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Didier Queloz comes to Cambridge



Main image: An artist's impression of the Kepler-11 system in which six exoplanets orbit the parent star. The system was discovered by the occultation method by the NASA Kepler satellite (Courtesy of NASA/Ames/JPL-Caltech/T. Pyle).

Exoplanet research is a relatively new discipline. It started in 1995 with the first definitive detection of a planet orbiting a normal star beyond the Solar System by Michel Mayor and Didier Queloz. Since then the field has expanded exponentially into a major world-wide activity - it is one of the areas of modern astrophysics that has particularly captured the public imagination.

We have been very fortunate to attract Didier Queloz to Cambridge. He takes up his position as Professor of Physics in the Cavendish in May 2013. As the founder of the discipline and among the leaders of this burgeoning area of astrophysics,

his appointment is of great significance for future astronomical research in Cambridge. As he writes:

'The search for planetary systems orbiting other stars and particularly the quest to find planets similar to the Earth is one of the great scientific, technological and philosophical undertakings of our time.

Considered yesterday by most as a wild dream, the search for and the study of Earth-like planets outside the solar system are becoming a reality. At a time when the required knowledge and technology are being defined worldwide, Cambridge and the UK can place

themselves at the forefront of this remarkable quest by capitalising on synergies and potentials present at Cambridge and in the country.

For the next decade, my main research objective is to conduct a coherent effort towards the detection and characterisation of planets with the goal of advancing our understanding of their formation, their structure, and eventually their habitability. ... The core of my research activity will be deployed to maximise the benefits of the UK's membership of ESA and ESO and existing access to world-class ground- and space-based astronomical facilities - HST, JWST, GAIA, VLT(I), ALMA ...'

Continued overleaf...

More than 800 exoplanets have been discovered and the new science and its challenges are spectacular. For some of the exoplanets, it has already been possible to study their atmospheres and compare these with those of the planets in our own Solar System. The ultimate goal is the study of large numbers of Earth-like planets orbiting nearby stars. This research is of considerable societal importance since it will enable the evolution and fate of our own planet and its atmosphere to be studied comparatively. It is a field of research that encompasses, or has the potential to encompass, physics, chemistry, astronomy, biology, molecular biology, ecology, engineering, geography and earth sciences. Cambridge has exceptional strength in all these areas.

But the challenges are very great. Although large numbers of exoplanets are known, most of these are quite unlike the Earth. The easiest to detect are the most massive 'Jupiter-like' planets which have orbits very close to the parent star, often closer than Mercury is to the Sun. Many have been detected by the technique used by Mayor and Queloz, the precise measurement of the radial velocity of the parent star with time (Fig. 1). These detections have resulted in a large number of surprises, among them the facts that the orbital periods of numerous exoplanets are very short, and the discovery of the existence of planetary systems made of 'Super-Earths' in compact orbital configurations. The structure and configuration of our Solar System have to be considered exceptional in the light of these discoveries.

A most promising route to discovering Earth-like planets is through transiting systems in which the planet occults the star, resulting in a tiny decrease in the observed luminosity of the star (Fig. 2). About one-fifth of the known exoplanets have been discovered by this means. These transiting exoplanets are of the greatest interest because their atmospheres can be studied as the light of the primary star passes through them, imprinting the signatures of the planetary atmospheric molecules. A number of the best candidates for potential habitable exoplanets have been found in this way (Fig. 3).

There are great technological challenges associated with all aspects of Didier's programme, and it is fortunate that these can be accommodated in the new Battcock Centre for Experimental Astrophysics. The Centre will bring all astronomers, astrophysicists and cosmologists from the Cavendish Laboratory, Institute of Astronomy and the Department of Applied Mathematics and Theoretical Physics together on a single site for the first time. There could be no more opportune time for Didier to bring his formidable skills and experience to this new phase in the evolution of Cambridge astronomy.

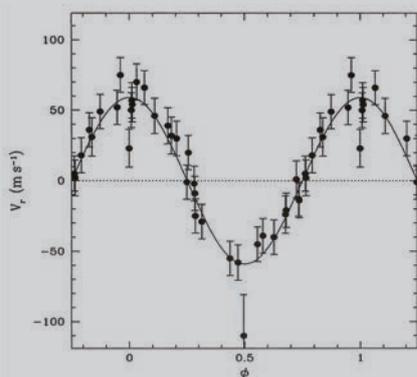


Fig. 1. The variation of the radial velocity of the star 51 Peg as a function of orbital phase. This is the signature of the first exoplanet discovered by Mayor and Queloz in 1995. Its period is 4.231 days.

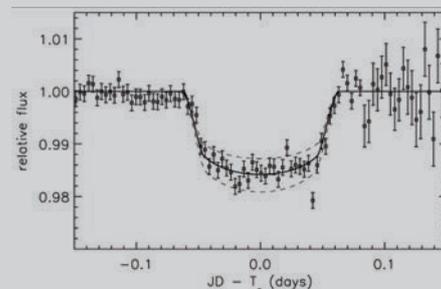


Fig. 2. The discovery record of the photometric time series for the star HD 209458 in 1999 by Charbonneau and his colleagues. The passage of the planet in front of the star results in a 1% decrease in the luminosity of the star.

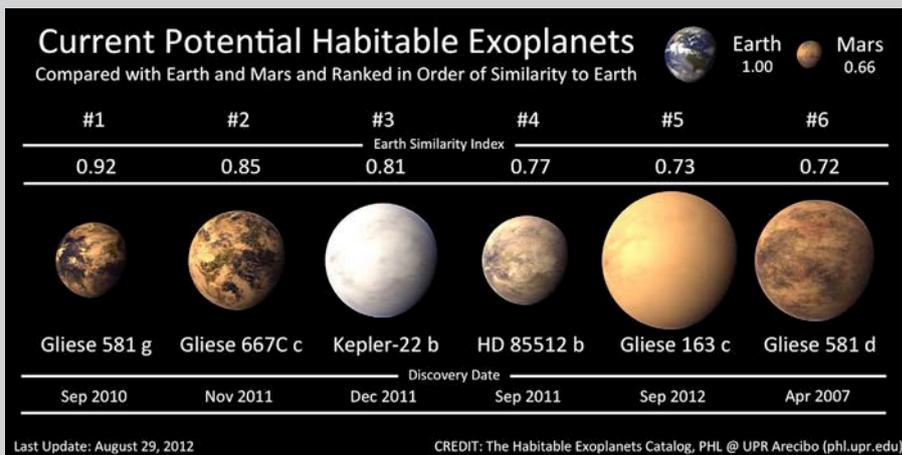


Fig. 3. Examples of current potential habitable exoplanets compared with the properties of the Earth and Mars.

Editorial Malcolm Longair

Another bumper edition of CavMag with many wonderful developments and terrific pieces of science. Physics is all about people and we are delighted to welcome three new staff members who will bring new dimensions, science and personality to the work of the Cavendish. In **Didier Queloz**, we have a world-ranking astronomer who is the doyen of extrasolar planet research and who will take up his post as Professor of Physics in May, and in **Claudio Castelnuovo** and **Austen Lamacraft**, we have two of the very best of the new generation of condensed matter theorists. While your editor can cope with extrasolar planets, he is relieved that Claudio and Austen have described some of what they do in their own words.

We also celebrate the ground-breaking of the Battcock Centre for Experimental Astrophysics – we are looking forward to occupancy next summer. Also, the first Winton Symposium has been held with great success, as described by **Richard Friend** and **Nalin Patel**. **James Stirling** describes the discovery of the Higgs boson and the apparent absence of a signature of supersymmetry at the LHC at CERN from the point of view of the professional. And we get an impression from **Ulrich Keyser** of the remarkable possibilities for molecular self-assembly of DNA origami nanopores.

Besides the lovely articles by **John Waldram** about Brian Josephson's discovery of the quantum tunnelling which bears his name and **Gareth Wynn-Williams'** piece about his father's invention of the Scale-of-Two Counter, there is an emphasis in this edition on many aspects of outreach, particularly the efforts of **Julia Riley**, **Dave Green** and **Lisa Jardine-Wright** in so many excellent programmes. But as **Athene Donald** emphasises in her blog, there is a long way to go - we are doing everything we can to encourage the next generation of the Didiers, Claudios and Austens who are already out there in the schools – and they are just as likely to be female as male.



Ground-breaking for the Battcock Centre for Experimental Astrophysics

Another significant step forward in the development of the Laboratory took place on 18th October 2012 with the official ground-breaking ceremony for the Battcock Centre for Experimental Astrophysics.

We were delighted that Humphrey Battcock was able to be present to mark this very positive outcome of his wonderful gift to the Laboratory. As described in the previous article, the timing of this development could not be better, with the arrivals of Roberto Maiolino earlier this year (see CavMag8) and Didier Queloz in May 2013. The associated gift from the Wolfson Foundation will be used to furnish the experimental astrophysics design suite which will be used extensively by Roberto and Didier, as well as the already existing Astrophysics Group members who specialise in astronomical technology. The plans for the new technologies to be developed include those in which the Group already has an international reputation, for example, in the design of aperture synthesis systems for radio, infrared and optical wavebands, as well as the new activities in high resolution optical and infrared spectroscopy which will be fostered by Roberto and Didier.



