THE UNIVERSITY *of* EDINBURGH

Issue 1
Autumn 2014

ENQUIRE

NEWS FROM THE SCHOOL
OF PHYSICS & ASTRONOMY

LIFE AT THE LIMIT

Can studying extreme environments on Earth help us to find life on Mars?

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Welcome

Professor Arthur Trew

Head of School

School of Physics & Astronomy

It is my pleasure to welcome you to our new newsletter for alumni.

In this we want to give you a flavour of the topical physics and astronomy research being carried out in your old department and also a view of how well we are doing.

The summary answer to the latter question is very well: within the last year our research has been awarded a number of accolades.

Although all will know about the 2013 Nobel Prize for Peter Higgs, you may not have heard that John Peacock won the Shaw Prize, the "Nobel of the East", for his work that constrained models describing the origin and evolution of the universe, or that Wilson Poon won an ERC Advanced Grant for his research into the physics of active particles.

More generally, we were recently judged by the 2014 Academic Ranking of World Universities (ARWU) to be the 20th best physics and astronomy department in the world, while QS 2014 rated us 37th. Either way, in a world of 20,000 universities, we are doing extremely well.

But research is only part of our work.

Teaching is equally important and I am pleased to note that over the past couple of years the numbers of undergraduates have reached new records. Competition for places is high with virtually all students holding straight As at Highers or A-Level.

Over the next few years we are aiming to roll out a programme to permit around half of all students the opportunity to undertake a paid, summer internship working on a research project in academia or industry. We hope this will expand the experience of our graduates and give a useful extra addition to their CV.

We are always pleased to hear from you, so please let us know what you are doing. And if we could use your experiences of work outside academia to give our current students a better impression of life after university, then this would be much appreciated.

Trew

School News and Events

News: www.ph.ed.ac.uk/news/latest-news

Events: www.ph.ed.ac.uk/news/events

How to weigh a galaxy?

ESA Herschel space observatory image of Andromeda. Image: ESA/Herschel/PACS & SPIRE Consortium, O. Krause, HSC, H. Linz

Researchers have found the Milky Way is approximately half the weight of the neighbouring Andromeda galaxy.

DR JORGE PEÑARRUBIA
INSTITUTE FOR ASTRONOMY

For the first time, scientists have precisely measured the mass of the galaxy that contains our solar system. They have found that the Milky Way is approximately half the weight of the neighbouring Andromeda galaxy, which has a similar structure to our own. The Milky Way and Andromeda are the two largest galaxies in a region called the Local Group.

A team led by the University of Edinburgh used recently-published data on the known distances between galaxies in the Local Group – as well as their velocities – to calculate the total masses of Andromeda and the Milky Way. Previous studies could only measure the mass enclosed within both galaxies' inner regions. In this new study, researchers were also able to work out the mass of invisible matter found in the outer regions of both galaxies, and reveal their total weights. They say 90 per cent of both galaxies' matter is invisible.

The team say that Andromeda's extra weight must be present in the form of dark matter, a little-understood invisible substance which makes up most of the outer regions of galaxies. They estimate that Andromeda contains twice as much dark matter as the Milky Way, causing it to be twice as heavy.

Researchers say their work should help them learn more about how the outer regions of galaxies are structured. Although both galaxies appear to be of similar dimensions, until now scientists had been unable to prove which is larger.

The study, published in the journal Monthly Notices of the Royal Astronomical Society, was carried out in collaboration with the University of British Colombia, Carnegie Mellon University and NRC Herzberg Institute of Astrophysics. The work was supported by the UK's Science and Technology Facilities Council. Findings from the study are supported by research led by Jonathan Diaz at the University of Cambridge, which used different data and methods and produced very similar results.

"We always suspected that Andromeda is more massive than the Milky Way, but weighting both galaxies simultaneously proved to be extremely challenging.

"Our study combined recent measurements of the relative motion between our galaxy and Andromeda with the largest catalogue of nearby galaxies ever compiled to make this possible."

Dr Jorge Peñarrubia, School of Physics and Astronomy, who led the study.

Life at the edge

The MASE (Mars Analogues for Space Exploration) research project will assess the habitability of Mars by studying how life survives in extreme environments on Earth.

Mars. Image: NASA

Dr Petra Schwendner, who plays a major role in the scientific co-ordination of MASE, explains the work of the MASE project, which is based within the UK Centre for Astrobiology.

DR PETRA SCHWENDNER
UK CENTRE FOR ASTROBIOLOGY

I have a strong background in the enrichment of anaerobic microorganisms with a focus on astrobiology. Over the next 3 years I will use a diverse set of present-day Earth-Mars analogue environments to help further the assessment of the habitability of Mars.

Detecting life on Mars, and investigating whether it was ever there, depends on knowledge of whether the combined environmental stresses experienced on Mars are compatible with life and whether a record of that life could be detected.

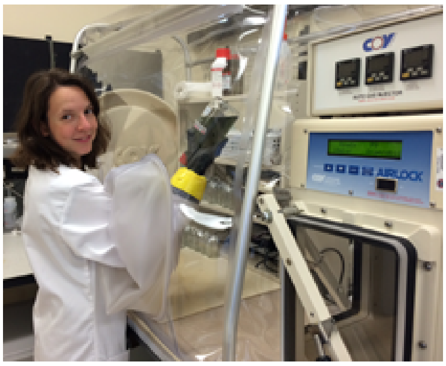
Therefore I will obtain samples from sites including the cold sulphidic springs of the Sippenauer Moor and Islinger Muehlbach in Germany, subsurface environments at 1.1 km depth in the Boulby salt mine (UK), permafrost in Canada and Russia, acidic cold lakes in Iceland, and the Rio Tinto sediments in Spain.

Each of these environments is characterized by exhibiting environmental extremes like low temperature, aridity, high salinity, acidity and low nutrient availability. Once I have obtained samples, I will try to isolate and characterize microorganisms that can thrive under anaerobic conditions.

Future goals are to study their responses to realistic combined environmental stresses that might have been experienced in habitable environments on Mars and their potential for fossilisation on Mars and their detectability.

I am looking forward to being part of this promising collaborative research project involving partners from across Europe.

The University of Edinburgh is the scientific coordinator of MASE. This 2.5million euro project is supported by the Seventh Framework Programme (FP7) of the European Community for research, technological development and demonstration activities.



Petra Schwendner working in the anaerobic chamber.

MASE website

http://mase.esf.org

Extreme conditions Physics... in a flash

Bismuth has become a prototypical system for studying phase transitions, and melting, under shock compression. It undergoes these transitions at relatively low pressures and temperatures, allowing us to investigate these phenomena at extreme conditions that we can attain in the lab.

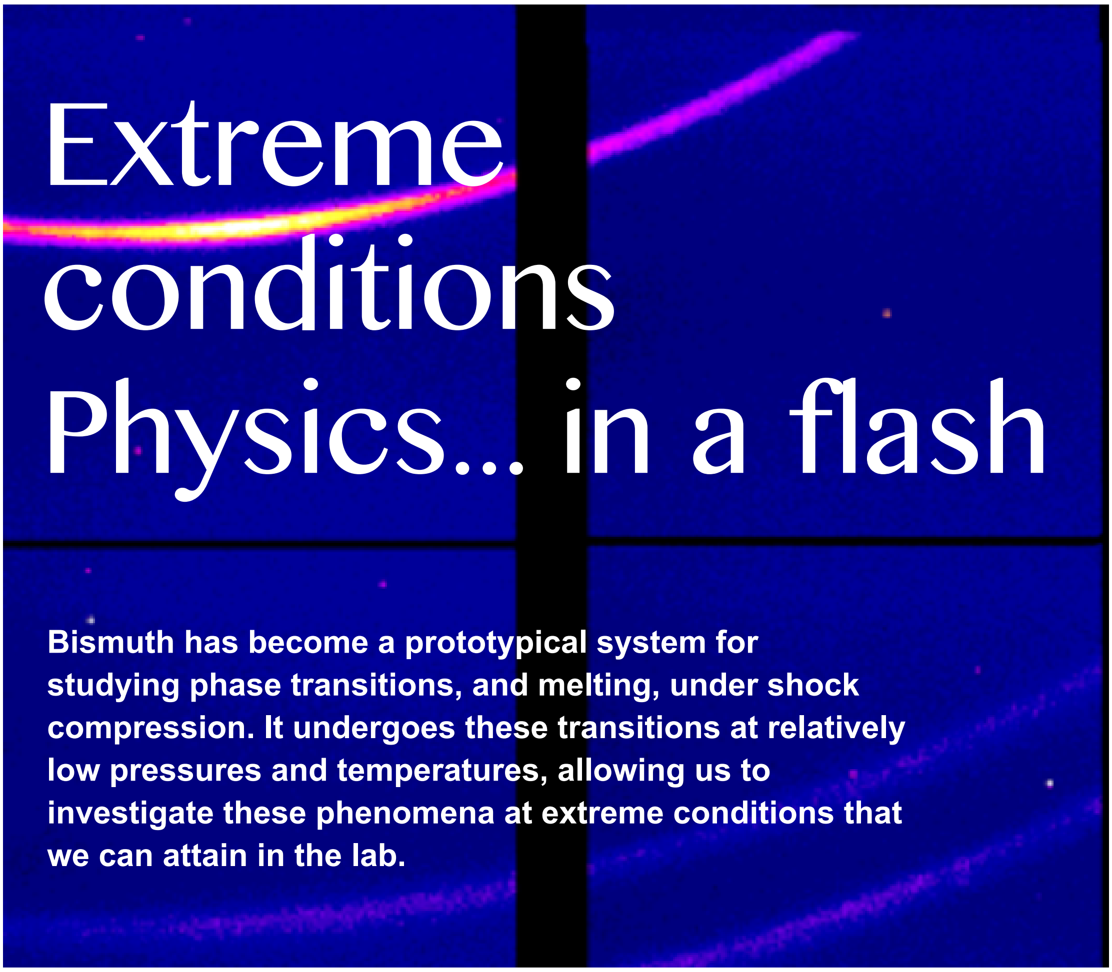


Fig 1: A diffraction pattern collected from a bismuth sample in 50 femtoseconds.

PROF. MALCOLM MCMAHON
EXTREME CONDITIONS GROUP

Some 30 miles south of San Francisco, and passing underneath Interstate Highway 280, is a 2-mile long piece of scientific apparatus, claimed to be the world's straightest object. This is the linear accelerator at the SLAC National Accelerator Laboratory.

Since 2009, the last third of the linear accelerator has been used to provide high-energy electrons for the Linear Coherent Light Source (LCLS), the world's first high-energy x-ray free electron laser (XFEL).

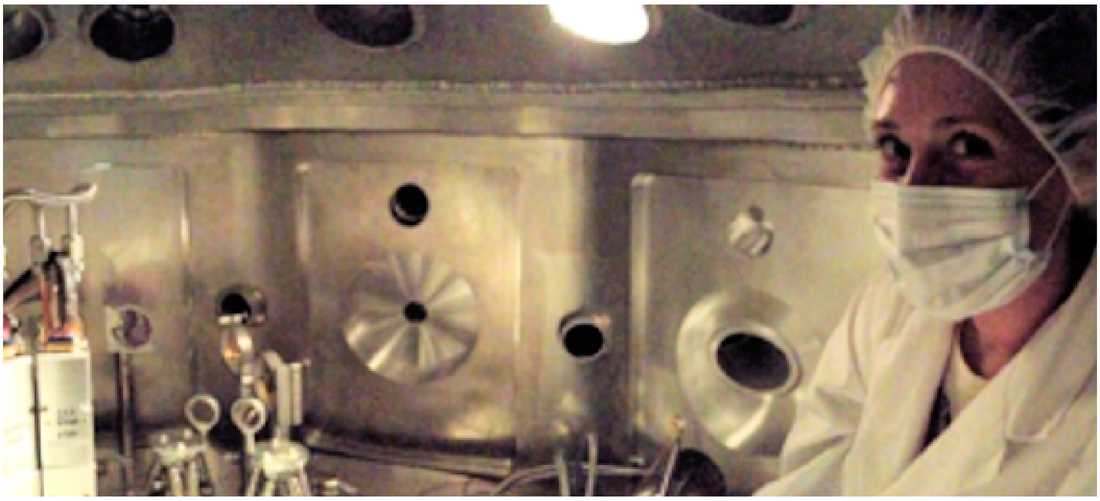
Many countries around the world, including the UK, have synchrotron x-ray sources, where extremely intense beams of x-rays are produced as high-energy electrons travel on a circular path through an array of powerful magnets. Such sources are 10^{12} times brighter than a typical medical x-ray machine and are used by a very wide range of researchers – from biologists to engineers – to look at the atomic structure of proteins, pharmaceuticals and minerals, and to study chemical and biological reactions.

