Lifetime Modification and Image Reconstruction', R. J. Marsh, S. Culley & A. J. Bain, Optics Express Optics Express, Vol. 22, Issue 10, pp. 12327-12338 (2014) http://dx.doi.org/10.1364/OE.22.012327

The principle of the Lifetime Image Reconstruction Super Resolution technique, termed LIR-SR, is illustrated for a hypothetical nanodomain structure depicting the Abbé criterion in Figure 3. LIR-SR has been shown to achieve non-destructive super resolution (ca 100nm) of fluorescently labelled nanobeads ingested by live HEK cells (Figure 4) and in fluorescently tagged microtubules (Figure 5).

We are currently refining the technique and investigating ways to rapidly switch off the depletion laser when it is not wanted (fast modulation). This work is in collaboration with the Optoelectronics Research Centre at Tampere University in Finland who are world leaders in the development of new visible semiconductor lasers which are ideal for LIR-SR (Figure 6).

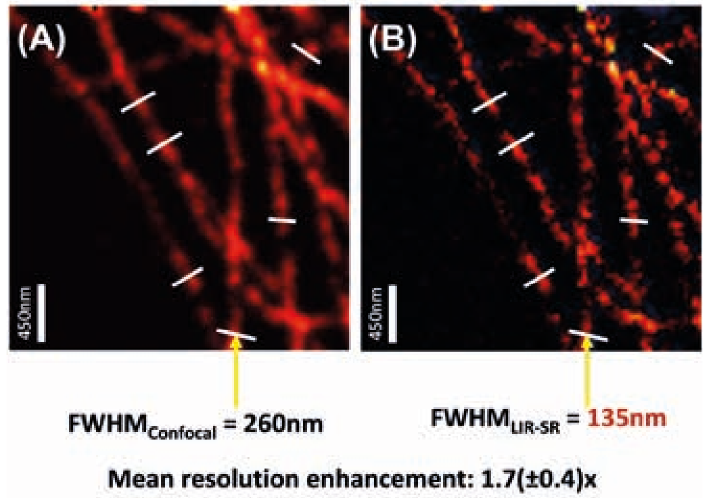


Figure 5
LIR-SR imaging of fluorescently labeled microtubules. Microtubules are a component of the cytoskeleton, found throughout the cytoplasm of cells. The outer diameter of a microtubule is about 24 nm, yet in a confocal microscope (A) this diameter appears to be 260nm. Using LIR-SR, the image is sharpened with an apparent diameter of 135nm. A low CW depletion power of ca. 7.5 mW at 595nm was used in this measurement.