Main image: James Stirling, Malcolm Longair, Michael Bienias, Humphrey Battcock and Francis Shiner, Director of SDC, the main contractor, digging the 'first sod' at the ground-breaking of the Battcock Centre for Experimental Astrophysics. Your editor is employing his Hawaiian digging-stick, used on an earlier occasion at the ground-breaking ceremony of the Gemini North telescope in Hawaii.

Above. The diggers and support team who have been involved in bringing about the successful initiation of the project.

DNA Origami Nanopores



When James Watson and Francis Crick published their paper on the double-helical structure of DNA 60 years ago, their main focus lay on detailing the mechanism of information storage in any living organism (Fig. 1). Their discovery of the pairing between the bases, Adenine (A) with Thymine (T) and Guanine (G) with Cytosine (C) using hydrogen bonding, allowed for a straightforward

explanation of heredity in biology. However, DNA is not only found in the form of the canonical double-helix but also forms more complex structures like Holliday junctions involving four DNA strands (Fig. 2). These rigid structures are the basis for using DNA as a building material for complex three-dimensional shapes harnessing base-pairing to guide self-assembly.

With recent advances in biochemistry, it is now possible to order hundreds of different DNA strands with well-defined sequences and thus design almost any shape using simple computer programs like CaDNAno. The assembly process resembles molecular cooking: all DNA strands are mixed in a small amount of liquid, heated up to 80°C and slowly cooled down in a well-defined sequence. After a few hours one finds billions of structures exactly resembling the designed shape. This process of design and synthesis is known as DNA origami. Fig. 2 shows a funnel shaped DNA origami nanopore that we designed to use as a molecular sensor for single molecules (adapted from Bell *et al.* Nano Letters **12**, 512 (2012)). Each of the red bars is a DNA double helix. The three-dimensional shape is stabilised by choosing sequences for the short strands that allow cross-overs between neighbouring helices every 8 base pairs. Because of the rigidity of the double-stranded DNA with its persistence length of 50 nm, this leads to an extremely stable molecular assembly as shown by the atomic-force microscopy and transmission electron microscopy images shown in the lower panels in Fig. 3 (from left to right).

These funnel-shaped DNA origami nanopores can be integrated into a molecular sensing platform for the detection of DNA molecules or proteins in aqueous solution. We use electric fields to incorporate the DNA origami nanopores into apertures of similar diameter made in silicon nitride membranes. Applying a voltage drives an ionic current through the DNA origami nanopore that changes when other small molecules pass the constriction and thus allows us to build an elegant, label-free molecular sensing system. We aim to develop these systems into practical biosensors incorporated into lab-on-a-chip technology. The advantage of using DNA origami nanopores is the possibility of building three-dimensional assemblies with atomic precision that can be tailor-

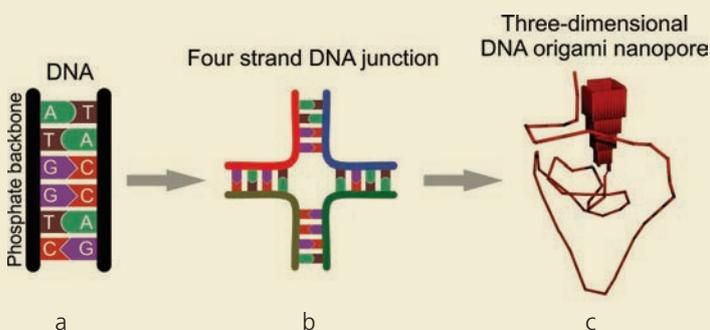


Fig. 2: (a) DNA is found as a double-stranded structure, where the two phosphate backbones (black) are connected by the base pairings of Adenine (A) - Thymine (T) and Guanine (G) - Cytosine (C). (b) Four DNA strands can also be assembled into a Holliday junction. (c) More complex structures like DNA origami nanopores can be created by DNA self-assembly.

made to fit the specific sensing purpose.

Beyond the great possibilities for the creation of improved molecular sensors, DNA origami might be of interest for building model systems which mimic proteins. Feynman famously stated, "What I cannot create, I do not understand." The rational design of proteins, and especially membrane proteins, is still elusive since proteins are the most complex structures found on the planet. Understanding the functionality of membrane proteins is especially challenging as often their three-dimensional structure is not known. We are at the moment exploring whether or not DNA origami self-assembly will allow the design of molecular structures that mimic membrane proteins. Each of the strands in the DNA origami nanopore could be modified into carrying a specific chemical characteristic that makes it responsive to voltage, salt concentration or specific pathogens. Incorporation into lipid membranes should be straightforward by making the outside of the DNA origami nanopores partly hydrophobic. These structures should be biocompatible and able to perform as novel drug delivery systems anchored in cell membranes.

Of course, the goal of creating artificial enzymatic structures is a great challenge, especially since evolution is cleverer than we are, according to Orgel's second rule. However, with the unique capabilities of DNA-based self-assembly we should be within reach of creating artificial membrane proteins and understanding better the functionality of their natural counterparts.

Ulrich Keyser

Ulrich Keyser is a member of the Biological and Soft Systems group, Cavendish Laboratory. In 2010, he received an ERC starting grant to investigate passive transport through membranes and leads an Emmy Noether research group investigating molecular transport through nanopores. email: ufk20@cam.ac.uk

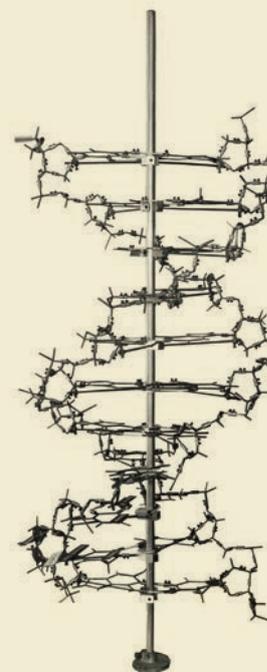


Fig. 1. The half-size model of the double helix structure of the DNA molecule constructed by Francis Crick and James Watson following their discovery of its structure in 1953. The model is in the Cavendish museum.

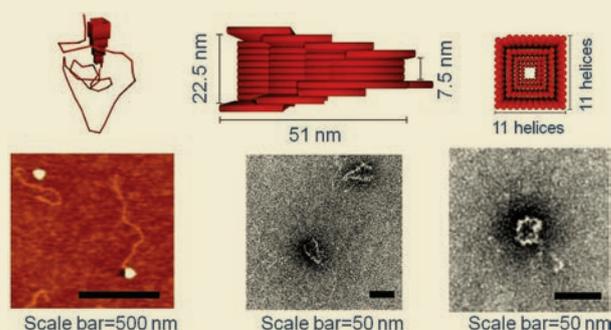


Fig. 3: Top-panels: a DNA origami nanopore with corresponding dimensions, each red cylinder representing a double-stranded DNA molecule. Lower panels: images of the folded DNA origami nanopore by atomic force microscopy (left) and transmission electron microscopy (centre and right). The funnel shape and rigidity can be clearly observed (Adapted from Bell *et al.* (2012)).

The Higgs Boson and a Challenge for Supersymmetry



In July 2012, scientists working at the Large Hadron Collider (LHC) at CERN announced the discovery of a new particle that had all the features of the famous and long-awaited Higgs boson, the missing piece of the Standard Model theory of fundamental particles and forces. It was a momentous event, beamed live across the internet to millions of people around the world and the culmination of decades of experimental searches at increasingly large and energetic particle colliders.

The Higgs boson is a natural consequence of a theory invented in the early 1960s by three teams of theoretical physicists, including Peter Higgs after whom the particle is named, working independently. It explains how fundamental particles are able to have non-zero mass without spoiling the mathematical consistency of the model.

Cavendish Laboratory experimental high energy physicists have been heavily involved in the LHC right from the start. They made major contributions to the design and construction of two of the detectors, ATLAS and LHCb. ATLAS is the largest particle detector ever constructed, roughly the size of Westminster Abbey, but packed with sensors and electronics to record and measure the particles produced when the LHC proton beams collide. Among the debris, scientists look for traces of new particles, including the Higgs boson. In contrast, LHCb is an experiment designed to uncover the mystery of the matter-antimatter asymmetry in the Universe and to look for phenomena in quantum processes involving heavy quarks, particularly 'bottom' quarks. LHCb is complementary to ATLAS and together they are capable of discovering new physics over a large energy regime and determining its origin.

In late 2011, signs began to emerge from the accumulated LHC data that a new particle was being created. Events observed in the detectors containing particular combinations of electrons, muons and photons seemed to point to a short-lived object that had production and decay properties characteristic of the Standard Model Higgs boson (Fig. 1). Data continued to be collected throughout the first half of 2012, and by early summer scientists working on the ATLAS and CMS experiments were confident enough in the strength of the signal to announce the discovery of a 'particle consistent with the Higgs boson'. The mass of the new particle was measured to be around 125 GeV (Giga electron volts), or about 133 times the mass of a proton.