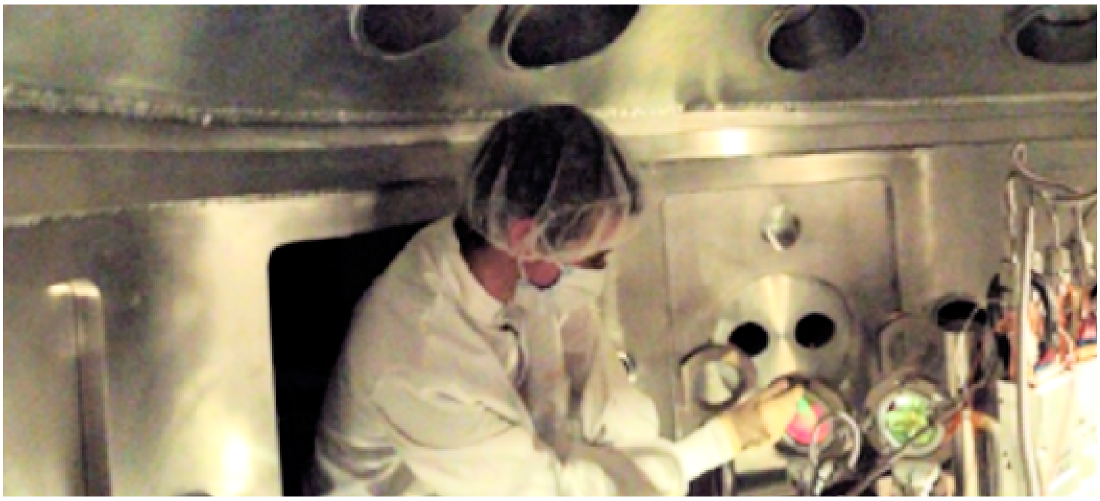
But the LCLS is a billion times brighter than any synchrotron, and produces enough x-rays in a single 50 femtosecond (50 million-billionths of a second) pulse to collect a full x-ray scattering pattern. The intensity of the LCLS is such that samples are often obliterated by the beam, but not before a "snapshot" image is obtained at the atomic level.

One of the principal uses of the LCLS, and other XFELs such as the Euro-XFEL soon to be completed in Hamburg, is to study materials at extreme pressures and temperatures, created by the use of powerful optical lasers. While the extreme conditions created this way are maintained for only a few nanoseconds (billionths of a second), this is still a million times longer than the "shutter speed" of the LCLS, allowing extremely detailed

The SLAC National Accelerator Lab

The SLAC National Accelerator Laboratory has been operational since the mid-1960s. It has been responsible for the award of three Nobel prizes in particle physics in the 1970s and 1990s.





Researchers from the School of Physics & Astronomy and Los Alamos National Laboratory dressed up in clean-room wear, setting up an experiment at the LCLS. Postdoc Richard Briggs and students Emma McBride and Martin Gorman have all been involved in this work.

studies of materials at the pressure-temperature conditions otherwise present only deep within large planets such as Jupiter.

Researchers from the School of Physics & Astronomy, in collaboration with scientists from Oxford University and Lawrence Livermore National Laboratory, performed their first experiment at the LCLS in February 2013, looking at the behaviour of the metal bismuth under high pressures and temperatures.

The quality of the x-ray scattering data obtainable at the LCLS is remarkable, as illustrated in Figure 1, which shows a diffraction pattern collected from bismuth in only 50 femtoseconds.

In their experiment, the Edinburgh researchers used a large laser to compress samples of bismuth to pressures 180,000 times higher than atmospheric, and then studied how the crystal structure changed on compression. They were also able to make a detailed study of how quickly the bismuth melted at high temperatures and high pressures, something over which there was a very large range of uncertainty.

By making a “movie” of the behaviour of the sample on a nanosecond timescale, they were able to show that bismuth melts in only a few billionths of a second, very much faster than previously believed.

Totally unexpected behaviour was also seen in the behaviour of the bismuth both on compression, and on decompression to ambient pressure. Unfortunately, the data were insufficient to fully understand the complex behaviour observed.

Access to the LCLS is extremely difficult, as researchers from all over the world compete for the limited number of experimental days available on this unique machine. The Edinburgh team very much hopes to return soon.

Inside the LCLS

The experimental set-up is contained within a large evacuated chamber.

This requires those setting up and aligning the equipment to dress up in clean-room wear, and crawl around inside the chamber making adjustments (see pictures above), while ensuring that they don’t touch (and therefore misalign) the many other mirrors, lenses and associated apparatus used to align and focus the numerous laser and x-ray beams entering the chamber. They must also complete a course on ladder safety!

We were one of the first users on the MEC beamline at LCLS to use the optical laser system to compress materials.

Prospering through innovation

The Edinburgh Complex Fluid Partnership is a knowledge-based organisation that supports companies with product innovation and provides consultancy in formulations, processing and product characterization.

DR JOE TAVACOLI

DR TIFFANY WOOD

EDINBURGH COMPLEX FLUIDS PARTNERSHIP

The School's Institute for Condensed Matter & Complex Systems (ICMCS) houses one of the world's top research groups in complex fluids. Here, researchers explore the fundamental science underlying the behaviour of dispersions, emulsions, protein solutions and liquid crystals.

Through a 5-year programme 'Design principles for New Soft Materials', researchers are discovering new material technologies that have the potential to improve the foods we eat, the personal care products we use and even ones that store, harvest and transport energy more efficiently.

From lab to market

Clearly, this type of research has potential for applications and strong links are being forged between ICMCS and industry through its knowledge-exchange branch: the Edinburgh Complex Fluids Partnership (ECFP).

The ECFP offers consultation work that ranges from standard characterisation of materials to fundamental problem-solving that can lead to the generation of new formulations and products. The latter is particularly suited to smaller and medium sized enterprises (SMEs) which generally have the immediate flexibility to incorporate novel ideas and solutions in their manufacturing processes.

Moreover, utilising a new approach or technology often grants SMEs a foothold in a competitive commercial environment and by adopting innovative technologies small companies can grow and, in turn, feed economic growth through job creation. The ready availability of funding that focuses on research and development projects between SMEs and academia has strengthened the relationship between the two even further.

Indeed, over the past year, ECFP has worked with 16 different organisations to improve fundamental understanding of formulations across a wide range

ECFP is based in the Soft Matter Research Group within the Institute for Condensed Matter & Complex Systems at the University of Edinburgh, and is able to draw on the world-leading expertise of its academics and collaborators and on its cutting-edge facilities.

It specialises in understanding the interplay of function, structure, interactions and dynamics between components within multicomponent mixtures.

Image: Pawsitively Natural

of sectors, including food & drink, pharmaceuticals, personal care, coatings and agrochemicals.

SMEs are the backbone of the UK's economy, accounting for 99.9 per cent of all private sector businesses in the UK, and a healthy SME sector translates to a healthy economy overall. By working with the ECFP, SMEs have access to the equipment and know-how that is often critical for their ongoing success.

Direct benefits

Below are some examples of innovative product development for SMEs supported by ECFP:

- A Scottish start-up company, Pawsitively Natural, sought to develop dog biscuits that were healthier for dogs. Researchers at ECFP helped improve Pawsitively Natural's recipe so that their wheat-free dog biscuit were more resistant to breakage – they are now stocked in pet shops across the UK.
- ECFP helped Lyon Healthcare Ltd, a Lockerbie-based Scottish start-up company, develop a formulation for a new toothpaste in which therapeutic ingredients, discovered by the company, are protected in the formulation and released on application. Follow-on funding is currently being pursued to bring development of this product closer to market.
- Jobson's Animal Health is a Carlisle-based company selling formulations for the veterinary care of farm animals. Researchers at ECFP carried out a feasibility study to develop a new hoof dressing formulation to release active disinfectant ingredients at the appropriate time.
- Macphie of Glenbervie makes food ingredients for the catering industry. ECFP identified an alternative and efficient set of emulsifiers which allowed the company to significantly reduce the total quantity of emulsifiers in a selection of products.

Better biscuits

Founder and managing director of Pawsitively Natural, Chris Louitt, said working with ECFP "helped me to understand better, from a non-technical perspective, the various tests which could be applied in making the biscuits as robust as possible and market-ready.

"All in all a very successful project which for me achieved its outcomes."

Find out more

To find out how ECFP can help your business, email the group, or call:
+44 (0)131 651 7687

Edinburgh Complex Fluid Partnership website

Translational biophysics: Antimicrobial molecules and their mode of action

The rise of antimicrobial resistance is an urgent global concern and one of the biggest health risks facing the world, according to a statement made in July by the UK Government and supported by the Wellcome Trust and the World Health Organisation. They have called for "concerted action" to address the problem.

PROF. JASON CRAIN

INSTITUTE FOR CONDENSED MATTER & COMPLEX SYSTEMS

The World Health Organization specifically highlighted the need for greater and more coordinated research and development, with the underlying molecular-level studies into the fundamental modes of action of antimicrobial molecules constituting an important part of this action.

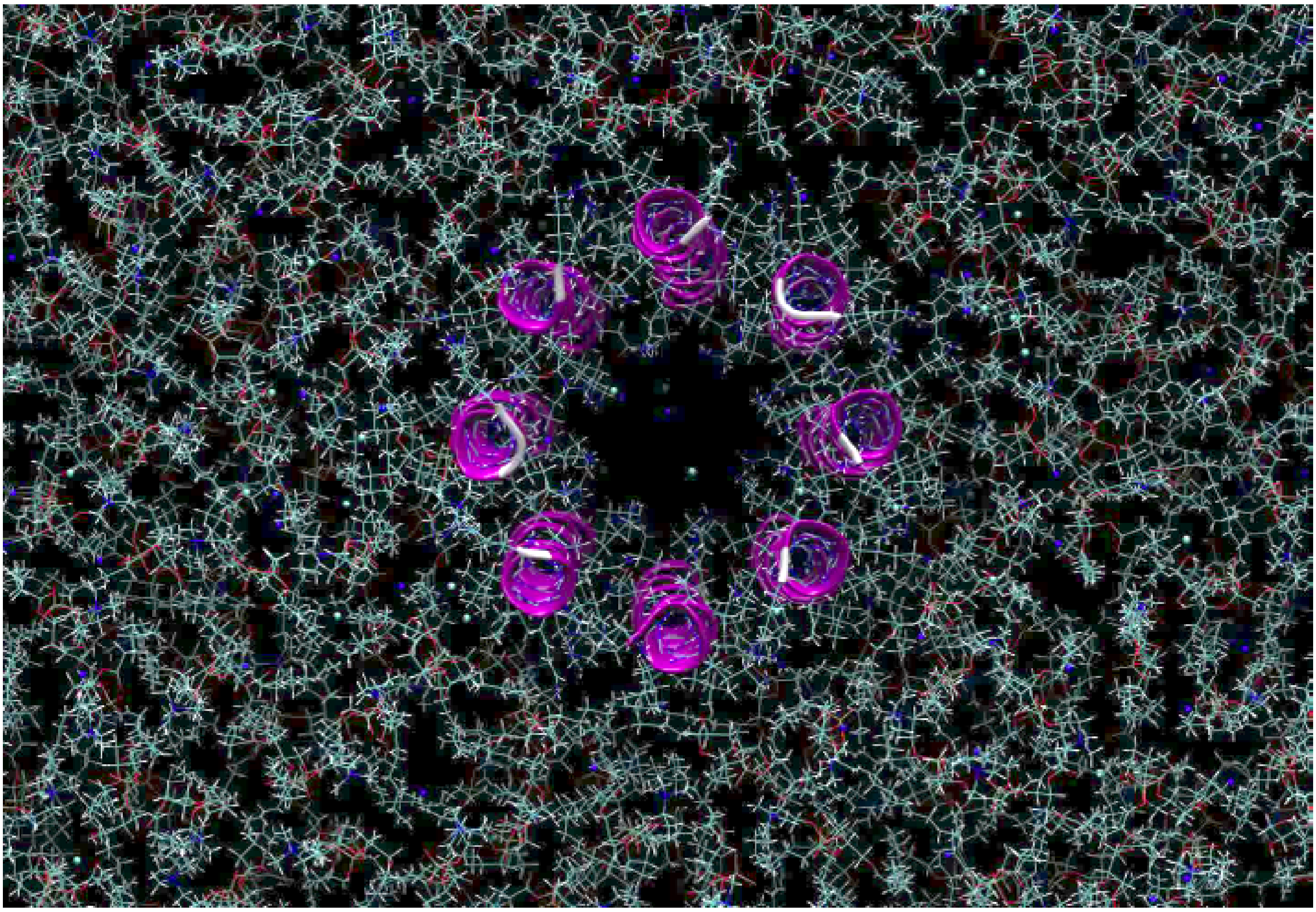
The physical sciences have a critical and underexploited role to play in addressing the challenge of antimicrobial resistance. They can develop new measurement methods to push the boundaries of resolution and chemical specificity, and also create the new computational models that are needed to reveal molecular-scale processes in unprecedented detail and so contribute to a rational design strategy for improved medicines.