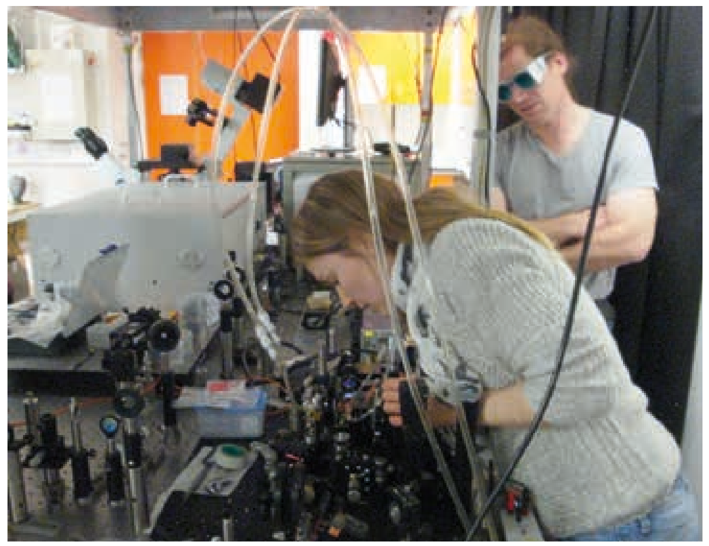
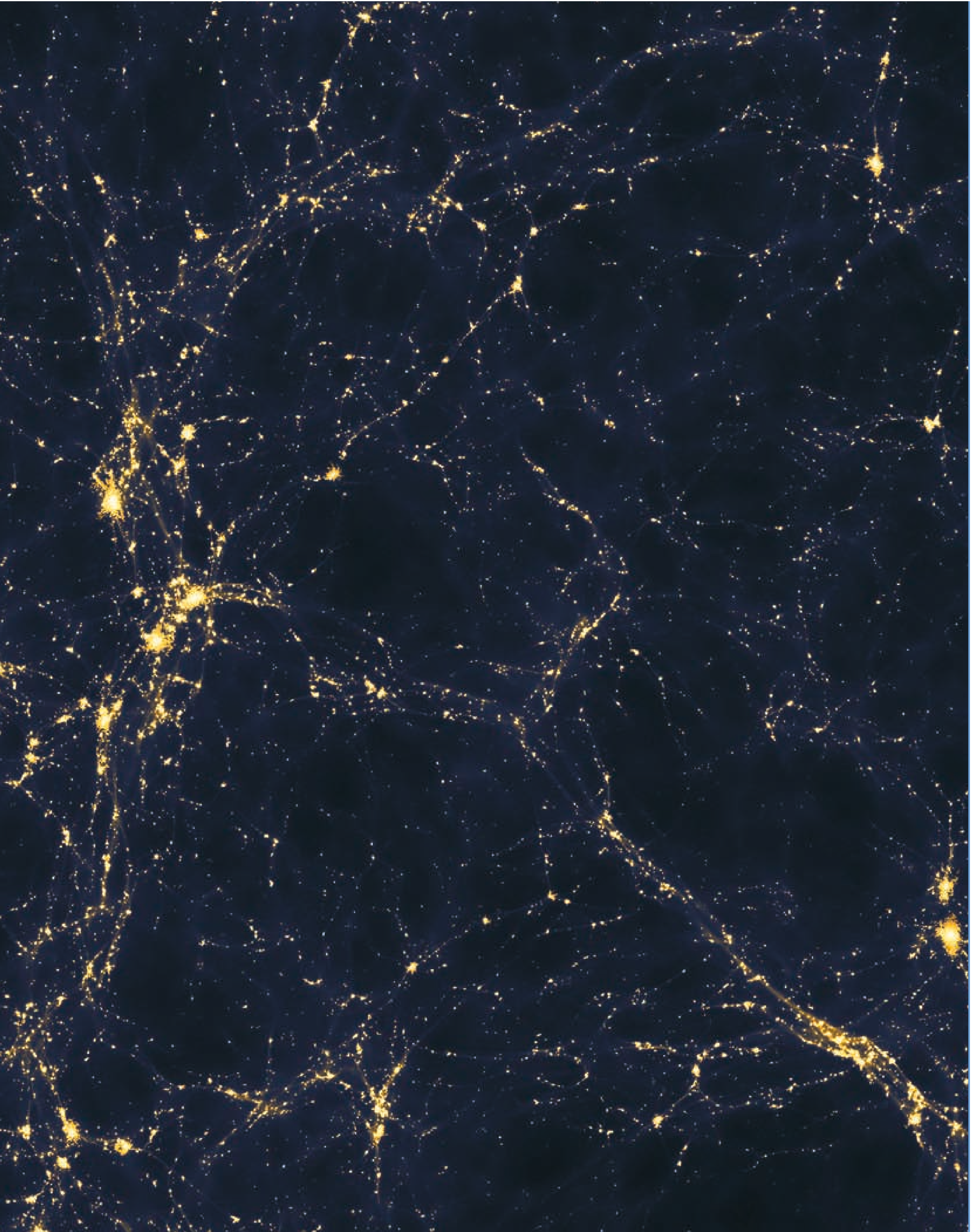


Figure 6
Emmi Kantola (Tampere University of Technology Finland) and Dr Richard Marsh working to install a Vertical Cavity Surface Emitting Laser (VECSEL) in our LIR-SR microscope.