Now that a Higgs-like particle has been found, the next challenge is to determine whether it is *the* Higgs boson of the Standard Model, or a subtle variant that could signal a more fundamental theory in which the Standard Model is embedded. The candidate theory most favoured by theorists is supersymmetry, in which all known particles have a heavier supersymmetric partner as yet undiscovered. The attraction of such theories is that they quite naturally contain a particle that could account for the Dark Matter that makes up 23% of the mass-energy content of the Universe.

The most popular version of supersymmetry theory predicts five different Higgs bosons, some or all of which could be detectable at the LHC. The lightest Higgs boson is expected to have properties similar, but not identical, to the corresponding Standard Model particle, and so could in principle be revealed by precision measurements of the particle whose discovery was announced in July. In the Standard Model, all the properties of the Higgs boson, in particular how readily it is produced and the probabilities for it to decay in different ways, can be accurately predicted once the mass is known. In supersymmetry theories, the predictions differ by small but calculable amounts. Cavendish theorists are part of an international team that has been involved in providing the LHC experimentalists with benchmark predictions for the Higgs boson production rates. This requires a very precise knowledge of how the energy of the colliding protons is shared between its various quark and gluon constituents, since it is these fundamental particles, one from each proton beam, that combine to create Higgs bosons.

Cavendish experimentalists are leading the search for these supersymmetric particles. In the ATLAS experiment, for example, physicists look for rare events characteristic of the direct production and decay of supersymmetric particles. Another very good place to search for evidence of supersymmetry is through the decay of B_s particles, which are composed of a bottom quark and a strange anti-quark, into two muons. In the Standard Model this is expected to be a very rare event but it can be greatly enhanced by the presence of new physics such as supersymmetry. This decay has recently been observed for the first time in the LHCb experiment (Fig. 2).

The B_s particle is not stable and decays within a millionth of a second after its production. During its short lifetime, it travels far enough, approximately a centimetre, to be observed by the LHCb detector. It can decay into a variety of other particles and, in an extremely rare occurrence, about a one in 300 million chance, into two muons. The team of physicists has analysed the enormous number of collisions recorded by the LHCb experiment to look for this particular

decay and have spotted a handful of likely candidates. Astonishingly, the results are exactly as predicted by the Standard Model. This comes as a set-back to the proponents of supersymmetry, since the new physics failed to show up where it arguably had the best opportunity of being observed. As remarked by Marc-Olivier Bettler, a member of the Cavendish analysis team, 'If new physics exists, then it is hiding very well behind the Standard Model'. Professor Val Gibson, leader of the Cambridge LHCb team, stated that 'An observation of this very rare decay is a key result that is putting our supersymmetry theory colleagues in a spin.'

The Higgs boson discovery heralds a new era for high energy physics. The years ahead will see much more data being collected and analysed at the LHC and, if the theorists are correct, many new particles discovered and new theories revealed. Thanks in part to a unique combination of experimental and theoretical expertise, which other groups around the world are trying to emulate, the Cavendish High Energy Physics group is well placed to play a leading role in this exciting endeavour.

James Stirling

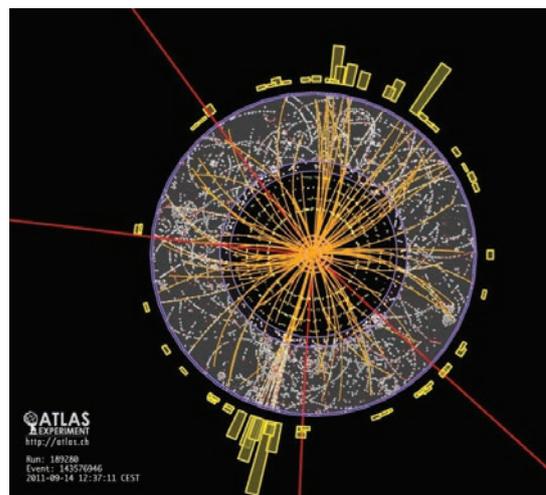


Fig. 1. A four-muon decay (the red lines) of a Higgs boson detected in the ATLAS experiment at the LHC.

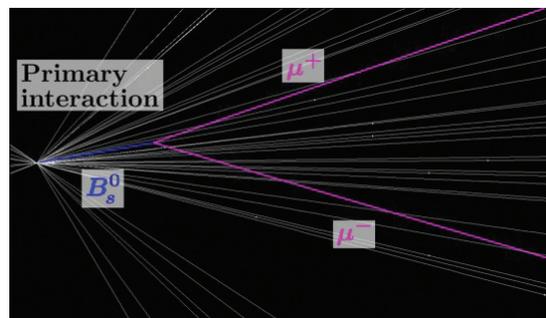


Fig. 2. An example of the rare decay of a neutral B_s particle into a pair of oppositely charged muons observed in the LHCb experiment at CERN.

Spin Ices and Magnetic Monopoles

We welcome Claudio Castelnuovo and Austen Lamacraft who have recently been appointed lecturers in the Theory of Condensed Matter Group



In recent years, my work has focused on frustrated magnetic systems. The term 'frustration' indicates the inability of a system to reach its lowest energy state in which all interaction terms are simultaneously minimised. The quintessential example is the triangular Ising antiferromagnet. In magnetism, frustration prevents the formation of ferro- or antiferromagnetically ordered phases at low temperature. This

allows the emergence of new phases of matter that often escape a conventional description in terms of local order parameters. Frustration is also at the core of paradigmatic non-equilibrium systems such as spin glasses.

A lattice structure that has been demonstrated to be particularly conducive to frustration and to lead to novel emergent phenomena is that obtained from tiling a volume with corner-sharing tetrahedra, known as a pyrochlore lattice. Notable examples are the spin ices, discovered experimentally in 1997 by Harris and Bramwell, which include materials such as $Dy_2Ti_2O_7$, $Ho_2Ti_2O_7$, and more recently $Dy_2Ge_2O_7$. In these materials with rare earth ions, which have large magnetic moments, pyrochlore lattices are formed. These are subject to sizeable local easy-axis crystal fields ($T \geq 200K$), short range exchange and long range dipolar interactions ($T \sim 1 K$ at nearest neighbour distance). The competition between interactions, crystal fields, and lattice geometry leads to frustration and to extensive degeneracy at low temperatures ($T \leq 2K$). The magnetic correlations do not appear to select a unique ground state but rather mimic the correlations in the positions of the protons in water ice - hence the name *spin ice*.

This low temperature phase, which is neither disordered like a paramagnet nor conventionally ordered, is characterised by an emergent gauge symmetry described in field-theoretic terms by a divergenceless field. This led to the prediction of distinguishing features in the magnetic structure factor known as pinch-points, which have been confirmed by neutron scattering experiments.

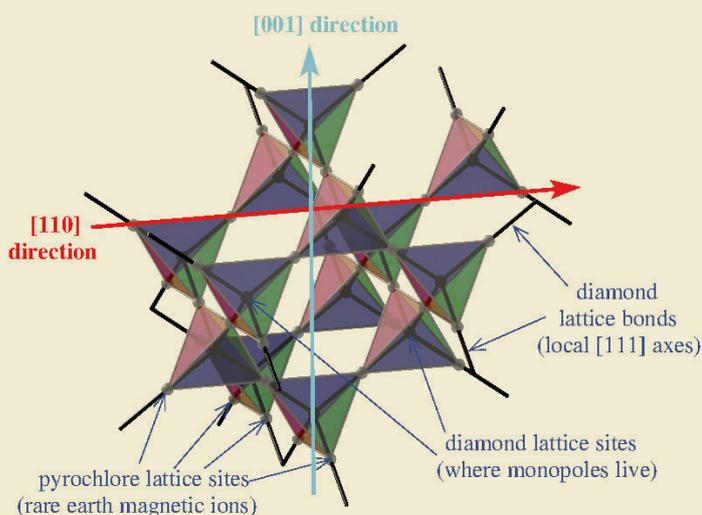


Fig.1: The magnetic moments in spin ice reside on the sites of the pyrochlore lattice, which consists of corner sharing tetrahedra. These sites are at the same time the midpoints of the bonds of the diamond lattice (black) defined by the centres of the tetrahedra. The Ising axes are the local [111] directions, which point along the respective diamond lattice bonds (Phys. Rev. B **84**, 144435 (2011)).

An even more striking feature of spin ices at low temperatures is the nature of their excitations. The familiar concepts of domains and domain walls are replaced by deconfined quasi-particle excitations free to move through the system. In a rare instance of fractionalisation in three dimensions, these point-like excitations carry a fraction of the microscopic dipolar degrees of freedom: a *magnetic monopole*. Thus, spin ices provide a unique playground where we can access experimentally magnetic charges free to move in three dimensions.

The existence of these emergent excitations has been demonstrated to have a direct effect on the thermodynamic properties of these systems, for example, with the observation of unprecedented phenomena such as a liquid-gas transition in a localised magnetic system, as well as on their response, relaxation, and far from equilibrium behaviour. In 2012, this combined research effort was recognised internationally by the Condensed Matter Division of the European Science Foundation with the award of the Europhysics Prize 'to S. Bramwell, C. Castelnuovo, S. Grigera, R. Moessner, S. Sondhi and A. Tennant for the prediction and experimental observation of magnetic monopoles in spin ice'.