We have been involved in an international collaboration involving the UK's National Physical Laboratory (with whom the University has recently signed a Memorandum of Understanding) and IBM Research in New York aiming to reveal new insight at the nanoscale into the mode of action of antimicrobial protein fragments (peptides) on model lipid membranes.

Recently published work was the first study to show a dynamic process where antimicrobial peptides form nanoscale pores, which expand until the membrane disintegrates.

Antimicrobial peptides are postulated to disrupt microbial phospholipid membranes. The prevailing molecular model is based on the formation of stable or transient pores, although direct observation of the

> "It is very exciting to see the physical sciences leading to new insights into biological processes.
>
> "Cross-disciplinary partnerships such as the one that underpins this work are essential in bringing new perspectives to a problem as challenging as understanding the mechanisms of antimicrobial activity at the molecular scale."
>
> Jason Crain



AMP3 Octamer Pore Model – 100 ns.

fundamental processes has been lacking.

New results, new antibiotics?

We have combined rational peptide design with topographical (atomic force microscopy), chemical (nanoscale secondary ion mass spectrometry) imaging on the same samples and simulated the results using computing resources provided by EPCC.

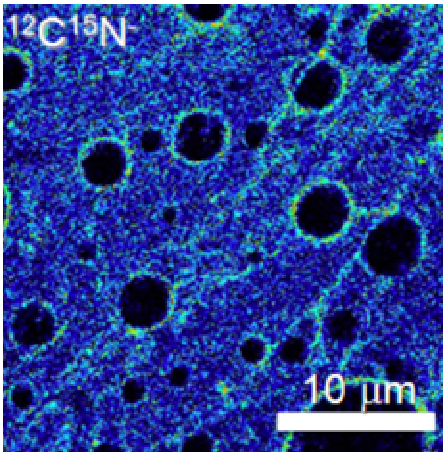
Our work has shown for the first time that pores formed by antimicrobial peptides in supported lipid bilayers are not limited to a particular diameter, nor are they transient, but can expand laterally at the nano-to-micrometre scale to the point of complete membrane disintegration.

The results offer a mechanistic basis for membrane poration as a generic physicochemical process of cooperative and continuous peptide recruitment in the available phospholipid matrix.

This discovery reveals a new mechanism and physical basis for bacterial membrane disruption - important for the development of new antiobiotics.

The work is performed in collaboration with the National Physical Laboratory and IBM Research. See for example - Nanoscale imaging reveals laterally expanding antimicrobial pores in lipid bilayers In: Proceedings of the National Academy of Sciences of the United States of America - PNAS, Vol. 110, No. 22, 2013, p. 8918-8923.

Nanoscale Secondary Ion Mass Spectrometry of Antimicrobial Poration. SIMS relies on the detection of secondary ions extracted from the surface by a focused 16KeV beam of primary ions (133Cs+) rastered across the sample.



Why **does** wet corn-starch behave like that?

A new theory addresses the sudden jamming behaviour of wet corn-starch powder and other ‘shear thickening’ materials.

PROF. MIKE CATES
SOFT MATTER PHYSICS GROUP

Consider traffic on a crowded motorway. If everyone drives at a modest speed, the flow is smooth and uneventful. But if all the drivers try to go faster, the opposite happens: cars now approach too closely, rapid braking is inevitable, and a chain reaction results in a traffic jam.

A similar kind of jamming arises in fluids containing suspended solid particles. One way to make such a material is to add just enough water to corn-starch (or custard powder) to create a smooth liquid paste. Stirring this fluid slowly with a spoon encounters very little resistance so long as the mechanical stress remains small. But raising the stress (by pushing harder on the spoon) causes fluid flow to stop altogether. Instead a solid is formed, which then fractures (see arrows in Fig 2).

This is an experiment you definitely should try at home! Alternatively, watch this video which shows people running across the top of a large tank of shear-thickening fluid – into which they sink as soon as they stop moving.

The thickened state, when sandwiched between layers of Kevlar fabric, can quite literally stop a speeding bullet: such Liquid Armor™ technology has been researched by BAE and other firms (see this BBC news story).

Despite its importance, the mechanism of shear thickening remains mysterious. What causes jamming when the applied stress is too large?

Work by physicists in Edinburgh and New York Universities (published in Physical Review Letters, January 2014) has developed an answer to this question. And it is... friction. At low flow rates, repulsions between a pair of particles keep them separated by a thin layer of fluid, which acts as a lubricant and allows them to pass by each other unhindered. But when the stress is too large, these films are broken, frictional contacts are

Shear-thickening puzzle

“Shear-thickening fluids flow freely when stirred gently, but solidify if you try to push them too fast.

“The mechanism behind this important effect should have been understood years ago, but only now are we edging towards a full explanation.”

Prof. Mike Cates

Fig 1: Wet corn-starch on a speaker.

Image created by PhD students Ben Guy, Jacob Tyrie and Daniel Hodgson.

created, particles have to slow down, and jamming is the result.

Experiments in Edinburgh led by Prof. Wilson Poon have already confirmed the importance of friction in corn starch as well as other industrially important suspensions, and detailed testing of quantitative aspects of the theory are underway.

Design principles for new soft materials

The Engineering and Physical Sciences Research Council (EPSRC) currently funds a flagship £5M Programme Grant on Design Principles for New Soft Materials. This supports a team of Edinburgh physicists, led by Prof. Mike Cates, working not only on shear thickening, but on many other projects involving soft materials such as liquid crystals, emulsions, gels and biological cells. Team members also work on the statistical physics of interacting self-propelled objects, including simplified models of traffic jams.

In 2012, team members founded the Edinburgh Complex Fluids Partnership (ECFP), which translates academic research from the Soft Condensed Matter group into a commercial context. See the article on p8 for more information.

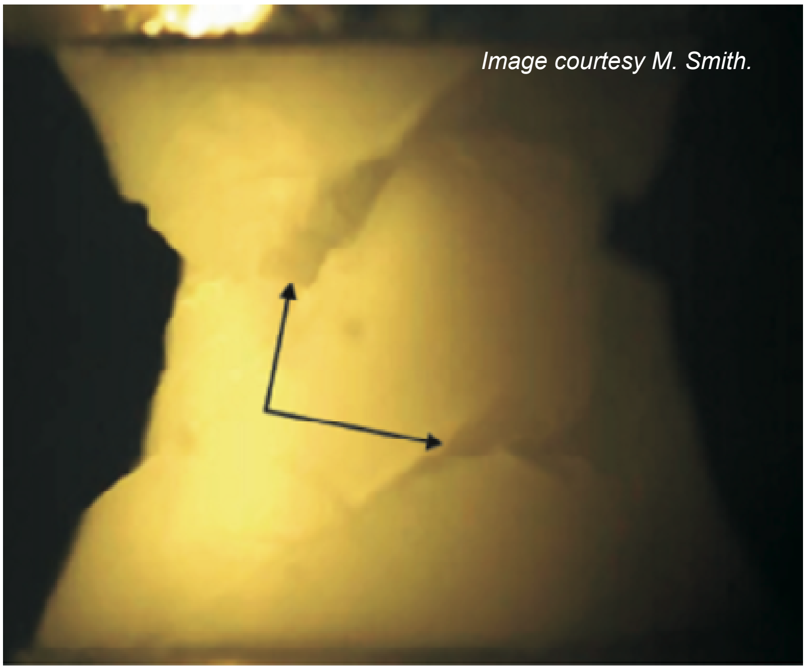


Image courtesy M. Smith.

Fig 2: Fractured solid.

Powering wave energy

Pelamis Wave Power Ltd, the Edinburgh-based developer of leading wave energy technology, is making use of EPCC's computing facilities to accelerate the designs for the first wave farms.

Pelamis Wave Power generates highly detailed numerical simulations of the hydrodynamics and control of the Pelamis machines to analyse performance and survivability.

A small-scale cluster computing platform has been used by Pelamis for many years to develop designs and control algorithms, and provide engineering load and motion data. These bespoke tools enabled the delivery of two second-generation Pelamis P2 machines, which are currently being demonstrated at the EMEC test centre in Orkney, providing a huge range of data from real sea operations. Research and development of the technology continues, so the next Pelamis design must provide another step up in performance and engineering efficiency.

The power available to a Pelamis machine depends on the incident sea conditions, but the physical design of the machine and the way it is controlled determines how much of that power can be extracted. The movements of the Pelamis machines are monitored in real time, making it possible to maximise their energy yield by controlling the power take off systems within the machine accordingly to tune their dynamic response to the changing wave conditions. Tailoring these control algorithms and settings to perform optimally across the full range of different wave conditions is key to increasing the power absorption, and therefore yield, of the Pelamis machines.

EPCC's INDY cluster offers a new order of magnitude of computing capacity to Pelamis and is opening up new frontiers of research through numerical optimisation methods that would previously have been too computationally expensive to apply.

Ross Henderson, Technology Director at Pelamis, said: "Our first challenge was adapting our existing core simulation code to compile and run on INDY, which with the help of EPCC was less painful than expected. This allowed us to successfully demonstrate INDY with a real application, conducting batches of hundreds of simultaneously optimising simulation runs. Our next challenge is to fully integrate INDY with our simulation front-end and database tools so such batches can be conducted with auditable inputs, and maximum usability of results. We are also keen to explore the application of specialist skills at EPCC to optimise our code for faster run-times.

"Wave energy is on the cusp of

ROSS HENDERSON
TECHNOLOGY DIRECTOR
PELAMIS WAVE POWER
ENQUIRIES@PELAMISWAVE.COM

EPCC's Indy cluster

INDY is a dual configuration Linux-Windows HPC cluster aimed at industrial users from the scientific and engineering communities who require on-demand access to mid-range, industry-standard HPC.

To find out more about using INDY, contact George Graham at EPCC.

entering commercial service as part of the wider renewable energy marketplace. We need to impress utility customers with the very first farms and these numerical simulations will play a vital part in delivering machines that can do this. Where we have been running on 40-60 cores on our own in-house cluster, we will soon be able to run on over 1500. This means that numerical optimisation of control systems and geometry of the machines becomes tractable using our 'virtual machine' simulations. This is very exciting as it may open up new routes to increasing performance and reducing costs.

"We already know that by increasing the volume of the Pelamis machine we can infinitely increase the power it captures, with no theoretical limits aside from the practical engineering constraints. However, there is an ultimate limit on the amount of power capture we are able to achieve from a Pelamis machine at each set volume and given geometry - a maximum energy output. With the machines which we're currently demonstrating in Orkney, we're still quite far from reaching that maximum output. So with the Supercomputing Scotland project with EPCC, we're looking at both how we can improve the control of existing machines, but also optimising the Pelamis design for future iterations.

"The initial demonstration studies we've run on INDY so far have already shed new light on the ultimate limits of wave power absorption for a given geometry of machine - and it is much higher than we've achieved to date. While demonstrations of the two machines in Orkney have yielded very positive and valuable test results over the last few years, there is much scope to further enhance our technology before reaching that maximum energy output.

"Wave energy in general, and Pelamis in particular, offers what is perhaps the fastest cost of energy reduction trajectory of any energy technology. This is because in addition to the traditional and accepted route of cost reduction through incremental design improvements and economies of scale, we can deliver major increases in the underlying capture efficiency through control and geometry optimisation. With such a big increase in the parallel computing resources available to us we hope to optimise these aspects of Pelamis technology faster, to get closer to an ultimate absorption limit with the early commercial wave farms."

HPC for industry

Pelamis and EPCC are working together as part of Supercomputing Scotland.

This joint EPCC-Scottish Enterprise initiative gives companies the knowledge to help them decide if using high performance computing makes sense for them.

The programme is primarily aimed at companies from the Energy, Life Sciences and Financial Services sectors but will consider engaging with any company on a case-by-case basis.