Research Statistics

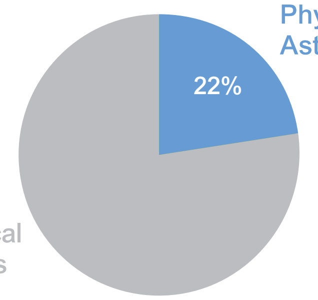
Research Statistics
Jan 2014– Dec 2014

Publication Summary

Research Group	Number of publications in refereed journals
Astro	170
AMOPP	93
CMMP	137
HEP	129

Active Grants and Contracts

In the last financial year (Aug 2013 – Jul 2014), the MAPS faculty as a whole yielded £44,528,000, with the Department of Physics and Astronomy contributing £9,865,000 (22%) of the total research income for the MAPS faculty.



Astrophysics

Euclid Implementation Phase (UKSA) PI: Dr Filipe Abdalla, £545,358

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

University Research Fellowship Renewal (Royal Society) PI: Dr Filipe Abdalla, £317,537

SKA preconstruction phase at UCL (STFC) PI: Dr Filipe Abdalla, £281,909

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

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

ESPAS: Near-Earth space data infrastructures for e-science (European Commission FP7) PI: Prof Alan Aylward, £199,537

UCL Astrophysics consolidated grant (STFC) PI: Prof Michael Barlow, £352,889

The properties of crab nebula molecules (STFC) PI: Prof Michael Barlow, £1,438

COGS – capitalising on gravitational shear (EU FP7) PI: Prof Sarah Bridle, £571,516

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

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

Archaeology of exo-terrestrial planetary systems and a search for water (STFC) PI: Dr Jay Farihi, £318,089

Kinematics galactic age chemistry and water fraction of asteroid polluted white dwarfs from the Sloan Digital Sky Survey (STFC) PI: Dr Jay Farihi, £180,237

Are all dwarf carbon stars binary? (STFC) PI: Dr Jay Farihi, £2,843

Ernest Rutherford Fellowship: Advancing weak lensing and intrinsic galaxy alignment studies to the era of precision cosmology (STFC) PI: Dr Benjamin Joachimi, £351,642

Computing the precision in precision cosmology (Royal Society) PI: Dr Benjamin Joachimi, £14,610

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

TESTDE: Testing the dark energy paradigm and measuring neutrino mass with the dark energy survey (European Commission FP7) PI: Prof Ofer Lahav, £1,844,558

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

Daphne Jackson Fellowship (Daphne Jackson Fellowship Trust) PI: Dr Maria Mendes Marcha, £77,401

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

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

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

Search for evidence of bubble collisions in the cosmic microwave background (John Templeton Foundation) PI: Dr Hiranya Peiris, £69,083

RS Fellowship: Connecting physics and galaxy formation (Royal Society) PI: Dr Andrew Pontzen, £453,692

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

University Research Fellowship (Royal Society) PI: Dr Amelie Saintonge, £466,973

Cold gas and the chemical evolution of galaxies (Royal Society) PI: Dr Amelie Saintonge, £69,577

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

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

FISICA – far infra-red space interferometer critical assessment: scientific definition and technology development for the next generation THZ space interferometer (EU FP7) PI: Dr Giorgio Savini, £270,117

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

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

Supa-terahertz technology for atmospheric and lower thermosphere (NERC) PI: Prof Bruce Swinyard, £3,101

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

University Research Fellowship Renewal: The exoplanet revolution (Royal Society) PI: Prof Giovanna Tinetti, £310,508

Exolights – Decoding lights from exotic worlds (European Research Council) PI: Prof Giovanna Tinetti, £1,560,377

Impact Studentship: Time senses analysis of chemical models of star forming regions (Columbia Systems Ltd.) PI: Prof Serena Viti, £21,084