The phenomenon by which magnetically charged point-like excitations emerge in spin ice is not dissimilar from the better known fractional anyonic excitations in quantum topologically ordered phases, whereby a spin ice is a rare experimental instance of classical topological order. The theoretical proposal of magnetic monopoles in spin ice has led to the speculation that they may be manipulated into novel magnetic circuits and magnetic memories with applications in information technology. These and similarly intriguing questions have fuelled a thriving research effort worldwide in this field.

Claudio Castelnuovo

- S.T. Bramwell & M.J.P. Gingras, *Science*, **294**, 1495 (2001).
- C. Castelnuovo, R. Moessner & S.L. Sondhi, *Nature*, **451**, 42 (2008).
- C. Castelnuovo, R. Moessner, & S.L. Sondhi, *Ann. Rev. Condens. Matter Phys.*, **3**, 35 (2012).
- O. Tchernyshyov, *Nature, News & Views*, **451**, 22 (2008).



Fig.2: Pictorial representation of a monopole-antimonopole pair in spin ice (Artist: A.Canossa).

Fig.3: above, right: Illustration of the magnetic field due to the monopoles (red arrows), from Monte Carlo simulations. **Bottom:** Averaged fields along the line joining to within 20% error, by the field from two point magnetic charges at the locations periodic deviations from the Coulomb form are due to spins which lie very close to midpoint between the monopoles (Phys. Rev. Lett, **108**, 217203 (2012)).

Wedge Issue



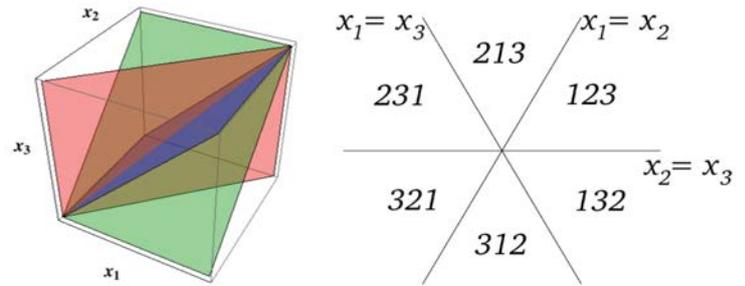
In the Physics Tripos we teach Fresnel's theory of diffraction published in 1818, but it wasn't until 1896 that this phenomenon was put on a sound mathematical footing by the young Arnold Sommerfeld, who showed how to compute the diffraction pattern of light incident on a wedge. Remarkably, this same problem turns out to have a bearing upon the kinetics of one dimensional gases, a problem currently

being studied by atomic physicists.

Statistical mechanics grew out of the kinetic theory of gases because the diluteness of these systems makes them theoretically tractable. To this day, the most complete description of the approach to equilibrium is provided by Boltzmann's equation for the distribution function of particle momenta and positions in a gas. According to the most familiar version of this equation, the evolution of the distribution function is determined by binary collisions that redistribute the momenta of the particles in a pairwise fashion.

If we consider the same processes in one dimension, we run into a difficulty. The conservation of momentum and energy means that a colliding pair of particles of equal mass can either retain or exchange their momenta. The distribution function is therefore unchanged and the familiar mechanism of equilibration ineffective. In 2006, a vivid experimental demonstration of this phenomenon in an ultracold gas of rubidium atoms by physicists at Penn State University was dubbed a 'quantum Newton's cradle'.

For equilibration to occur, we need to consider collisions of *three* particles. An elegant way of thinking about such collisions in one dimension is to treat the coordinates of the three particles (x_1, x_2, x_3) as a point in three dimensional space (Fig. 1, left). The particles interact through short range potentials on the three planes $x_1 = x_2, x_1 = x_3,$ and $x_2 = x_3$. For equal mass particles the centre of mass moves along a line parallel to $(1, 1, 1)$ and so this motion may be eliminated by looking at the plane perpendicular to this direction. This plane is cut into six 60° wedges (Fig. 1, above), corresponding to the six possible permutations of the three particles on the line.



$$r_{13}t_{12}r_{23} = t_{12}r_{23}r_{12} + r_{12}r_{13}t_{12}$$

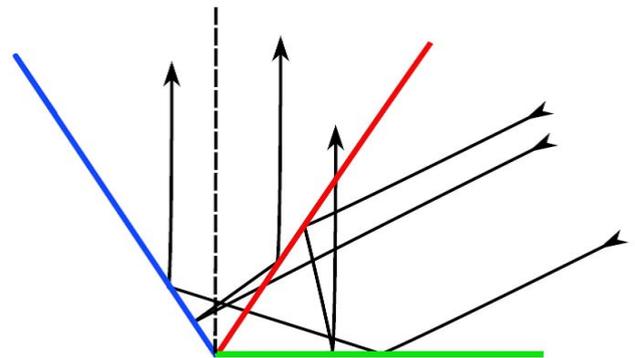
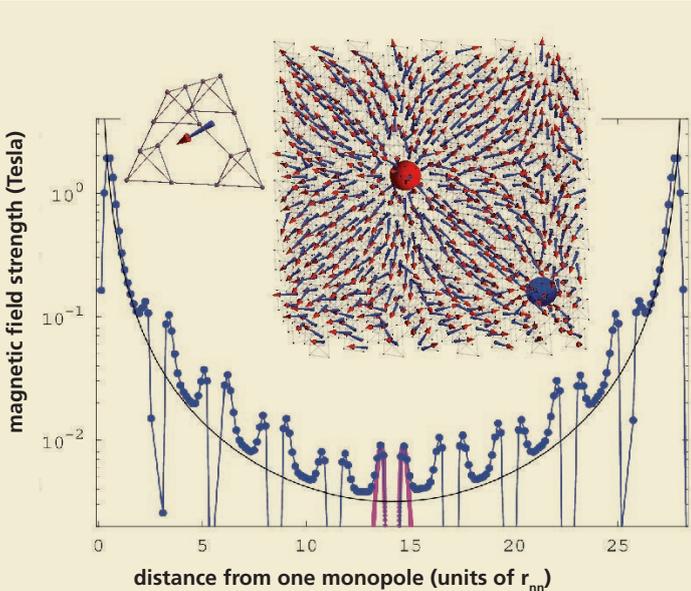


Fig. 1 (top): Geometrical description of three particle scattering in real space. (Left) Particles interactions in the three planes defined by $x_i = x_j$. (Right) Projection along the centre of mass motion in the $(1, 1, 1)$ direction. The six wedges correspond to different orderings of the three particles on the line, given by a three digit code, for example, 213 corresponds to $x_2 < x_1 < x_3$.

Fig. 2 (bottom): Three rays starting in one wedge and finishing in the next. In order for plane waves to surface, the amplitudes of the outgoing waves must match on either side of the dotted line.



and blue spheres) visualised by unit vectors in the local field direction (red-blue arrows) connecting the two monopoles (connected blue dots). The leading behaviour is captured by the theoretical prediction (black line). The magenta line - this contribution is explicitly shown in magenta for the spin at the

The quantum state of three particles with definite momentum prior to collision can be described by an incoming plane wave in one of the wedges. Thus we have to solve a diffraction problem, of exactly the type considered by Sommerfeld more than 100 years ago.

This situation reminds us a little of a kaleidoscope, but now (a) our mirrors meet at a point and (b) they can be partially reflecting and partially transmitting, according to the strengths of the interactions between particles. Does a finite set of plane waves describe the system, as in the cases of a kaleidoscope or corner reflector? By tracing three possible rays passing from one wedge to its neighbour we can arrive at the condition for this to take place in terms of the reflection and transmission amplitudes for the different parts of the plane wave-fronts to match (Fig. 2, above). If this condition holds, we can write everything in terms of six plane waves corresponding to permuting the initial momenta between the three particles, and there is no equilibration. This condition, known as the *Yang-Baxter equation*, leads to the same thing happening for collisions of any number of particles. If it fails, the amplitudes on either side of the dotted line in Fig. 2 do not match, and diffraction smears out the difference. The resulting continuous distribution of outgoing momenta leads to thermalisation of the gas, and showing that in one dimension it's all done with mirrors.

Austen Lamacraft

50th Anniversary of Brian Josephson's Nobel Prize Discovery



Brian Josephson's dramatic predictions concerning the supercurrent flowing through tunnel junctions were first published in 1962.

A lively meeting

to celebrate the 50th anniversary of Brian's discovery was held in Cambridge on 23rd June 2012. It included a video message from Phil Anderson, descriptions of the original events, and accounts of modern developments¹— plus a first revelation of the commemorative plaque to be erected on the old Mond Laboratory in Free School Lane (Fig. 1). John Waldram recalls the excitement of these days.

Brian arrived in Cambridge from Cardiff High School to read Mathematics in 1957, the year the revolutionary Bardeen–Cooper–Schrieffer theory of superconductivity was published. Bright Trinity mathematicians then read Maths Part II in two years. Brian concentrated on the Applied Maths side, chiefly because he was getting better marks in it, but found the Maths Tripos approach to physics rather out of touch with reality. He decided to switch to Part II Physics.