Greener computing: addressing energy use in parallel technologies

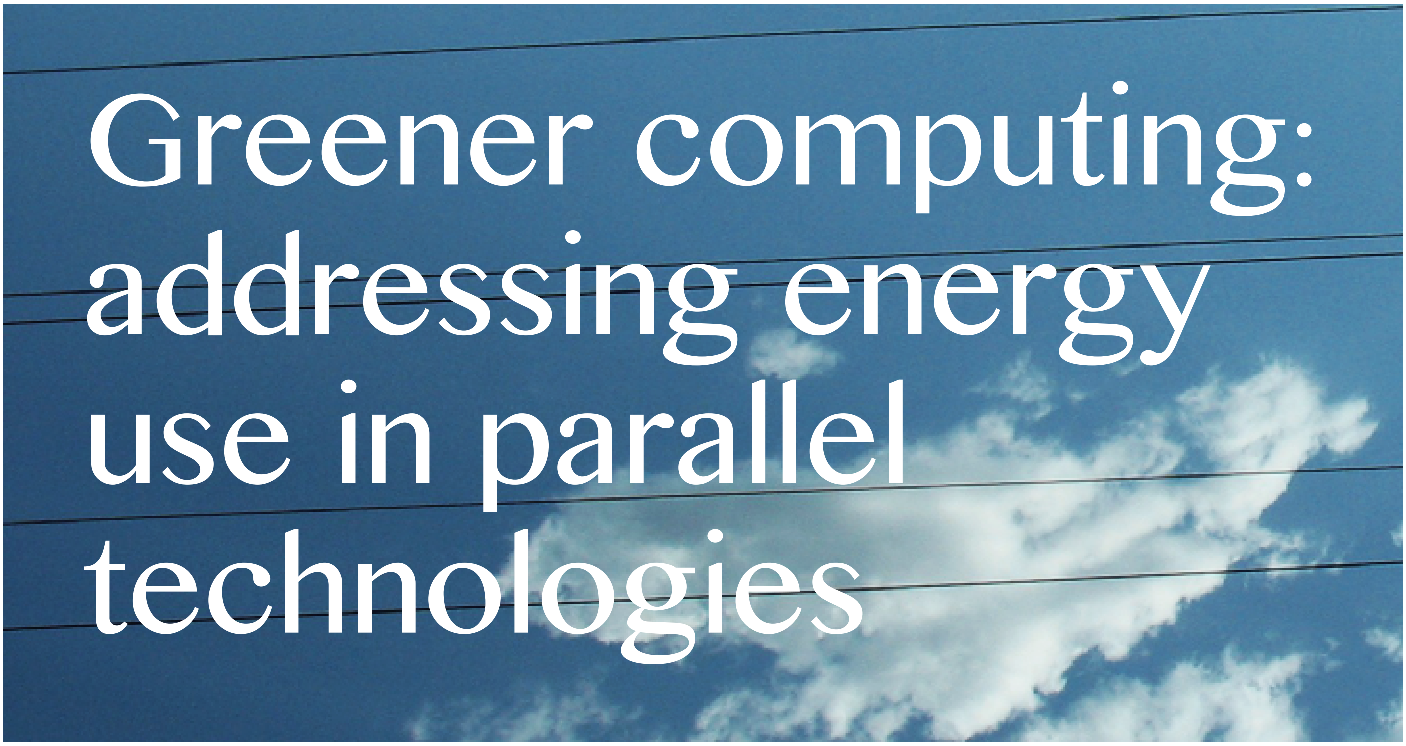


Image: rockygirl05, Flickr

The problem of energy efficiency in parallel computing is being tackled by the Adept project, a consortium of universities and companies led by EPCC, the high-performance computing centre based within the University of Edinburgh.

DOUG ROCKS-MACQUEEN
EPCC

High performance computing (HPC), also known as supercomputing, uses parallel computing techniques for performance.

As HPC systems grow larger and more powerful the need for energy savings increases - every megawatt (MW) in power reduction results in savings of more than $1 million. For example, in 2009 when the US government was creating projections for the future of HPC they estimated that one of their supercomputers would require 166 million computing cores and use 67 MW of power. To put that into perspective, 1 MW is enough energy to power 2600 British households, which is roughly a town the size of Fort William.

Any reduction of energy consumption by supercomputers would result in significant money savings. It would also result in a reduction in their carbon footprint.

Challenges of embedded systems

The expansion of traditional parallel computing hardware into embedded systems – computers with dedicated tasks that are “embedded” in products – is posing challenges.

These systems, like tablet computers, mobile phones, and GPS devices, are constrained by energy use limits. Engineers want to make these systems more powerful by using parallel computing techniques, but they have to take into account power and energy use. No one wants their tablet to run out of battery power after watching a few minutes of a movie because the video-processing software is too power-hungry. There is a growing concern in this sector about the higher energy use of parallel computing with the current power limits.

Less energy, more performance

The goal of the Adept project is to demonstrate that it is possible to

> “This is an extremely challenging project.
>
> “We have to design benchmarks which will expose the performance and power consumption of a variety of machines, from System-on-Chips to supercomputers; design and build a system capable of performing fine-grained power measurements on these machines at high temporal resolution; and learn how to use this data to optimize applications with the added constraints of peak-power and total energy consumption.”
>
> Nick Johnson, EPCC

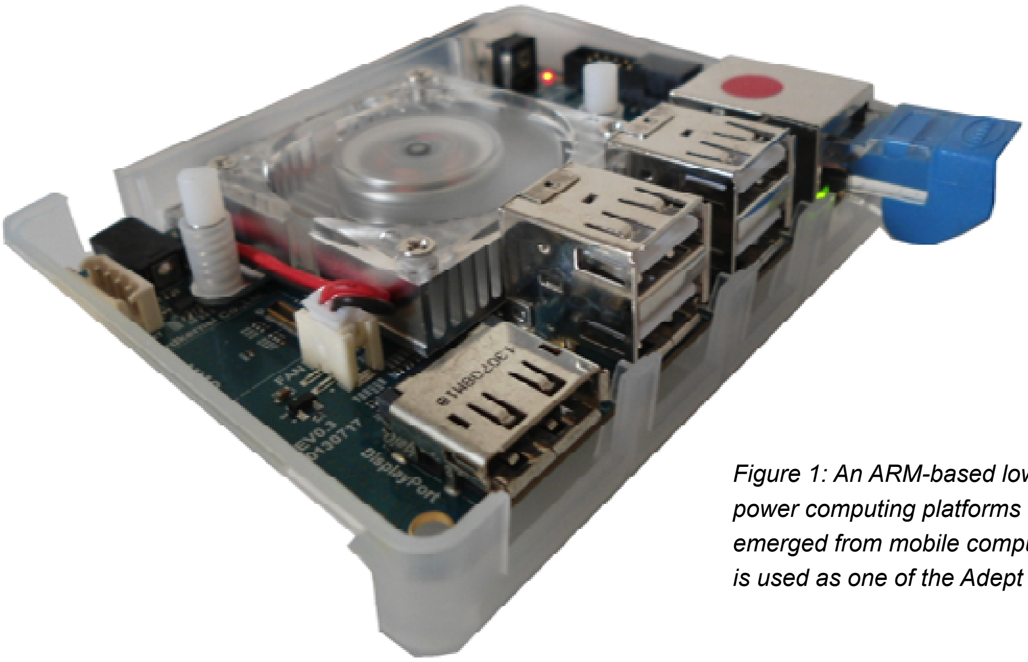


Figure 1: An ARM-based low-power computing platforms that has emerged from mobile computing and is used as one of the Adept test beds.

reduce the power use in HPC by 50% without losing performance by adapting the programming techniques and the hardware that is being used.

At the same time Adept will try to increase the performance of embedded systems by 50% by enabling the use of more powerful systems but continuing to stay within a strict power and energy budget.

How will Adept achieve this?

The consortium is developing a tool to help software developers model and predict the power use of their parallel software. It will provide an analysis of what causes high power use and poor performance so that the code can be improved.

Another benefit of the Adept tool is that it will allow users to evaluate how different hardware will affect power consumption. In the past, similar tools were hardware specific, which made it difficult for software engineers to estimate how their code would perform on different platforms. This tool will be able to model how the software performs on different types of hardware. Furthermore, the Adept tool will give results in seconds instead of hours, which has been a problem in the past.

Michele Weiland, EPCC, said: “We are especially excited to be working with several universities and industry partners from across the EU on this project because the benefits of energy-efficient computing affect a whole range of people, from researchers to anyone using a mobile phone or tablet.

“Our partners are helping us tackle these diverse user needs through their knowledge input, gained from years of experience in either academia or industry.”

Adept is a European Union-funded FP7 project.

Adept

addressing energy in parallel technologies

Find out more

Adept is about to finish its first year, and the early results look promising.

You can learn more about the project and see some of the case studies that will be used to test the Adept tool at the Adept project website.

Getting under the skin of the Universe

The availability of intense beams of gamma rays at facilities such as the Thomas Jefferson National Laboratory, USA, and the MAMI microtron, Germany, has opened up exciting new opportunities for precision studies of nuclei and the fundamental nature of bound quark systems. Such objects make up most of the visible mass in the universe yet remain poorly understood. Edinburgh researchers are using gamma ray beams to tackle some of the main issues.

PROF DAN WATTS
NUCLEAR PHYSICS GROUP

The neutron skin

Nuclear theories predict heavy nuclei form a skin of neutrons on the nuclear surface, with thickness 0.05 to 0.4 trillionths of a centimetre. Accurate measurement of the skin is a hot topic as it would discriminate between nuclear theories and provide constraint on the density dependence of the energy of nuclear matter (ie the equation of state). This has direct implications for neutron star properties such as radii, cooling mechanisms and gravitational wave emission.

Edinburgh researchers led a new measurement published in Physical Review Letters, which gave the first measurement of the skin using a gamma ray beam. The data have such precision that it was possible to establish both the size and shape of the neutron skin.

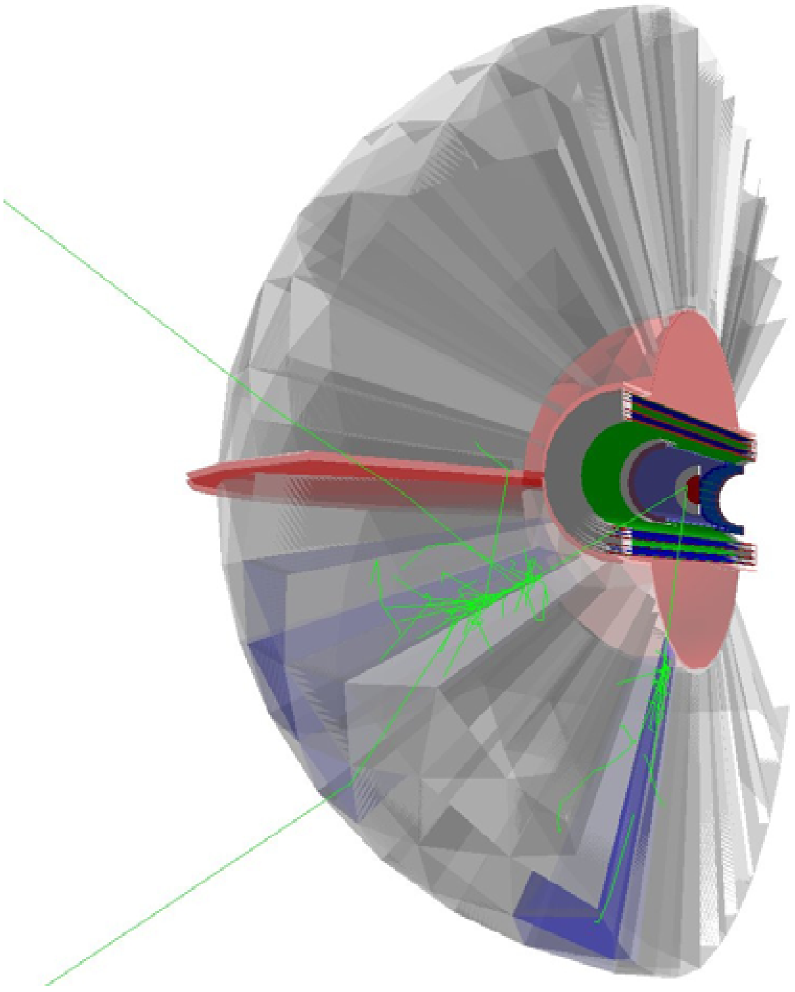
"The new results are particularly exciting because of the high impact on a wide range of fields. "

The particle and nuclear physics frontier

Over 98% of the "mass" of the protons and neutrons (or nucleons) constituting the atomic nucleus is actually energy, arising from the interactions of the component quarks with each other and the vacuum.

Although we have a theory for the force between the quarks, based on the exchange of gluon particles, it is only in recent years utilising advances in high performance computing that it has been possible to obtain ab-initio predictions of the properties and excited states of nucleons from theory.

Also the calculations show that a whole new family of "hybrid" 2 and 3



A computer simulation (using the Geant4 software package) of the photon detection apparatus (CrystalBall) used in the experiment to measure the neutron skin.

The image shows the target (red); the NaI crystals (grey); and the charged particle subdetector systems (blue and green). Only a section through the apparatus is shown (the right hand side is not shown for clarity).

The green tracks correspond to 2 photons from the electromagnetic decay of a neutral pi meson. The photoproduction of neutral pi mesons was used to extract information on the neutron skin.

quark systems should exist in nature. The term “hybrid” indicates that the maelstrom of gluons is excited to a higher energy state. Their discovery would provide the cleanest experimental signature for the role of gluons in the mass generation process.

Despite the major theoretical advances, current experimental data are woefully inadequate to assess whether the theory of the strong interaction can fully describe nature at the scale of the atomic nucleus. For example, the theory predicts many more excited states for the nucleon than are currently established experimentally.

Edinburgh researchers lead a programme of experiments using gamma ray beams to excite the nucleon and detect the subsequent decays of the excited states to nucleons and other particles. Two recent results published in Physical Review Letters disfavoured models in which two of the quarks pair inside the nucleon, and also measured the spin directions of the decay nucleons, a key advance to unambiguously establish the excited states.