LASSIE – laboratory astrochemical surface science in Europe (EU FP7) PI: Prof Serena Viti, £159,107

UCL Astrophysics Consolidated Grant (STFC) PI: Prof Serena Viti, £318,935

Novel mathematical techniques for advanced tool-paths to transform high value optical fabrication (STFC) PI: Prof David Walker, £281,780

STFC DiRAC Project Office 2014 – 2017 (STFC) PI: Dr Jeremy Yates, £377,026

AMOPP

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

In situ quantification of metabolic function using florescence lifetime imaging (BBSRC) PI: Dr Angus Bain, £218,061

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

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

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

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

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

Verification of models of quantum computing (EPSRC) PI: Dr Dan Browne, £19,007

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

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

Spectroscopy of Positronium: Atom control and gravity measurments (European Commission) PI: Dr David Cassidy, £75,000

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

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

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

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

Hybrid cavity-QED with Rydberg atoms and microwave circuits (EPSRC) PI: Dr Stephen Hogan, £524,578

Impact Studentship: Sono-acoustical trapping of microbubbles (NPL Management) PI: Dr Philip Jones, £35,618

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

Ultrasensitive fluorescence detection and novel magnetic force spectroscopy (Royal Society) PI: Dr Isabel Llorente Garcia, £15,000

A fast fluorescence and photonic force microscope with nanometre and femtonewton resolution (MRC) PI: Dr Isabel Llorente Garcia, £50,000

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

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

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

Coherence in excitonic-plasmonic systems: towards novel frequency filters and lasing mediums (EPSRC) PI: Dr Alexandra Olaya-Castro, £17,534

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

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

Studentship: What are the laws of quantum thermodynamics? (FQXi) PI: Prof Jonathan Oppenheim, £40,360

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

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

Magnetic sensor systems for the detection of metallic objects – identifying and characterising materials using magnetic field interrogation (Atomic Weapons Establishment) PI: Prof Ferruccio Renzoni, £143,070

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

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

Impact Studentship: Atomic magnetometers for medical applications (NPL Management Ltd.) PI: Prof Ferruccio Renzoni, £32,583

Studentship: Application of quantum magnetometers to security and defence screening (Defence Science and Technology Laboratory) PI: Prof Ferruccio Renzoni, £124,662

All optical magnetometer for heart magnetic induction tomography (EPSRC) PI: Prof Ferruccio Renzoni, £17,068

Studentship: Cylindrical magnetic imaging tomography (Atomic Weapons Establishment) PI: Prof Ferruccio Renzoni, £61,500

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

Coherent quantum matter out of equilibrium from fundamental physics towards applications (EPSRC Fellowship) Fellow: Dr Marzena Szymanska, £1,222,168

Novel superfluid phenomena in semiconductor microcavities (EPSRC) PI: Dr Marzena Szymanska, £295,981

The UK theory of condensed matter summer school (EPSRC) PI: Dr Marzena Szymanska, £170,029

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

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

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

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

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

Impact Studentship: Dan Underwood – sulphur trioxide/oxide high-temperature spectroscopic databases (Technical University of Denmark) PI: Prof Jonathan Tennyson FRS, £33,591

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

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

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

Studentship: James Hamilton – Electronic impact vibrational excitation of water molecules (Quantemol Ltd.) PI: Prof Jonathan Tennyson FRS, £12,900

Studentship: Modelling of spectra of hot molecules (Servomex Ltd.) PI: Prof Jonathan Tennyson FRS, £18,150

Atomic and molecular data services for Astrophysics (STFC) PI: Prof Jonathan Tennyson FRS, £47,110

Fellowship: RichMol - Optical activity of molecules with rotational chirality (European Commission) PI: Dr Sergey Yurchenko, £173,462

CMMP

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

Impact Studentship: Modelling electron transport in multi-heme proteins (PNNL) PI: Dr Jochen Blumberger, £52,598

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

Impact Studentship: A computational investigation of charge transfer in organic semiconducting materials (PNNL) PI: Dr Jochen Blumberger, £34,167