In his final undergraduate year he published, to general amazement, a ground-breaking paper on the Mössbauer effect. I remember, as a first year research student, reading *New Scientist* to find out what he had done, and overhearing Nicholas Kurti, the external examiner from Oxford, huddled in the Old Cavendish with David Shoenberg and demanding *sotto voce*: 'Who is this chap Josephson? He seems to be going through the theory like a knife through butter!'

Brian was, however, determined to do an experimental PhD, and joined the Royal Society Mond Laboratory. It was an exciting place to be: David Shoenberg was busy sorting out the de Haas–Van Alphen effect, Joe Vinen had just shown that the circulation of superfluid in He⁴ was quantised, while Brian Pippard had a reputation as an all-devouring lion of both superconductivity and transport effects in metals. It was Brian P who took on Brian J.

The previous year Paul Richards had been a visitor to the Mond Laboratory measuring the magnetic field dependence of the superconducting penetration depth at microwave frequencies. The results had not worked out quite as Brian P expected and so Brian J was landed with carrying out a similar experiment at the lower frequency of 174 MHz. This involved building a low temperature cavity, setting up high frequency circuits and a large electromagnet, and worst of all producing the samples. Because they had to resonate



Fig. 1: The commemorative plaque on the old Mond Laboratory in Free School Lane.



Fig. 2: Brian Josephson at the 50th Anniversary celebrations.

at a low frequency they were complicated geometrically and difficult to electropolish. It was quite a task— for the next three years that was Brian's day job. So the theory of Josephson effects had to be worked out in his spare time.

How did the theory come about? During Brian's first year Ivar Giaever's experiments on tunnelling between superconductors was published. Here was this unbelievably simple idea — you simply arranged to differentiate the I - V characteristic of your tunnel junction, and *there* was the BCS electron density of states, plotted out on your x - y recorder! Then Phil Anderson came to visit for an extended sabbatical year. He gave a marvellous lecture course, explaining amongst many other things the nature of the superconducting order parameter which had a *phase* like a wave-function. Phil's presence in Cambridge was crucial, for there was no one else around who understood the order parameter at that time. Brian talked incessantly to Phil, rapidly building up a good working interaction, and then went away to cogitate — he realised that the order parameter's phase might be made observable in a tunnelling experiment like Giaever's.

The theory, however, looked formidable. But then in February 1962 the paper by Cohen, Falicov and Phillips appeared giving

for the first time a decent explanation of why the BCS coherence factors had cancelled out in Giaever's experiments — Giaever, ever the experimentalist, had just *assumed* they would. Moreover, they employed a new tunnel Hamiltonian, which at the time was extremely controversial, and that provided Brian with the crucial theoretical framework he needed. He was looking initially for a phase-dependent term in the *normal* tunnelling, and did indeed find one. He was considerably taken aback however to find *another* term of similar magnitude, the famous term describing *superconductive* tunnelling, which we had all assumed would be too small to be observable.

His predictions were published in June 1962, in the first issue of *Physics Letters*, and he promptly set out to check them himself experimentally. He and Phil had worked out that there would be quantum interference and so it would be necessary to compensate the Earth's magnetic field, which Brian did—but couldn't find the predicted effect.

In July 1962 John Bardeen published a magisterial rebuttal of Brian's theory, and in September of the same year a famous confrontation occurred at the Low Temperature Conference at Queen Mary College, London. Brian had not planned to go, but the organisers thought that the newly opposed views of tunnelling demanded public discussion. The debate was very gentlemanly. Bardeen, always a man of few words, explained gently why he thought Brian's results were wrong, and Brian stood up and explained very politely why he thought they were right. Then somebody defended Brian. Not much was said after that: it was just the electric contrast between the distinguished Nobel prize-winner and pretty extreme youth that so struck everyone. The following January, John Rowell at the Bell Laboratories conclusively showed experimentally that the Josephson effects were there.

The next Low Temperature conference was in Colgate NY. It was the time when Brian's predictions were having maximum impact, and everywhere we went he was mobbed. He received a large number of job offers, and went off to Illinois for a year. Later, when Brian was back in Cambridge, he and I gave a joint course on superconductivity. Characteristically, he decided to tackle the experimental part. This, unfortunately, left the theory for me, but under his instruction I did come at last to understand what I was really talking about.

In 1973 Brian was awarded his Nobel Prize, and of course we asked him what he was planning to do with the money. He thought for a little while and said he planned to upgrade his bicycle.

John Waldram

¹ Much more detail of what was said at the meeting may be heard and seen at www.phy.cam.ac.uk/conferences/Josephson

Eryl Wynn-Williams and the Scale-of-Two Counter



Nowadays it is rare to find any kind of scientific laboratory that is not stuffed full of electronic equipment. But, when and where did this trend begin? A

good case can be made that it started in the Cavendish Laboratory in the early 1930s, and that my father, a young Welsh scientist, C.E. Wynn-Williams, played a pivotal role in fostering this electronic revolution.

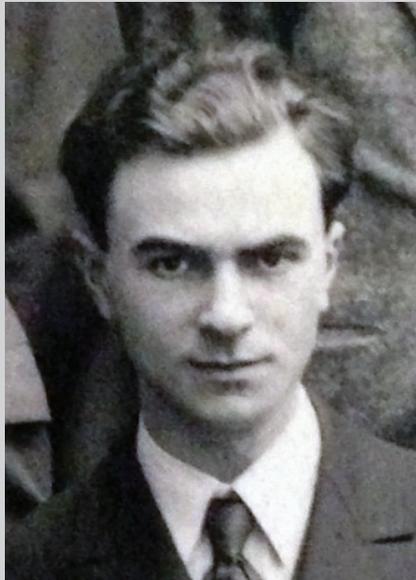
Wynn-Williams was born in 1903, and brought up in Wrexham. His father, William Williams, was himself a physicist having earlier been on the staff of the Royal College of Science, now Imperial College, and published papers on dimensional analysis and Fourier series. By the age of 22, Eryl Wynn-Williams had already obtained BSc and MSc degrees at the University of Wales in Bangor where he developed a new kind of oscillograph. He moved to the Cavendish in 1925 and completed a PhD thesis on the production and absorption of millimetre waves – a subject that anticipated some of the preoccupations of the radio astronomy group several decades later.

Much of the research in Rutherford's laboratory in this era involved counting α -particle production rates from different radioactive elements. Direct observations were slow and tedious so researchers were on the lookout for ways to automate their data collection techniques. Photographic recording methods led to some improvements, but 40 minutes of observations required a 400 foot roll of bromide paper and many hours in the darkroom.

Mechanical counters were clearly an answer but in their raw state were impractical because of their low speed. In 1930 Wynn-Williams devised a way to use electronic valves as counting devices. He connected several *thyatron*s in a ring circuit in which only one thyatron at a time could pass a current. Successive electric pulses would activate the thyatron in sequence. A ring of five thyatron s connected to a mechanical counter could therefore handle five times the pulse rate of the counter itself. His ring counter was a great success, but he realised that the circuit could be considerably simplified if the ring were reduced to just a pair of thyatron s, which also much improved their performance and stability. He then optimised the use of valves for counting by connecting such pairs of thyatron s in series so that each pair counted only every second pulse received by the preceding pair. He termed this invention which is at the heart of all modern computing the "scale-of-two" counter. His innovations therefore marked the dawn not only of the use of electronics for



Fig. 1. Wynn-Williams' Scale-of-Two counter in the Cavendish Collection.



Left: Eryl Wynn-Williams in the 1920s.

Right: Thyatron s, which first became commercially available in 1928, are triode valves which contain a low pressure gas such as argon or mercury vapour. If a positive pulse is applied to the grid of a thyatron, a self-sustaining anode current is set up that can only be stopped by dropping the voltage of the anode. The device therefore behaves like a two-state system rather than a linear amplifier.



counting purposes, but also the use of the binary numbers for electronic computation. Several three-bit counters were built for the laboratory, one of which is on display in the Cavendish museum (Fig. 1). They were quickly put to use by the Cavendish's physicists, including Chadwick who used one in his experiments that led to the discovery of the neutron in 1932. R. V. Jones, UK Government Scientific Intelligence advisor in the Second World War, wrote in *Nature* in 1981: '... the modern computer is only possible because of an invention made by a physicist, C.E.Wynn-Williams, in 1932 for counting nuclear particles: the scale-of-two counter, which may prove to be one of the most influential of all inventions.'

In 1935 Wynn-Williams moved to Imperial College, London where he worked with G.P. Thompson's group studying neutron physics. During the war he was brought in by Max Newman to utilise his electronic skills to speed up the code-breaking efforts at Bletchley Park. He designed and developed

the counters of Heath Robinson, a machine which was a direct precursor of Colossus, the world's first programmable digital electronic computer.

After the war Wynn-Williams returned to Imperial College for the remainder of his career, but his connections with Cambridge and Trinity College were revived in the 1960s when my brother and I obtained physics degrees there.