In future work, Edinburgh researchers will hunt for the hybrids. They have proposed a new experiment at Jefferson Lab, MesonEx, with colleagues from Europe and the USA. Gamma ray beams are predicted to produce hybrids when they interact with a proton target. The researchers will isolate the signature of the hybrids from their decay to lighter particles.

The advances in theory and experiment in the coming decade are set to reveal a deeper understanding of matter.

Find out more

Physical Review Letters: Neutron skins

Physical Review Letters article: Nucleon excited states

Physics Letters B article: Nucleon excited states II

Footprints of new physics? Charm resonances in beauty decays

New insights from the Edinburgh particle theory group show that charm resonances discovered by the LHCb experiment at the Large Hadron Collider are topsy-turvy compared to the most common expectations.

DR ROMAN ZWICKY
PARTICLE PHYSICS THEORY GROUP

The LHCb experiment is a facility at the Large Hadron Collider (LHC) dedicated to measuring decays of *b*-quark bound states.

It aims to find new sources of CP-violation which are necessary to explain the matter anti-matter asymmetry in the universe. These decays are sensitive to structures beyond the Standard Model and set severe constraints on leading models such as supersymmetry through the decay of $B_s \rightarrow \mu\mu$.

The LHCb collaboration has observed a distinctive pattern charmonium resonances in the $B \rightarrow Kll$ decay [1]; shown in Fig. 1 as a function of the lepton-pair four-momentum q^2.

The $B \rightarrow K\,ll$ decay corresponds to a decay of a beauty quark (b) to a strange quark (s) at the quark level: $b \rightarrow sll$ c.f. Fig.2. In the Standard Model of particle physics such decays are induced through quantum fluctuations and are considered to be highly-sensitive probes of physics beyond the Standard Model.

Charmonium is a bound state of a charm quark (c) and an anti-charm quark state and appears as a subprocess $b \rightarrow s$ *(charmonium→photon→ll)* to the so-called dominant penguin process shown in Fig. 2.

It was shown by researchers at the University of Edinburgh that these resonances cannot be described by the commonly used factorisation approximation (FA) shown in blue cyan bands in Fig 1.

In fact, rather surprisingly, a good fit to the data is obtained by scaling the FA by a factor of -2.5 [2].

This means that the interference pattern is upside down and rather strong compared to the FA prediction.

In the FA, exchanges of strong force particles (gluons) between the bs-quarks and the charm quarks are neglected. The FA is described by the product of well-known form factors and experimentally accessible data on electron-positron annihilation into charmonium states.

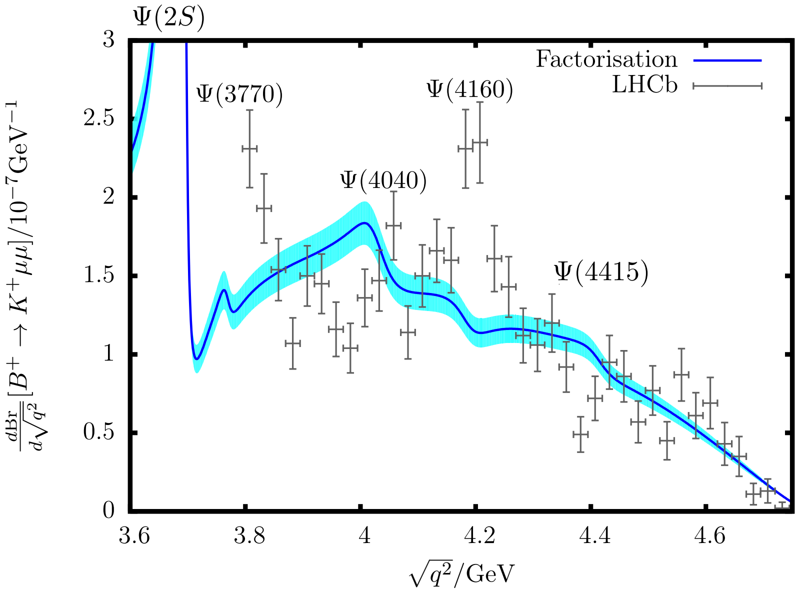


Fig 1: The crosses correspond to the LHCb data points and the blue cyan band is the FA-prediction [2].

The $\psi(2S)$, $\psi(3770)$, $\psi(4040)$, $\psi(4160)$ and $\psi(4415)$ denote charmonium resonances. The width of the peaks and dips are related to how fast these particles decay by virtue of the uncertainty principle.

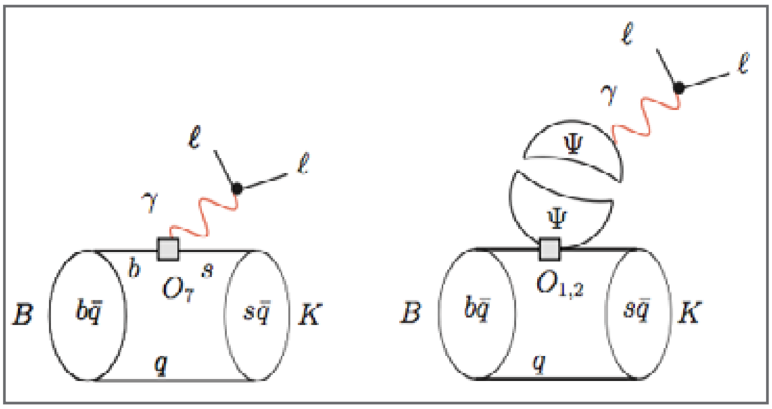


Fig 2: Subprocesses of the decay $B \to K l^- l^+$ where B and K are bound states of b,q quarks and $s\bar{q}$ quarks respectively and $l^\pm$ denote leptons. The photon and ψ (charmonium) are intermediate particles and the symbols $O_{7,1,2}$ denote interaction terms in the Hamiltonian.

Left: the so-called penguin process, which happens at short distances. Right: the long-distance charmonium type transition, which happens at long distances.

In view of the discrepancy of the FA and the experimental results, the crucial question becomes whether or not the corrections to the FA can give rise to the large shift.

The investigations in Ref. [2] indicate that this is rather unlikely since the expected correction averaged over the interval [c.f. quark-hadron duality] of the four charmonium resonances, visible in Fig 1. leads to a correction of -0.5 and not -3.5 as the data indicate.

It is therefore a logical possibility that there is structure beyond the Standard Model in $b \to \bar{c}cs$ transitions.

On the one hand this is somewhat unexpected and one would need to construct a microscopic model that evades further constraints, but on the other hand has the potential to explain further tensions in the field of flavour physics. One such example is the 3.7 standard deviation, reported by the LHCb collaboration in 2013 [3], in the angular observable P'_5 in $B \to K^* ll$ at low q^2.

In any case the results in [1] have taught particle physicists something new and the findings have to be integrated into future predictions in the appropriate observables.

It is rather fortunate that in the near future progress on these questions can be made by extracting information on the charmonium resonances $\psi(1S) \equiv J/\psi$ and $\psi(2S)$ whose data has yet to be carefully analysed by the LHCb collaboration.

Bibliography

[1] R. Aaij *et al.* [LHCb Collaboration], “Observation of a resonance in B+ → K+ μ+μ- decays at low recoil,” Phys. Rev. Lett. 111 (2013) 11, 112003 [arXiv:1307.7595 [hep-ex]].

[2] J. Lyon and R. Zwicky, “Resonances gone topsy turvy - the charm of QCD or new physics in b→s *l+l-*?,” arXiv:1406.0566 [hep-ph].

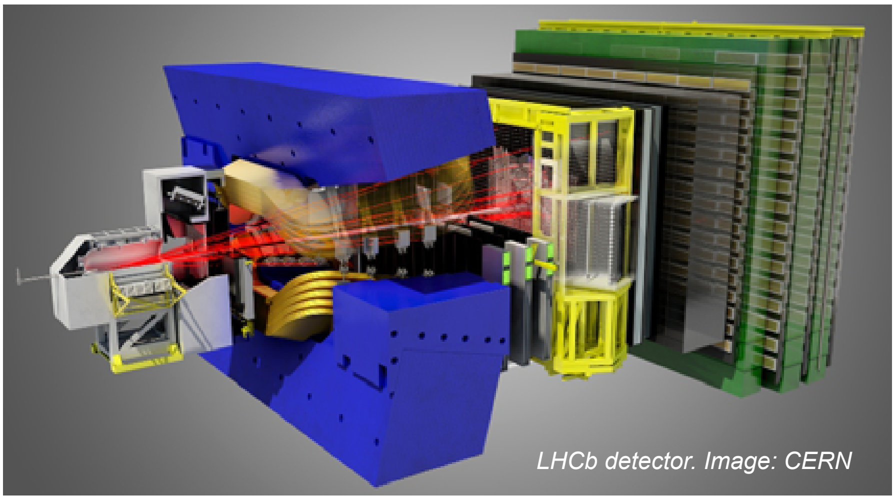
[3] R. Aaij et al. [LHCb Collaboration], “Measurement of form-factor independent observables in the decay B0→K*0 μ+ μ-,” Phys. Rev. Lett. 111 (2013) 191801 [arXiv:1308.1707 [hep-ex]].

Quark-hadron duality

The particles of strong interaction are bound states of hadrons made out of quarks. By the confinement hypothesis no quark itself will ever be observed in a detecter or seen through a resonance effect as shown in Fig.1. Hence ideally computations ought to be done with hadrons but for technical reasons of feasibility are performed with quark and gluons. The results of the latter agree with the former when averaged over a suitable energy interval. This concept is known under quark-hadron duality and can be made precise through so-called dispersion relations which rely on the famous Cauchy’s integral theorem.

Bound state

A particle composed of more elementary constituents. Example: the proton and the electron are bound into the hydrogen atom.



LHCb detector. Image: CERN

LHCb experiment: searching for a strange phase in beautiful oscillations

The LHCb experiment at CERN is attempting to solve the puzzle of why nature prefers matter over anti-matter.

DR GREIG COWAN

PARTICLE PHYSICS EXPERIMENT GROUP

The Standard Model (SM) of particle physics describes the properties and interactions of all known particles and forces (except gravity). It tells us that there are 12 fundamental particles and their anti-particles and describes how these particles interact with each other via the exchange of the force-carrying bosons.

The last piece of the puzzle, the Higgs boson that gives all particles their bare mass, was discovered in 2012 at the Large Hadron Collider (LHC) at CERN, Geneva.

Despite this amazing success we know that the SM jigsaw is incomplete as there remain some holes in our knowledge of the Universe. For example, how do we explain gravity, or the dominance of matter over anti-matter? And how do we account for all of the Dark Matter that we believe exists in the Universe but has so far evaded our detection?

The LHCb experiment at the LHC is attempting to answer one of these questions by studying the tiny differences between matter and anti-matter (termed CP violation) that can be observed in the decays of B and D mesons produced in the proton-proton collisions of the LHC.

Research staff and students in the Edinburgh Experimental Particle Physics group are leading members of the LHCb collaboration, playing a role in many aspects of the detector development, operation and data analysis.

The LHCb detector is 100m underground and is large: approximately 5m x 5m x 20m. It is composed of different detector technologies that help us reconstruct what has happened in each proton-proton collision and to identify those that are interesting.

It is hoped that LHCb will measure new sources of CP violation that cannot be explained by the SM and would, therefore, be unambiguous signs of new physics.