University Research Fellowship Renewal: Understanding gas transport in hydrogenases through novel computer simulations (Royal Society) PI: Dr Jochen Blumberger, £339,813

Characterisation of electron transport in bacterial nano-wire proteins through high performance computing and experimentation (EPSRC) PI: Dr Jochen Blumberger, £321,327

Impact Studentship: Exploration of the performance of a CDFT for the calculation of parameters that govern the thermodynamics and kinetics of interfacial ET reactions (PNNL) PI: Dr Jochen Blumberger, £12,365

Studentship: O(N) density functional theory for dye sensitised solar cells (Jiangsu Kuga Digital Group Co.) PI: Dr David Bowler, £29,257

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

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

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

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

Impact Studentship: Directing crystal growth with functional surfaces (PNNL) PI: Dr Dorothy Duffy, £37,515

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

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

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

Consequence analysis postdoctoral research associate (Ministry of Defence) PI: Prof Ian Ford, £227,288

MIIA – driving the 2D materials revolution: A scalable method for dissolving layered materials (EPSRC) PI: Dr Chris Howard, £17,752

Graphene based revolutions in ICT and beyond (European Commission) PI: Dr Chris Howard, £9,559

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

University Research Fellowship Renewal: Nanomaterials for biomolecular sciences and nanotechnology (Royal Society) PI: Prof Thanh Nguyen, £347,058

Nanoscale magnetism in next generation magnetic nanoparticles (Air Force Office of Scientific Research) PI: Prof Thanh Nguyen, £46,397

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

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

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

Multiscale modelling of metal semiconductor contacts for the next generation of nanoscale transistors (EPSRC) PI: Prof Chris Pickard, £292,850

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

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

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

EngD Studentship: Oliver Dicks – Tuning electronic properties of thin films and interfaces using defects (Argonne National Laboratory) PI: Prof Alexander Shluger, £58,412

Impact Studentship: Ashley Garvin - laser materials interaction (PNNL) PI: Prof Alexander Shluger, £45,400

MORDRED- modelling of the reliability and degradation of next generation nanoelectronic devices (European Commission FP7) PI: Prof Alexander Shluger, £413,099

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

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

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

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

Effect of framework modification on the electronic structure of 12CaO.7Al203 (Lockheed Martin Corporation) PI: Dr Peter Sushko, £85,327

OPTIMAX – Optimal imaging with present and future coherent x-ray sources (European Research Council) PI: Dr Pierre Thibault, £901,675

Studentship: High resolution tomography of energy materials with hard x-rays (Diamond Light Source Ltd.) PI: Dr Pierre Thibault, £2,100

Studentship: Development and application of ptycho-tomography at 113 (Diamond Light Source Ltd.) PI: Dr Pierre Thibault, £34,707

HEP

Development and maintenance of atlas run time tester (STFC) PI: Prof Jonathan Butterworth, £327,246

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

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

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

Ultra-low activity material screening with in-house ICP-MS (STFC), PI: Dr Chamkaur Ghag, £99,890

Low background screening facility at Boulby for rare event research experiments (STFC), PI: Dr Chamkaur Ghag, £85,565

Sample preparation equipment for ultra-low background screening with ICP-MS (STFC), PI: Dr Chamkaur Ghag, £99,845

IPPP Associateship 2013 -2015 (University of Durham) PI: Dr Keith Hamilton, £1,000

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

Modelling of Higgs backgrounds at the LHC (University of Durham) PI: Dr Gavin Hesketh, £3,000

Dorothy Hodgkin Fellowship: Investigating the neutrino with MINOS and liquid argon detector technology (Royal Society) PI: Dr Anna Holin, £464,226

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

Calorimetry for proton therapy (STFC) PI: Dr Simon Jolly, £49,531

Studentship: A calorimeter for proton therapy (NPL Management Ltd.) PI: Dr Simon Jolly, £34,107