The story of the scale-of-two counter is a classic example of how a modest investment in pure science research – in this case the donation of six thyatron s to the Cavendish by the BTH company – can lead to massive benefits to society many years later.

Gareth Wynn-Williams

Gareth was a demonstrator in the Cavendish Laboratory from 1973 to 1978. He recently retired as Professor of Astronomy at the University of Hawaii.

First Winton Symposium – Energy Efficiency



The Winton Inaugural Symposium, held on 1st October 2012, brought speakers from across many areas of science to talk on the theme of 'Energy Efficiency', and drew a capacity audience, of 450, to the Pippard Lecture Theatre (Fig. 1). The 'homework' for the day was to test how well we, and nature, generate, distribute and use energy. Are



we most of the way to perfect efficiency, so far as the second law of thermodynamics permits, or is there still a lot of headroom to do things better? The answer? nature does a great job, but has had a very long time to find good solutions to difficult problems, and, our man-made technologies are not always so smart.

Lest we presume that better technology will naturally cause us to use less energy, Malcolm Keay, from the Oxford Institute for Energy Research, set out the Jevons Paradox – that when prices fall, consumption rises and overall spend increases. From 1800 to 2000, the transition from candles to electrical lighting increased demand for light some 10,000 times, though fortunately a 100 fold increase in efficiency has limited the increase in energy consumption to just a factor of 100! Better technology may be a useful tool but only when deployed very carefully.

Information technology is a rapidly growing user of energy - now at 2% of electricity consumption in the USA - so it is good to check how well we are using it. Stuart Parkin from the IBM Almaden Laboratory gave an exhilarating tour through the many new technologies for storage. We need static storage that uses no energy to retain information, but which is also very fast to access. Not trivial to achieve, but delivered now by magnetic storage with electrical read and write. Remarkably electrochemical changes in very small structures now also seem capable of high speed and reliable operation.

Electronic computation may be fast and powerful, but Eli Yablonovitch from UC Berkeley used some deceptively simple analyses to show that silicon technology works at much too high a voltage – we could still be safe from noise if we dropped from today's half a Volt a hundred fold, to a few millivolts, reducing power consumption equivalently. This requires a replacement for the CMOS silicon transistor that just needs



Fig. 1: Networking during the Winton Symposium

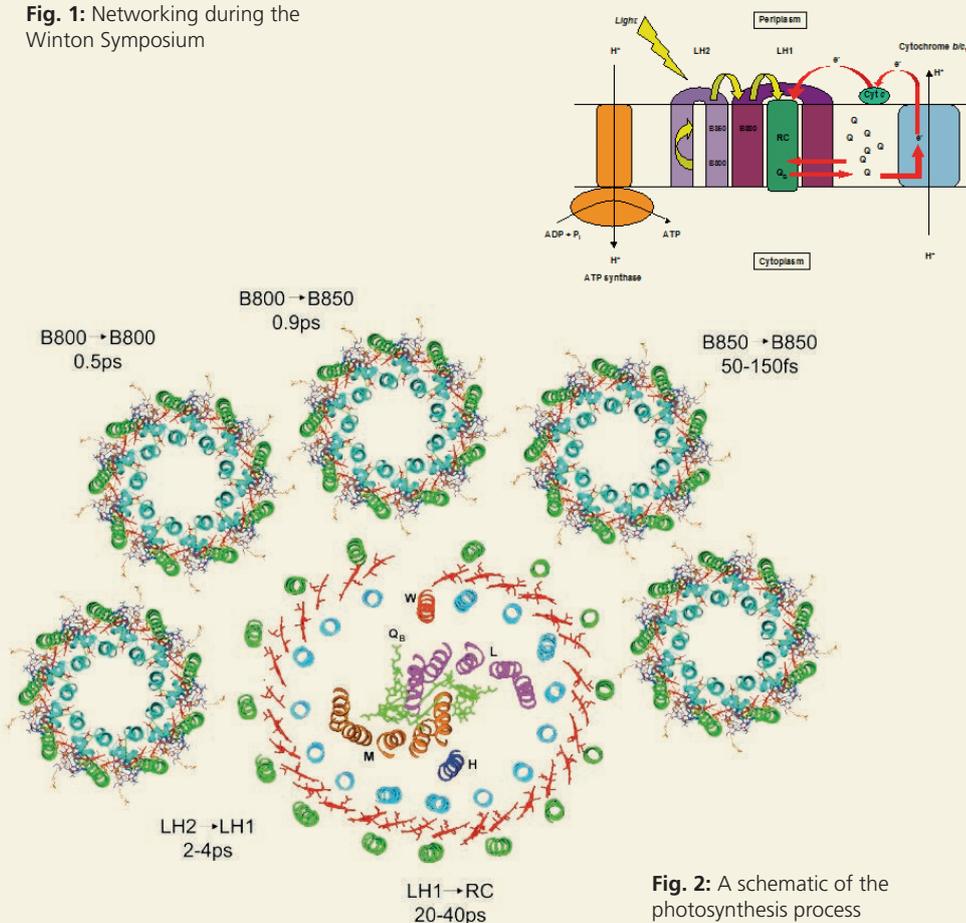


Fig. 2: A schematic of the photosynthesis process

too much voltage. Old technologies such as tunnel diodes may be able to do this.

Simon Laughlin from the Department of Zoology in Cambridge countered these with his talk "what makes brains efficient?" He showed how nature uses chemical methods to carry out Boolean algebra at the local level, and electrical methods for communication over distance, at a much higher energy cost, but at the same millivolt levels that Eli Yablonovitch advocates.

Jenny Nelson from Imperial College gave an insight into how solar cells convert sunlight into electricity. Matching the absorption

'colour' of the light-absorbing semiconductor against the broad spectrum of sunlight, from UV to infrared is a compromise between the fraction of the solar spectrum absorbed, favouring low bandgaps to capture the solar spectrum out to the infra-red, and the cell photovoltage, which scales with bandgap, favouring high bandgaps. This sets the maximum theoretical limit to the efficiency of a single bandgap solar cell to just over 30%, the Shockley-Queisser (S-Q) limit [2]. To do better, we can use multi-junction devices, that filter out different parts of the solar spectrum so that each is used more efficiently, but the catch is the increased costs due to more complex device architectures.

Current research on reshaping the solar energy spectrum through photon up and down conversion may provide the long-term solution.

In contrast to the relatively poor efficiency of the solar cell, the reverse process, turning electrical energy to light in the light-emitting diode, LED, has now become very efficient. James Speck from the University of California, Santa Barbara, showed how these advances in gallium nitride LEDs and those currently being engineered are transforming the lighting industry, replacing not just incandescent lamps but also the unloved compact fluorescent lamps that had replaced them.

Richard Cogdell, Director of the Glasgow Biomedical Research Centre, explained how light harvesting occurs in nature, using purple bacteria as his example. A schematic of the photosynthesis process is shown in Fig. 2, with photons absorbed in the antenna LH2 complex then funnelled to the LH1 complex, which surrounds the reaction centre (RC) where the reaction takes place leading to the conversion of ADP to ATP which acts as the chemical energy store [3]. Richard concluded by pointing out that nature does not always evolve to optimise energy efficiency, this being only one of the several evolutionary survival factors.

Transportation is a large user of energy, but real numbers on achievable efficiency are hard to come by. Donald Hillebrand from the Argonne National Laboratory did just this, in a fast moving survey of the automobile industry and its prospects. With some parallels to Malcolm Keay, Don showed that full system analyses are needed. Sadly some of the well-publicised schemes for battery-powered vehicles fail that test, but steady engineering improvements will take us a long way beyond current performance.

The Symposium for 2013 will follow a similar format to this year with a one-day event at the Cavendish. The broad theme will be "Materials Discovery".

Further information on the Winton Programme and future events is available on the Winton Website www.winton.phy.cam.ac.uk or by contacting the Winton Programme Manager at winton@phy.cam.ac.uk.

[1] Professor Athene Donald science blog – <http://occamstypewriter.org/athenedonald/2012/10/09/energy-efficiency-and-education>

[2] William Shockley and Hans J. Queisser, "Detailed Balance Limit of Efficiency of p-n Junction Solar Cells", *Journal of Applied Physics*, Volume 32 (March 1961), pp. 510-519

[3] A.W. Rosnak et al., Crystal Structure of the RC-LH1 Core Complex from *Rhodospseudomonas palustris*. *Science* (2003) 302:1969-1972.

Richard Friend and Nalin Patel

Athene Donald blogs Physics at Work



According to the Confederation of British Industry's year-on-year reports, companies feel they cannot get enough qualified scientists and engineers

to fill their jobs. Kids at school just aren't flocking to do science A-levels and subsequent degrees in the numbers apparently needed, despite the ostensible promise of a healthy job market.

The increase in A-level entrants for science subjects in recent years is encouraging, but it has still not caused numbers to recover to the levels of 20 years ago. It is not difficult to see one of the reasons why this might be so. How can schoolchildren get a taste for what a life in science might be like? How can they find out what it is that scientists "do" day by day, or what it might mean to be a scientist? Or even what a trained scientist might do far removed from the lab, but where their scientific background is still crucial. And if they don't have a clue about these things, how can they make sensible choices at critical stages in their schooling about what courses and exams they should pursue?