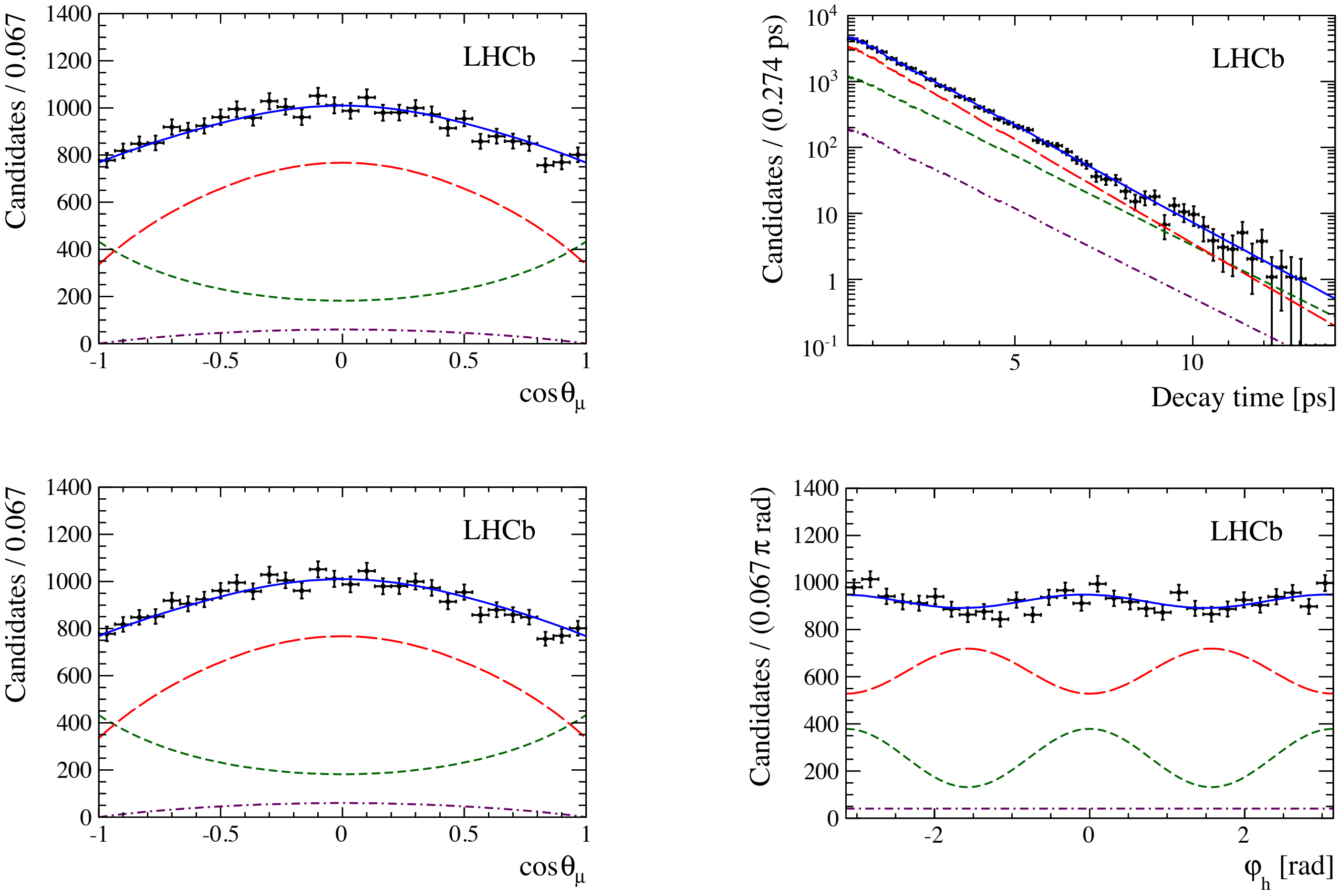
A particular focus of the group is the study of mesons composed of a

The missing quarks

Although absent from the Universe today, particles known as 'beauty (b) quarks' were common in the aftermath of the Big Bang, and are generated in their billions by the LHC, along with their antimatter counterparts, anti-beauty quarks.

The "beauty" or "bottom" quark is the second heaviest of the quarks and is the source of the "b" in LHCb's name. 'b' and 'anti-b' quarks are unstable and short-lived, decaying rapidly into a range of other particles.

Physicists believe that by comparing these decays, they may be able to gain useful clues as to why nature prefers matter over antimatter.



"beauty" quark and a "strange" quark (so-called B_s^0).

Since these particles are neutral they form an interesting quantum mechanical system where the B_s^0 meson can oscillate (ie change) into its anti-matter particle at a rate of about 3 million million times per second. Fortunately, the LHCb detector is sensitive enough that we can measure these oscillations and can use them to look for a tiny phase difference in the rate of $B_s \to$ anti-B_s and anti-$B_s \to B_s$ oscillations that would be characteristic of CP violation.

The Edinburgh group is currently using the full LHCb Run-1 data set to finalise their study of (anti-)B_s^0 mesons decaying to the well-known J/ψ and ϕ mesons.

This "golden channel" will allow them to make the most precise measurement of the CP-phase in the oscillations, allowing them to test the SM at a deeper level than has been possible with previous generations of experiments at CERN and other international laboratories.

Any sign of the phase being different from zero would be a very intriguing hint of something that is not included in the SM.

A related, but rarer, decay mode of the B_s^0 meson is the decay $B_s^0 \to \phi\phi$. The CP-violating phase in this channel is expected to be very close to zero, so any deviation from that would be of great interest to the physics community.

The Edinburgh group has recently published its measurement in this mode and find it to be consistent with the SM prediction. However, due to the lower rate of occurrence of these decays, the sensitivity is not as great as the golden $B_s^0 \to J/\psi\,\phi$ channel.

Therefore, this decay mode is one to watch closely in the future, particularly after the upgraded LHCb detector comes online later this decade (see next article).

Images above show decay-time and helicity-angle distributions for $B_s^0 \to J/\psi\,\phi$ decays (data points) with the one-dimensional projections of the fit function. The solid blue line shows the total signal contribution, which is composed of CP-even (long-dashed red), CP-odd (short-dashed green), and S-wave (dotted-dashed purple) contributions.

Two papers explore this further:

"Measurement of CP violation and the B_s^0 meson decay width difference with $B_s^0 \to J/\psi K^+K^-$ and $B_s^0 \to J/\psi \pi^+\pi^-$ decays", Phys. Rev. D 87 (2013)

"Measurement of CP violation in $B_s^0 \to \phi\phi$ decays", arXiv:1407.2222, Submitted to Phys. Rev. D

Find out more

LHCb experiment at CERN

LHCb at Edinburgh

Developing the next generation of particle detectors

The experimental particle physics group (PPE) at the University of Edinburgh is currently developing the next generation of particle detectors, which will be able to meet the increased challenges that the High Luminosity upgrade of the Large Hadron Collider (HL-LHC) will impose on the detectors of the LHCb and ATLAS experiments.

DR GREIG COWAN
DR STEPHAN EISENHARDT

PARTICLE PHYSICS EXPERIMENT GROUP

The aim of the HL-LHC is to extend the reach of the CERN physics programme by increasing the rate of proton-proton collisions by an order of magnitude beyond the LHC design value. This increase will result in a significant growth in the amount of data that the LHC experimental collaborations can collect, hopefully lighting the path towards the next set of discoveries. However, to make best use of this increase in collision rate, the current detector technologies need to be upgraded or replaced before the HL-LHC comes online in 2020.

LHCb upgrade

For the LHCb upgrade, the Edinburgh group is designing and building the front-end of the photon sensors that form the Ring Imaging Cherenkov (RICH) detectors. These sensors are used by LHCb to detect the rings of Cherenkov photons emitted by charged particles (pions, kaons etc) traversing a gaseous detector medium. The size of the ring can be used to the identify the type of emitting particle, critical information for LHCb physicists as they try to reconstruct what happened during each LHC proton-proton collision. The main challenges that need to be addressed for the upgrade are the increased rate of photons produced by the increased number of particles traversing the gaseous detector and the increased readout speed that will be needed to get all of the data off of the detector, processed by a CPU farm and securely stored offline for later analysis.

The group is currently finishing the characterisation of two novel vacuum photon detectors. Both technologies are qualified for use in the LHCb RICH system as they are sensitive to single photons, have good spatial resolution and a fast readout (40MHz). They utilise multi-anode photomultiplier tube (MaPMT) technology and a very high active area but differ in spatial resolution (~3mm vs ~6mm) to better match the occupancy profile across the RICH detector area of approximately 3m^2 (effecting to ~230,000 optical channels). Effectively this is a 0.2M pixel camera, which is sensitive to single photons and can sustain a continuous frame rate of 40M images per second.

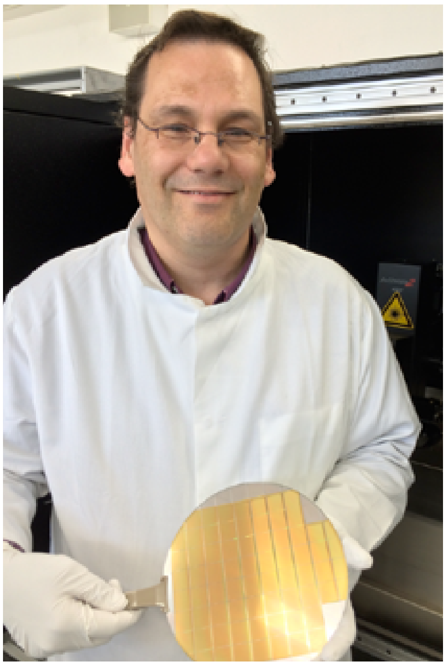
Following initial tests, Edinburgh is now leading the development of the quality assurance programme that will process all detectors that will go into the upgraded RICH. This will ensure that the new RICH detector

Advanced Detector Development Centre (ADDC)

ADDC is a set of newly refurbished laboratories of the Edinburgh PPE group equipped to work with photon and silicon pixel detectors.

Continous investment in state-of-the-art facilities enables the development and small-scale production of leading-edge single particle detection technologies.

Matthew Needham (Chancellors Fellow) and Viktoria Hinger (IAESTE summer student) inspect a "flatpanel" PMT prior to testing at the Edinburgh ADDC facilities.



Far left: The first prototype of a flexible tape to operate and read out more than half a million silicon pixels (5 modules of 4 sensors at 26880 pixels each): the tape integrates low voltage power (up to 4A), high voltage bias (up to 1100V), fast control and data readout (160Mbit/s).

Near left: Stephan Eisenhardt (RA & PPE lab coordinator) holding a wafer with 60 FE-I4 readout chips, ready to be tested on the wafer prober in the background.

will retain its excellent performance in the identification of hadrons in the final states of the particle collisions, despite handling 10x the instantaneous data rate compared to the current system.

ATLAS upgrade

For the ATLAS upgrade, the Edinburgh group is researching and developing a completely new Inner Tracking (ITk) detector that will be installed in 2023. Such tracking sensors are essential to detect the path of charged particles as they traverse the detector. The ITk will be placed in the innermost volume of ATLAS, closest to the proton-proton collision region, with the aim of greatly improving the resolution for reconstructing the 100s of proton-proton interactions that occur at each LHC bunch crossing.

The inner layers of this detector are being designed to use novel silicon pixel sensors that will help it withstand the unprecedented rates of particles per unit area that will be experienced so close to the interaction region. This detector is in the form of a barrel, ~70cm in diameter and covering the region ±70cm of the proton-proton interaction point.Edinburgh's development of the Forward Pixel Detectors for the ITk will extend the barrel section to at least ±2m, providing sensitivity to tracks with angles down to 10° from the beam-line. As individual pixels have the size of only 50x250μm (50μm is the thickness of a thin human hair) this system will have between 100-200 million readout cells, depending on the final choice of the layout.

Forward Pixel Detectors

The Edinburgh group has led the design and integration of the services for the Forward Pixel Detectors, building the first prototypes for the integrated on-module bus-tapes that distribute power to the sensors, control their operation and read the collected data.

Similarly to the quality assurance of the LHCb RICH, the Edinburgh group has performed the wafer-level probing of the current generation of FE-I4 readout chips to assess their quality before the wafers are diced up and the good chips are used to build prototype readout modules.

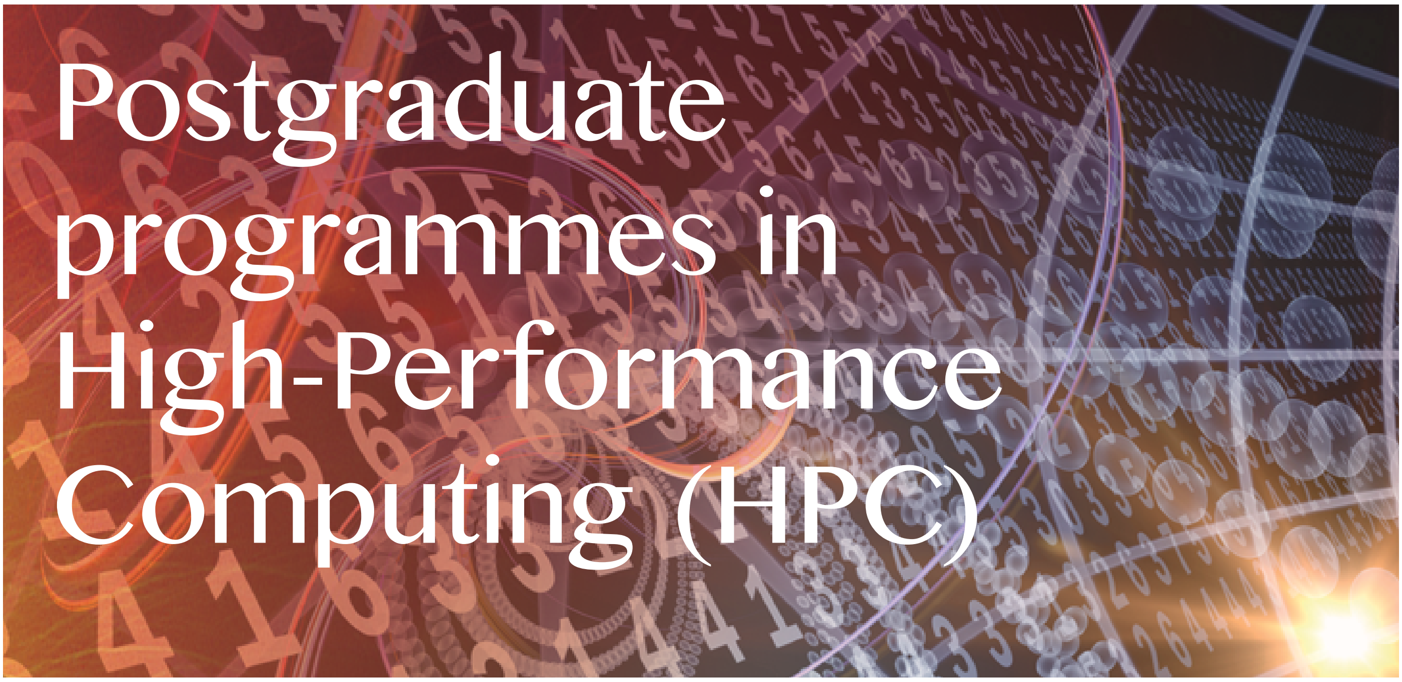
Using this expertise Edinburgh will become one of the sites where significant parts of the Forward Pixel Detectors will be built and tested prior to installation in the ATLAS ITk upgrade.