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

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

ATLAS Phase II upgrades 2014-15 (STFC) PI: Prof Nikos Konstantinidis, £87,810

Ernest Rutherford Fellowship: Heavy quarks a window into new physics at ATLAS (STFC) PI: Dr Andreas Korn, £363,285

LHC capability – ATLAS tracker upgrade readout (STFC) PI: Dr Andreas Korn, £40,000

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

Measurement of the anomalous magnetic moment of the muon to a precision of 0.14ppm (STFC) PI: Mark Lancaster, £4,889

Measurement of the anomalous magnetic moment of the muon to 0.14ppm using the FNAL G-2 experiment (STFC) PI: Prof Mark Lancaster, £246,429

University Research Fellowship extension - neutrino and cosmic ray studies with minos, anita and cream tea (Royal Society) PI: Dr Ryan Nichol, £316,804

LBNE and the Fermilab liquid argon detector programme (STFC) PI: Dr Ryan Nichol, £4,058

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

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

University Research Fellowship Renewal: Higgs studies and a search for dark matter at the Atlas experiment (Royal Society) Fellow: Dr Emily Nurse, £274,703

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

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

Low background techniques for particle physics and astrophysics (STFC) PI: Prof Ruben Saakyan, £22,207

University Research Fellowship: Determining the true nature of the Higgs-like particle (Royal Society) PI: Dr Tim Scanlon, £483,706

Determining the true nature of the Higgs-like particle (Royal Society), PI: Dr Tim Scanlon, £85,277

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

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

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

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

Travel for the CHIPS R&D Programme (STFC) PI: Prof Jennifer Tomas CBE, £15,122

The path to CP violation in the neutrino sector: mega-ton water detectors (Leverhulme Trust) PI: Prof Jennifer Thomas CBE, £383,431

IPPP Associateships 2009-15 (University of Durham) PI: Prof Robert Thorne, £17,000

Theory Consolidated Grant – Standard Model Phenomenology and beyond (STFC) PI: Prof Robert Thorne, £410,047

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

Terauniverse - Exploring the terauniverse with the LHC, astrophysics and cosmology (European Commission FP7) PI: Prof Robert Thorne, £360,514

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

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

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

Capital Equipment for UCL Experimental Particle Physics (STFC) PI: Prof David Waters, £36,536

Consolidated Grant Supplement (STFC) PI: Prof David Waters, £11,685

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

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

Impact Studentship: Diagnostics for a proton-driven plasma Wakefield Experiment (Max Planck Institute for Physics) PI: Prof Matthew Wing, £31,627

Photon-driven plasma Wakefield acceleration – a new route to a TeV e+e- collider (STFC) PI: Prof Matthew Wing, £26,777

Data acquisition for Comet Phase I experiment (STFC) PI: Prof Matthew Wing, £16,190

Staff Snapshot

Head of Department

Professor J. M. Butterworth

Deputy Head of Department

Professor R. K. Prinja

Astrophysics

Head of Group: Professor M. J. Barlow

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

Professorial Research Fellow:
D. D. Walker

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

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

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

Research Associates:
M. Banerji, A. Benoit-Levy, C. Bergfors, T. Bisbas, J. Braden, F. Elsner, D. Fenech, P. Guio, G. Harker, M. Hirsch, C. Jackman, S. Jouvel, R. Juanola Parramon, D. Kirk, B. Leistedt, A. Leonard, M. Lochner, M. Manera Minet, A. Merson, M. Rivi, N. Roth, B. Rowe, I. Sadeh, S. Thaithara Balan, M. Tessenyi, E van Uitert, I. Waldmann, P. Woods

Support Staff:
D. Brooks, J. Deacon, J. Fabbri, C. Jenner, D. Jones, K. Nakum, M. Rangrej

Atomic, Molecular, Optical and Positron Physics

Head of Group: Professor P. Barker

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

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A. J. Bain, D. Browne, D Cassidy, C. Figueira de Morisson Faria, S Hogan, P. H. Jones, A. Serafini, M. Szymanska