Careers advice at school is often inadequate due to funding and time pressures, with many schools no longer able to provide face-to-face advice. Even in those schools which do have formal careers advisers, they are likely to be unfamiliar with the range of careers associated with scientific disciplines. A depressingly low percentage of such advisers themselves possess a science degree and so have any kind of first-hand knowledge to pass on.

The consequence is that many schoolchildren will end up ill-informed, their knowledge of science beyond the classroom likely to be limited to either science fiction films and books or programmes they have seen on TV. CSI is probably not the best introduction to scientific practice in real life and, although series such as Brian Cox's recent blockbusters undoubtedly contain good science, the life he leads cannot be said to be typical of a physicist, let alone a scientist more generally. The idea that a scientific training is useful in all kinds of jobs beyond the obvious is also likely to be unappreciated; examples where we need more trained scientists include journalism, politics and the civil service. Even the more 'obvious' career choices, such as engineering or computer gaming, may mean very little to students in terms of what is involved and what qualifications they need to get into such jobs.

Nevertheless, it is encouraging to see that the numbers taking science and maths A-levels has steadily increased over the past decade, including this year. There is also a

small but steady rise in the number of girls taking both physics and chemistry at A-level.

How can scientific work be made more accessible to children and how can they be helped to appreciate the kinds of things scientists get up to in practice? Typical outreach events are designed to excite and intrigue the students, get them enthusiastic about the subject rather than provide them with much insight into the job market. In contrast to the standard Science Festival fare, for more than 25 years the Cavendish Laboratory, the University of Cambridge's Physics Department and my place of work, has opened its doors once a year to a range of exhibitors to enable them to showcase their activities, their companies and their practicing scientists as part of the annual Physics at Work event. During three days in September 2012 there was an invasion of more than 2,500 schoolchildren, mainly year-11s, to sample the exhibition. This is a major opportunity for the exhibitors – about 25 each year from industry and academia – to highlight what it is that physicists do in their daily work and why they find it exciting.

Over the years it is obvious how valuable teachers find Physics at Work as a way of informing their classes. What is the evidence for that statement? That they keep coming back! They even come half way across England to attend, the most distant group this year coming from Liverpool.

What do the children see when they come? They get to see a selection of half a dozen or so of the 25 exhibits, and they get to meet the people who do the science. They'll discover that scientists are articulate and passionate about what we do. Most won't be wearing white lab coats, or have Einstein-like hair. Exhibitors this year ranged from Rolls-Royce to the British Antarctic Survey, from Domino Printing to The Technology Partnership Consultancy, as well as several research groups from the physics department and further afield in the University. Something, one would hope, to appeal to everyone.

I believe we need more events like this across the country to help students visualise what a life in science, or a career built on a science qualification but which isn't necessarily directly scientific, might mean. If all they think scientists do is sit at a bench intoning over bubbling test tubes, they are *missing the big picture*. We need to broaden their horizons and give them a taste of the spread of options in principle open to them. Sharing the excitement is vital, but sharing the reality is too.

This blog first appeared on Occam's Corner, hosted by the Guardian on Tuesday 18 September 2012. This is a slightly edited version of that text. Keep looking at Athene's blogs for her latest thoughts.

The Sutton Trust Summer Schools in Physics



As part of the Physics and University outreach programmes, we have been running a Sutton Trust Summer School in Physics in the Cavendish every year since 1999 – 2012 was our fourteenth school.

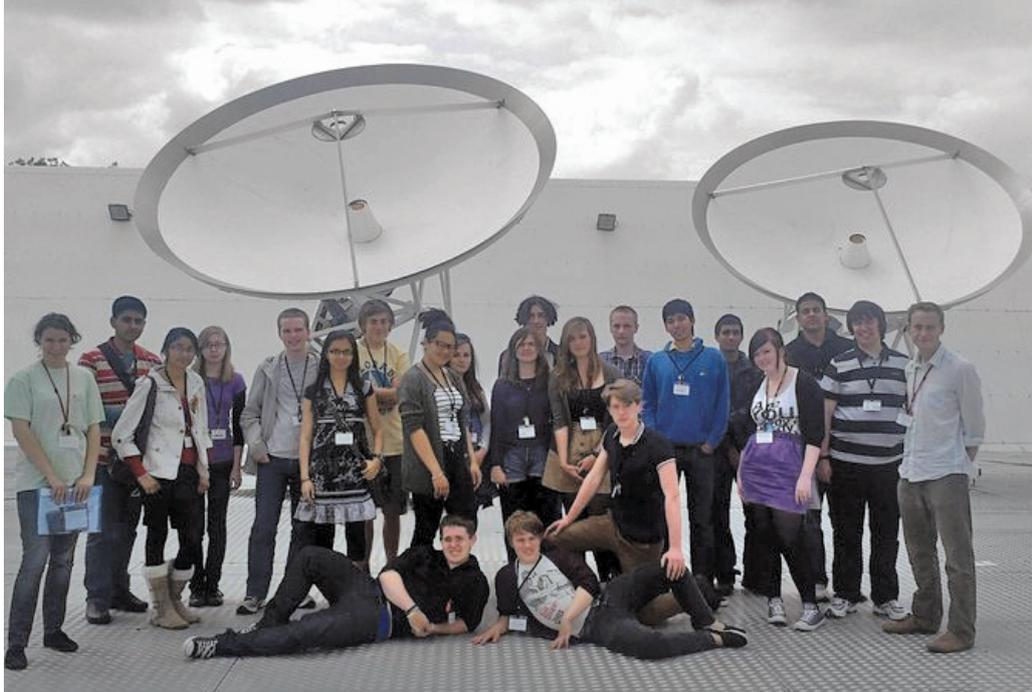


Fig. 1. Ben Huddart and Mamta Ramgi, current first-year students in Natural Sciences, who attended the Sutton Trust Physics Summer School in 2011, provided this photograph of their group in the Arcminute Micro Kelvin Imager Small Array enclosure at the Mullard Radio Astronomy Observatory.

University Summer Schools were the very first project initiated and funded by the Sutton Trust educational charity in 1997. Cambridge ran its school for 60 students in three subjects in 1998 - last year there were about 400 students across 22 subjects attending the summer schools in Cambridge over four separate weeks. These week-long, fully-funded, summer schools are designed to give bright students from less-privileged backgrounds the opportunity to experience what it is like to be a student at a leading university. Priority is given to students who are the first generation in their families to plan to attend university and also are from schools and colleges which do not send many candidates to top universities. The students will just have completed their first year in the sixth form and so are actively thinking about university applications. The participants gain an impression of the challenges and opportunities offered by undergraduate study; they live in a Cambridge college for a week and follow an intensive course of university-style teaching - attending lectures, experiencing small-group teaching, carrying out practical work and so on.

The Physics summer school is very demanding. Students are expected to be taking Physics and Mathematics at A-level and to have very good GCSE grades. The competition for places is increasingly strong - last year there were over 200 applications for the 20 places available.

The basic structure is much the same as it was when we started in 1999. There is a four-lecture course given by Dave Green - at the usual physics slot of 9 am - entitled 'Reference Frames and Special Relativity'. It is a shortened version of a similar set of lectures given to our first-year physicists. There is an accompanying problems sheet which includes modified first-year examples; the participants work through these problems in classes at which we are

on hand to give help where needed. This is followed up by supervisions in pairs on the last day. We also run two practical classes, similar to those undertaken by our first-year undergraduates. In one of these the students investigate the motion of a ball rolling down an inclined plane, from which they obtain a value of the acceleration due to gravity using difference measurements to remove systematics and learn about the idea of systematic and random errors. In the second practical they study the Fraunhofer diffraction patterns of single slits produced by a laser, using these to deduce the wavelength of the laser light and also to measure the diameter of a hair from its diffraction pattern. There is a session in which they are introduced to the use of Excel spreadsheets to investigate two bodies orbiting around each other - if nothing else, they learn that great care is needed when setting up such computational models if the physical laws are not to be violated!

There are three lectures of more general interest. 'Spin and Angular Momentum' is given by Mark Warner and, in addition to an introduction to new concepts not encountered at school, there are several hands-on demonstrations. Chris Lester talks about 'Particle Physics, CERN and the Large Hadron Collider' - this year he gave his lecture very shortly after the announcement of the discovery of Higgs-like particles at the LHC and so he was able to give the students up-to-the-minute information about this remarkable event. Keith Grainge talks about 'The Big Bang and the Cosmic Microwave Background' providing insights into the study of cosmology, the latest discoveries and the instruments with which they are made. Keith's talk provides an excellent introduction to the tour of the Mullard Radio Astronomy Observatory at Lord's Bridge on the last afternoon of the summer school.

Whilst the aim of the summer schools is to

increase the aspirations of the students and encourage them to apply to top universities, not necessarily Cambridge, we are delighted that so many of them then apply to us. Over the past few years more than half of those attending the Physics summer school have applied to Cambridge and of those who did apply about 40% were made an offer - this is a better than average success rate for sciences as a whole in Cambridge. This supports the conclusions of research carried out at Bristol University which indicates that students who have attended the Sutton Trust Summer Schools are significantly more likely to get into a highly competitive university than students with similar academic profiles who have not.