ATLAS detector: additional challenges

Next to the prime challenges of coping with particle rates and radiation damage, the ATLAS system development faces several other, partially conflicting, requirements and constraints.

For example, the detector should be made of as little material as possible to limit its degrading influence on measurements taken at larger distances. At the same time the support structure has to be self-supporting, rigid and safe against fatigue and vibrations.

In addition, the first stage of readout electronics requires significant processing power, but may only use low electrical power, to enable the operation of the system at a maximum temperature of -20C°. The data links have to be high speed (10Gb/s) over ~3-4m length, which is very challenging to achieve with metal-based links (optical drivers do not survive the radiation levels).



Postgraduate programmes in High-Performance Computing (HPC)

MSc in HPC
MSc in HPC with Data Science

These MSc programmes equip participants with the multidisciplinary skills and knowledge required to lead the way in HPC, parallel programming and data science. Both programmes are based at EPCC, one of the leading centres of supercomputing expertise in Europe, and offer access to ARCHER, the UK's national supercomputer service.

MSc in HPC

High Performance Computing (HPC) is the use of powerful processors, networks and parallel supercomputers to tackle problems that are very computationally- or data-intensive. The same HPC techniques can be used to program the world's largest supercomputers containing hundreds of thousands of processors or to exploit the full potential of a multi-core laptop.

The MSc in High Performance Computing will provide you with a thorough grounding in HPC technologies and their practical application. It will appeal if you have a keen interest in programming and would like to learn about HPC and parallel programming.

MSc in HPC with Data Science

Data science is concerned with the manipulation, processing and analysis of data to extract knowledge. This area is undergoing a revolution in which HPC is a key driver. HPC provides the power underpinning the management and analysis of big data; the increasingly large, complex and challenging data sets that are now generated across many areas of science and business.

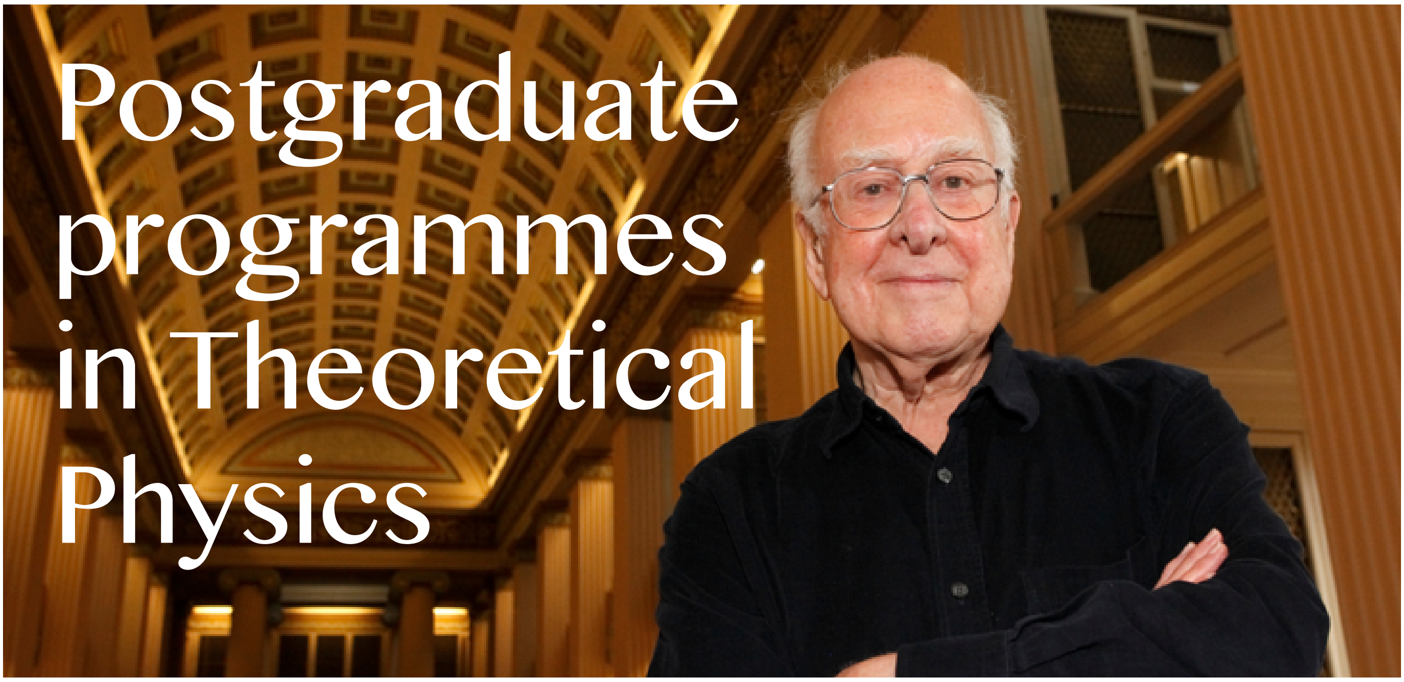
The MSc in High Performance Computing with Data Science will provide you with a thorough grounding in HPC technologies together with a practical understanding of the key ideas and techniques of data science and the HPC tools that underpin them.

> "EPCC's MSc in High Performance Computing has always been a leader in its field. Coupling it to Data Science responds to the huge increase in demand for graduates with both HPC and Data skills from both science and business."
>
> Prof. Mark Parsons
> Executive Director, EPCC

Scholarships

Scholarships are available each year. Find out more on the website:

MSc programmes in HPC



Postgraduate programmes in Theoretical Physics

MSc in Theoretical Physics
MSc in Mathematical Physics

These two programmes mark a new era in theoretical physics, with the discovery of a Higgs boson at CERN. The MSc programmes in Theoretical Physics and Mathematical Physics introduce advanced ideas in theoretical physics and apply them to solving real-world problems.

The MSc programmes in Theoretical Physics and in Mathematical Physics are designed to prepare students for a research career in academia or industry by introducing advanced ideas and techniques that are applicable in a wide range of research areas, while emphasising the underlying physics concepts.

Both MScs build upon our integrated Masters (MPhys) programmes and our graduate-level courses.

The MSc programmes are a core part of the Higgs Centre for Theoretical Physics, which was established to create opportunities for physicists and students from around the world to come together to formulate new theoretical concepts to take us beyond the limitations of current paradigms. MSc students are taught by members of the Higgs Centre, and may choose to join research projects as part of their dissertation, or undertake research in a company affiliated to the Centre. Students will take part in the Centre's activities, including bi-weekly colloquia and workshops involving physicists from around the world.

Which degree is for you?

The two degrees have a similar structure. The MP degree requires students to take a number of Mathematics courses, which can be up to 50% of the taught course element. Contrastingly, TP students have more freedom to take a wider range of optional courses.

> "I'm very pleased to support the two new MSc programmes in theoretical and mathematical physics. This initiative will greatly help the University of Edinburgh to play a major role in training the next generation of theoretical physicists."
>
> Prof. Peter Higgs
> Emeritus Professor
> University of Edinburgh

Further information

Find out more on the website:

MSc programmes at the Higgs Centre

University alumni: a lifelong community

Graduates of the School of Physics & Astronomy are part of a vibrant worldwide community of over 220,000 University of Edinburgh alumni.

The Alumni Team is responsible for sustaining a lifelong relationship with this global community.

We provide opportunities for alumni to stay connected with the University and each other through events, reunions, clubs, networks and volunteering. We support alumni by facilitating networking and professional development opportunities, and by providing a programme of benefits and services, including a range of publications.

By highlighting and celebrating the achievements of our alumni, we aim to inspire the next generation of Edinburgh graduates.

Contact the Alumni Team

To find out more about how you can keep in touch or get involved, see the Alumni Services website or email us.

You can also find us on:

- Facebook
- Twitter
- Linkedin
- Pinterest
- YouTube.

CJ COCHRAN

ALUMNI MANAGER,
SCHOOLS AND COLLEGES

Alumni mentoring: supporting our current students

One of the best ways for students to gain an insight into what a particular job is really like is to talk to someone who is doing it.

PROF. JUDY HARDY
E-LEARNING GROUP
EPCC
PHYSICS EDUCATION RESEARCH

The choice of careers open to physics and astronomy graduates is vast. Career destinations reported by our recent alumni range from the scientific, technical, IT and financial sectors to the environmental industry, healthcare, teaching, retail, publishing and NGOs amongst others.

While some students have very clear career aims, others can be bewildered by the wide choice and find it difficult to know where to start, or may not even be aware of the full range of options open to them.

Mentoring is an excellent way to help students explore and choose their career goals by talking to someone who is already doing a particular job.

The Careers Service has recently launched an alumni e-mentoring scheme, Connect.ed, which links our alumni with current students or fellow alumni who are interested in a career in a similar area. By sharing experiences, offering suggestions or simply passing on information about their chosen field, e-mentors can help students to make informed career choices and to take their first steps towards achieving their aspirations.

There are also benefits for the e-mentor, with opportunities to consider and reflect on working practices, develop communication skills in a wider setting and build professional networks, as well as the personal satisfaction that comes from supporting others.

In outline, the scheme works as follows: e-mentors register their details, including a short career profile, via the secure MyEd Alumni Portal. Students can then browse the alumni profiles, again via MyEd, to identify and contact potential e-mentors.

The e-mentor can then accept the relationship, which is conducted by email. The length of the relationship is flexible and can range from a simple one-off exchange of emails to a longer-term connection.
The duration of the mentoring relationship, its scope and subject matter are agreed by e-mentor and e-mentee at the outset.

All University alumni are invited to become e-mentors. For e-mentees, the scheme is currently open to 3rd, 4th and 5th year undergraduates and all postgraduate students.

Why be an e-mentor?

- Share your experiences and insights into the realities of your job or career sector
- Help current students explore and decide on their career goals
- Reflect on your current role and working practice
- Enhance your interpersonal and communication skills
- Build links with other alumni, the School and the University.

Contact

To sign up as an e-mentor, or to find out more about the scheme, see the Connect.Ed website or email the team.

We are also happy to offer guidance and support for e-mentors.

Staff profile: Victoria Martin

Victoria Martin graduated from Edinburgh with a BSc in Mathematical Physics in 1996 and stayed on to do a PhD, graduating in 2000.

She is now a Reader in the Institute for Particle & Nuclear Physics and a member of the Atlas experiment at CERN, which discovered the Higgs boson in 2012.

At school, I thought I wanted to study chemistry as I was fascinated about molecules and atoms. But in my penultimate year at school, I realised that structure of atoms and molecules is described by physics. And when I got to university I realised the protons and neutrons inside the atom have even smaller components, quarks, and I knew I'd made the right choice.

Early influences

My favourite lecturer was Ken Bowler. His lectures were always very clear. The most inspirational lectures, and also the most disorganised course I took, were from Ken Peach who taught particle physics. There were only three students in the class after the first few weeks. I guess the others couldn't cope with the random delivery and the 9am start. But for me these were the more fascinating and they turned out to be the most influential, as my career since then as been researching particle physics. One of the other two students in the class was Phil Clark, who is, like me, now an academic back in Edinburgh!

I also took two lecture courses from Peter Higgs, and I'm sure that had some influence on my later research!

First career steps

I sheepishly asked Ken Peach if there was a possibility of staying on in Edinburgh to do a PhD in particle physics. My degree was Mathematical Physics, so I had hardly any experience in the lab, or with data analysis, but Ken managed to find funding for me, and I started my PhD in 1996, just a few months after graduating with my BSc.

Current research

I work as a member of the Atlas experimental collaborations at the Large Hadron Collider (LHC) at CERN, near Geneva. It's great for me as the LHC and Atlas is where all the action is!

By it's very nature it's very collaborative research. Within Atlas I have two main research interests: analysing the data to look for Higgs bosons and working with the Atlas trigger system.