Lecturers:
A. Emmanouilidou, A. Olaya-Castro, J. Underwood

Senior Research Fellow (Crick):
I. Llorente Garcia

Senior Research Associate:
S. Yurchenko

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L. Banchi, A. Bayat, T. Blacker, S. Brawley, C. Coppola, A. Deller, F. Fassioli-Olsen, M. Genoni, A. Gerakis, R. Guichard, C. Hill, H. Hossein-Nejad, D. Holdaway, L. Lodi, S. Lopez Lopez, L. Marmugi, R. Marsh, T. Mavrogdatos, L. McKemmish, J. Millen, D. Monahan, E. O'Reilly, O. Polyansky, A. Rahman, M. Scala, M. Trivedi, C. Vaillant, T. Wall, A. Wallis, A. Wickenbrock, A Zamora, C. Zagoya Montiel, V Zhelyazova

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K Bouzgan, J. Dumper, R. Jawad, S. Khan

Condensed Matter and Materials Physics

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Lecturers:
M. Buitelaar, C. Howard, F. Kruger, S. Schofield, P. Zubko

Senior Research Associate:
T Duc Le, M. Watkins

Research Associates:
K. Fraser, S. Hepplestone, A. Kimmel, A. Kubas, N. Kuganathan, A. Lim, D. Little, L. Masanes, A. Pappa, L. Santarelli, N. Seidler, G. Schusteritsch, V. Tileli

Most Research staff are employed through the LCN

Support Staff:
C. Jordan, J. Rooke

High Energy Physics

Head of Group: Professor M. A. Lancaster

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

Readers:
M. Campanelli, R. Nichol, E Nurse

Lecturers:
F. Deppisch, C. Ghag, K. Hamilton, G. Hesketh, S. Jolly

Royal Society Fellowship:
A. Holin (Dorothy Hodgkin)

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

Research Associates:
A. Basharina-Freshville, M. Cascella, B. Cooper, R. D'arcy, A. Davison, L. Deacon, A. Desai K. Gregersen, J. Harz, L. Harland-Lang, W-C. Huang, E. Jansen, K. Laney, R. Litchfield, A. Martyniuk, J. McFayden, P. Motylinski, I. Ochoa de Castro, L. Reichhart, T. Scalon, S. Torre, C. Vilela, D. Wardrope, L. Whitehead

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Director of Postgraduate Studies:
T. S. Monteiro

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F. Renzoni

Principle Teaching Fellow:
P. Bartlett

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D. Armoogum, E. Bailey, M. Coupland, L .Dash, P. Donovan, N. Nicolaou

Laboratory Superintendent:
D. Thomas

Laboratory Technicians:
B. T. Bristoll, M. A. Sterling, K. Vine

IT Systems Manager (Teaching & Learning):
T. Wriedt

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

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

University of London Observatory

Director: I. D. Howarth

Teaching Fellows:
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T. Schlichter

Technical Support:
M. Pearson

Maps Workshop

Superintendent:
R. Gollay

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J. Benbow, J. F. Percival

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Deputy Departmental Manager:
K. Heyworth

Examinations and Research Group support:
K Bouzgan

Grants Officer:
J. Barrett / R. Walker

Accounts Officer:
L. Duffy

Finance Officer:
D. Buck

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N. Waller

Undergraduate Administrator:
J. Davies

Teaching Support Administrator:
C. Jordan

Group Administrator Astro:
K Nakum

Group Administrator AMOPP & HEP:
K Bouzgan

Group Administrator CMMP:
K Bouzgan

IT Co-ordinator:
B Waugh

Science Centre Organiser:
S. Kadifachi

Visiting Professors and Emeritus Staff

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

UCL Department of Physics and Astronomy • Gower Street • London • WC1E 6BT
Telephone: +44 (0)20 7679 7155
www.phys.ucl.ac.uk