The trigger system is the online

DR VICTORIA MARTIN

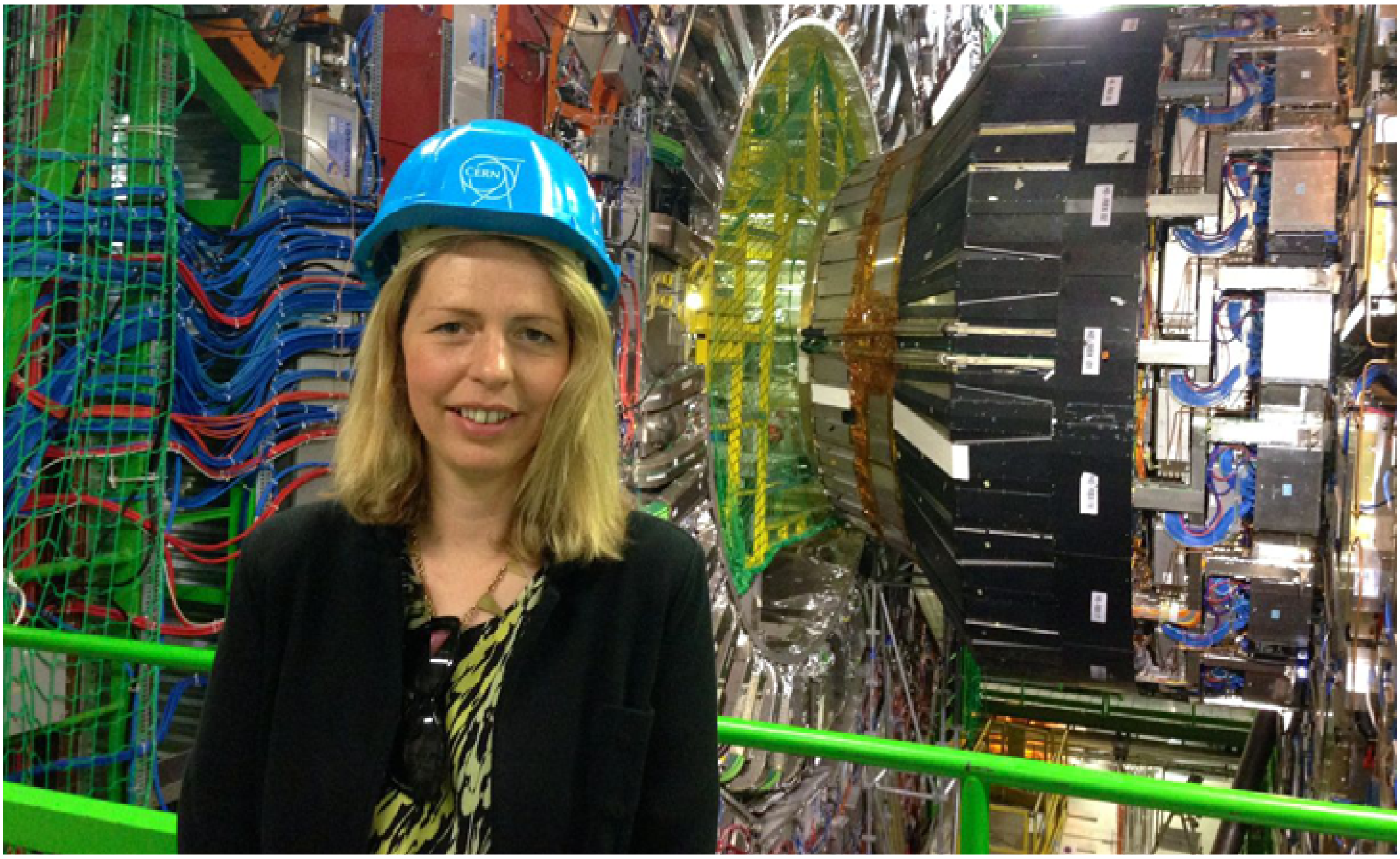
PARTICLE PHYSICS
EXPERIMENT GROUP

Working and living in Edinburgh

The advantage of working in Edinburgh is the supportive environment. But the true advantage to working in Edinburgh is the city itself! It's beautiful, well connected, close to the sea and the hills, and it really doesn't rain that much.

We have a bumper crop of undergraduates this year, and more and more PhD students. In our particle physics group we have students from Scotland, England, Germany, Italy, Chile, China and South Africa!

Many students want to continue into research, but many others want to use their skills outside of physics.



Victoria at CERN.

data selection system. Every time the protons collide inside the Atlas detector, the trigger system decides if the collision looks interesting or not. The information from non-interesting collisions is thrown away. Only information from about 1 in 100,000 collision is actually kept for further analysis.

Highlights so far

I have been involved in two big discoveries.

In 2012, the Higgs boson was discovered by the ATLAS and CMS collaborations at CERN. What was exciting for me as a collaborator was to watch the evidence build up over a number of months. The evidence relies on the fact that Higgs boson is not a stable particle: it decays almost instantly into other subatomic particles. My research is actually looking for the Higgs boson when it decays into quarks.

However, we haven't seen any evidence for quarks being produced from Higgs boson decays. What we've seen is the Higgs boson decaying into photons and W and Z bosons (somewhat analogous to heavy photons). So maybe my big Higgs moment is still to come, if we finally see some evidence for the Higgs boson decaying into quarks!

The second highlight was during my PhD, when I worked with the NA48 collaboration at CERN. We were measuring the properties of subatomic particles called neutral kaons, which are composed of a strange quark and a down quark. By measuring the properties of the decay of these neutral kaons we proved the existence of "direct charge-parity violation", which is a particular difference between matter and anti-matter.

It was very exciting at the time as many people were convinced it didn't exist. The results formed the basis of my PhD thesis.

Another highlight is working with great physicists from all over the world, and seeing the impact that Edinburgh physicists are making at the LHC. It's great to see so many people interested in our work.

Future directions

Next year, the LHC will start a new phase, colliding protons at almost double the energy of the first run. This will give us opportunities to study the Higgs boson in more detail.

But the big mystery is dark matter. Astrophysical observations suggest around 25% of the universe is composed of dark matter, but we have no idea what it is. With higher collision energy, there's a chance that the LHC will be able to produce dark matter in the lab for the first time. That would be a real breakthrough!

Get in touch

I'd love to hear from other alumni about what they are doing now, and if their physics degree has been useful!

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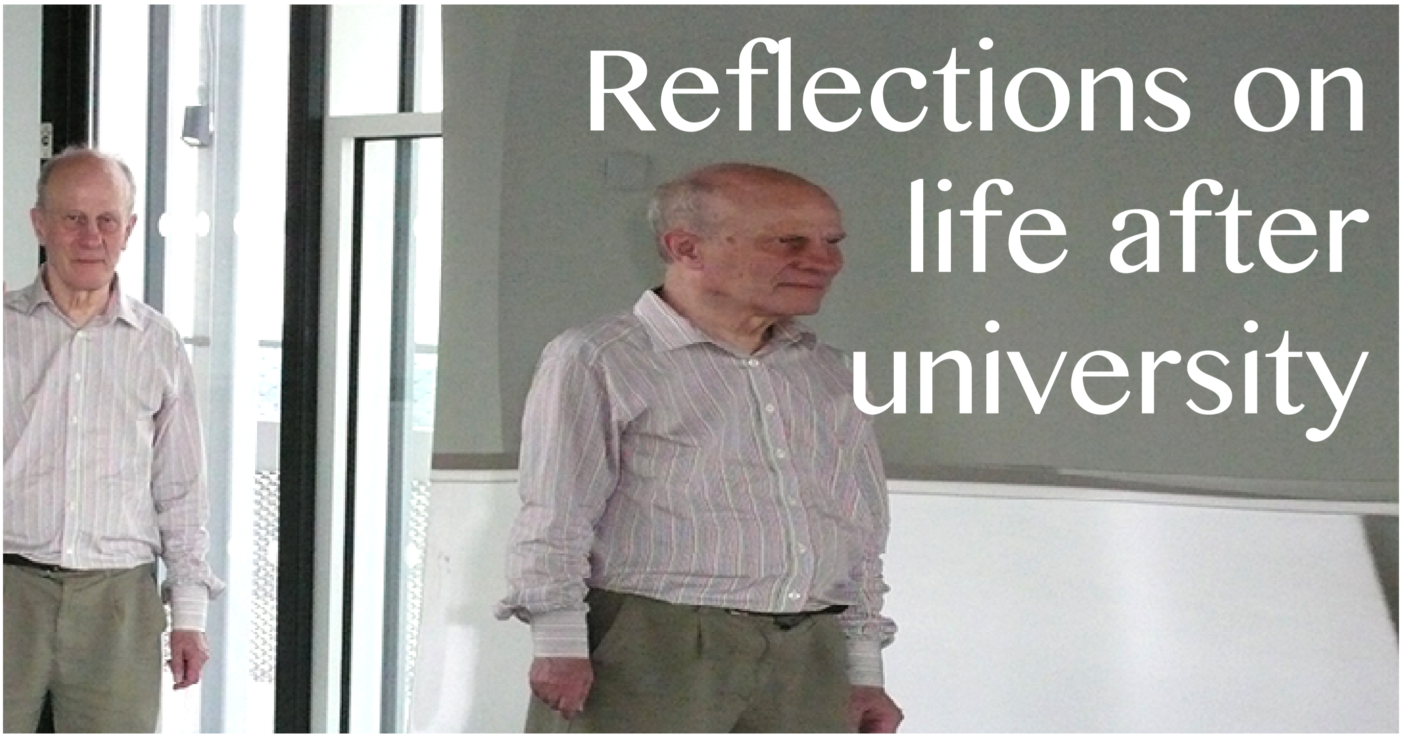
Reflections on life after university



Brian with the concave mirror designed by Anish Kapoor and located inside the Arcelormittal Orbit, Stratford, London. Image: Daphne L Richardson.

Edinburgh Physics graduate **Brian Blandford** talks about his career as an optics specialist.

Brian Blandford graduated from the School of Physics & Astronomy at the University of Edinburgh in 1967.

He then, under the supervision of the late Professor H. H. Hopkins FRS, obtained a PhD from Reading University, in the field of optical design for coherent optical processing.

His experience includes optical designs for microfilm readers, photographic printers, head up displays, night vision goggles, laser scanners, submarine periscopes and infrared scanners and objectives.

“The main career-making event in my four years studying at Edinburgh was hearing an invited speaker from the National Physical Laboratory addressing the Physical Society. As a comment at the end of his talk, he invited applications for a studentship during our final summer vacation. My six weeks in the Optical Metrology Department led on to a PhD in optics.

“After that, I worked in the optical industry, with companies such as Rank, Dallmeyer, Marconi, British Aerospace and Thales, designing optics for infra-red, night vision and photographic applications.”

Optical design

“One of the greatest pleasures of optical design work is hearing about a new idea, and taking it through to prototypes and – hopefully – production. The work is interesting and varied. You get to work with entrepreneurs, mechanical designers, electronic engineers and production engineers, in companies big and small.

Brian’s advice for new graduates

“Unless you have a job already lined up, think of a business name, register with HMRC as a self-employed consultant, and design your own spreadsheets to keep track of the finances (thereby saving the need for an accountant).

“For anyone with an Edinburgh Physics degree, there are projects out there which need what you have to offer.”

Anish Kapoor's Sky Mirror and the protective pool designed by Brian in Arlington, Texas. Image: Vincent Huang, Flickr

For example, Aircraft Medical in Edinburgh make the McGrath laryngoscope with a tiny objective lens I designed. Zumbach, a Swiss firm, are still making the ODAC310 for non-contact measurement of the diameter of plastic gas pipes during extrusion. The National Physics Laboratory Differential Absorption LIDAR vehicle, launched recently, has my design for the UV and IR detector lenses.

"And a sapphire prism I helped to test made it all the way to Titan, Saturn's moon, with the Cassini mission, in an attempt to measure the refractive index of the oceans there (it failed because it landed on a dry rock!)."

Safety analysis

"More recently I have been self-employed. My main work has been safety analysis for sculptures by Ryan Gander and Anish Kapoor. These dramatic reflective sculptures are potentially dangerous in sunlight. Recently a vast Anish Kapoor Ten Metre Sky Mirror was installed in front of the Dallas Cowboys Stadium in Texas. I designed the water feature, whose sole purpose is to stop members of the public from getting cooked!"

Current interests

"One of my main current interests is to develop an energy-saving window, comprising brise-soleils (external shades) tuned to maximise the obstruction of sunlight in the summer, and minimise it in the winter. The materials and the technology for this are currently being fitted on the concave south face of a building in the City of London, not to my design, but again to protect the public from concentrated reflected sunlight.

"There is always work to be found in this field. Last year, I was an expert witness in the High Court over the patent for the optical design of a zoom rifle telescope. I have travelled all over the world lecturing on optical design, and am now developing some web-based tutorials on this subject."