The students themselves comment really positively every year on the Physics summer school:

- 'The academics here are 'normal' people who are friendly and always willing to help';
- 'coming to Cambridge has dispelled a lot of myths and has made me really want to apply';
- 'very enjoyable to spend time with other students with the same interests';
- 'developed time management skills, made new friends, experienced student life, confidence of fitting into university, taste of university-style teaching, learnt more about physics at university';
- 'gained confidence in my academic ability and realised that asking for help is not a weakness and that everyone is very willing to help you learn';
- 'I will aim higher';
- 'problems were challenging in a positive way'.

Clearly, whether or not they apply to Cambridge, they have benefitted in many different ways from the experience of attending the summer school.

Julia Riley and Dave Green

Outreach and Educational Events

Even More Outreach!

Physics at Work 2012 – 2265 Student Visitors!

Athene Donald waxes lyrical in a previous article about the ever popular Physics at Work event, which hit record highs this year. Athene's blog can be supplemented by the comments of the teachers.

Reasons to visit

- 'Broaden the horizons of the students and allow them to see the extent to which physics impacts on life',
- 'Raise the profile of physics and make students, especially the girls, aware that physics is relevant and there are career opportunities.'

Impacts

- 'Their interest in science and physics in particular has increased',
- 'Pupils now see physics as a vocational choice as well as an academic one',
- 'The students that have attended in previous years have gone on to study triple science – they have been motivated and interested in participating',
- 'Even the students with no interest in Physics come away with a positive image of the subject. It changes the opinion of some who then do it, but mainly it is a positive confirmation of decisions to follow physics.'

Cambridge Colleges Physics Experience

On October 10th and 12th 2012, the Cavendish welcomed 90 year-11 students from a new group of schools in collaboration with Christ's, Clare, Newnham and Pembroke colleges. Students spent half a day in a Cambridge College learning about University life before making their way out to the Cavendish for an afternoon of physics talks and practical sessions on 'Light, the Universe and Everything'.

This brand new programme has been made possible by funding secured through the University to engage with students whose schools have little experience of engagement with the University of Cambridge in order to encourage widening participation in physics and in the University in general.

We are also using this project as an opportunity to investigate perceptions of Cambridge and physics and, subject to proof of the impact this initiative has, we hope that this project will run for a minimum of 3 years. Preliminary data shows that even a single day's experience of Cambridge can have an important impact on student perspectives. Workshops as part of this programme will take place three times a year - year 11 students visit in October, year 12 students in February and year 9 students in May.



Above: Lisa receives the Institute of Physics Phillips Award, which recognises individuals who have given distinguished service to the Institute of Physics, from the President of the IoP Sir Peter Knight.

Cambridge Physics Centre Lectures

The Cavendish Laboratory hosts a series of six lectures each academic year aimed at year 12 and 13 (sixth form) students, one per month in October, November, December, February, March and April. The 2012-13 series has already featured John Nunn from the National Physical Laboratory, Rob Wallach from the Department of Material Science and Metallurgy in Cambridge and Hugh Hunt from the Department of Engineering in Cambridge talking about *Boomerangs, Bouncing Balls and other Spinning Things*.

The programme for the Lent Term 2013 is:

Thursday 7th February, 2013

Galactic Archaeology - Uncovering lost populations in the Milky Way.

Dr Apoorva Jayaraman, Institute of Astronomy, University of Cambridge

Tuesday 19th March 2013

News from CERN and the Large Hadron Collider.

Dr Christopher Lester, Cavendish Laboratory, University of Cambridge

Thursday 25th April 2013

Cosmology, String Theory and the Multiverse.

Dr Steve Gratton, Institute of Astronomy, University of Cambridge

To find out more about this series please visit our website and click on 'Cambridge Physics Centre'.

School Workshops – Electricity & Electronics

On the 12th and 13th December 120 students, aged 11 to 13, visited the Cavendish for an afternoon of talks and practical workshops on the physics of electricity and electronics and current research in these topics here at the Cavendish Laboratory. During the afternoon the students built a dark detecting torch to take away in a practical session developed by the Cavendish. The resources from this and all other workshops are available on our website.

The school workshop series is programmed for key stage 4 students in March/April each

year with key stage 3 students visiting in December each year.

Online booking for 18th and 19th March 2013 will be open soon from the school workshop section of our outreach page.

Cavendish Physics Teachers Residential 2013: Places available now

From the 29th June to 1st July, A-level physics teachers from across the United Kingdom are invited to visit Cambridge for a residential workshop kindly hosted by a Cambridge College (Churchill in 2011 and Robinson in 2012) and sponsored by the Ogden Trust. This course focuses on the following objectives:

- Many talented students are unable to attend the Senior Physics Challenge (SPC) as we do not have the spaces to host them. This opportunity will enable teachers to take the SPC back to school and into the classroom by providing attending teachers with all the resources and background materials.
- To provide an opportunity for first-hand experience of collegiate Cambridge and the base of physics research in Cambridge. The programme will include a session on Cambridge admissions from directors of studies in physics and admissions interviewers.
- To discuss ideas and concepts with teachers to further understand students' conceptual difficulties and bridge the gap between A-level and university physics.
- Access to an inspirational environment in which to discuss physics and physics education with like-minded teachers, time out from school to refresh, think in alternative ways and experiment.
- To provide an opportunity to observe the Senior Physics Challenge students in action and to see how they respond to the material and environment.

Any teachers interested in attending the course should go to our website and click on 'Physics Teachers' Residential'. This residential has now run for two very successful years and we look forward to welcoming new teachers in 2013.

Information about all our outreach programmes can be found at our website

www-outreach.phy.cam.ac.uk

More general residential and outreach initiatives are coordinated by the Cambridge Admissions Office in conjunction with the University departments. Further information can be found at their website

www.cam.ac.uk/admissions/undergraduate/events

Lisa Jardine-Wright

Development: Cavendish 3 - Principles for Design



The Department is very encouraged that the University is continuing to regard the redevelopment of the Laboratory as a very high priority. Indeed much of the summer has been taken up with refining plans and writing bids. We are hoping to launch a major fundraising campaign in the spring of 2013.



We have already presented a first version of a potential design to members of the Laboratory. In this article, we almost take a step back and describe some of the principles which are guiding the design process.

The existing buildings

Although in desperate need of replacement, the existing buildings have in many ways served the physics community rather well. The flexible design, with very few internal structural walls, has been a great asset when the experimental laboratories have needed reconfiguration and refurbishment. Almost all these laboratories have been through this process in the last decade, as research needs have changed, so it is essential that flexibility remains at the core of the design process.

Our predecessors were also wise enough to ensure that a large proportion of the floor space was on the ground floor. This makes it much easier to accommodate vibration-sensitive equipment, for which the upper floors of the current flexible structures are completely unsuitable. Therefore we will want to ensure that the new designs include at least as much space suitable for this type of research work. Indeed, studies have already been carried out to assess the geotechnical state of the site.

The future buildings

There are aspects of the current buildings which we would not want to see replicated in future construction. We would want to see far better use of internal space. Currently, our buildings are dominated by long and wide corridors, expensive to heat, dispersing the community. The new buildings will therefore be designed around a principle of increased usable to gross area, without compromising ease of access. We need to be able to install large pieces of new equipment without too much difficulty.

Energy efficiency, both in construction and use, is obviously essential in today's world. The current CLASP buildings were designed before the oil crisis of the 1970's and are poorly insulated. The new laboratories must be much better in terms of their energy usage and incorporate solar, photovoltaic and ground source heat pump technologies as appropriate. Thankfully, we will be spared the nightmare of asbestos.

Although we currently have central departmental spaces such as the Common Room and Library, a sense of community is increasingly harder to achieve. Many find their social centre in college or their research group, but it is essential for the scientific life of the Laboratory that there are places which form the heart of the community. The new designs will seek to achieve this. We will want to ensure that the undergraduates are more embedded into the heart of the Department: teaching and research are currently too separate.



Fig. 1. The red building is the existing Centre for the Physics of Medicine.



Fig. 2. An illustrative diagram showing how the present site could be redeveloped in a number of phases to provide adequate space for all the types of activities carried out in the Laboratory. Red is primarily laboratory space, blue primarily office space, yellow communal interactive and seminar space and green teaching and research infrastructure space.

Finally, we would want the buildings to be iconic. They will house one of the great physics laboratories of the world and in their design they need to say that.

Given the vision, how could it be realised on the existing site? We have carried out a feasibility study with our colleagues at the architects BDP to understand how we could maintain the continuity of the research and teaching programme while rebuilding the Cavendish on its present site. Fig. 1 shows the present Cavendish with the Physics of Medicine Building shown in red. Fig. 2 shows a concept of how the site could be redeveloped in stages, producing a world-class physics research and teaching laboratory to the highest international standard.

There are other options, but at this stage we have demonstrated clearly that the project is viable and fulfils all the goals we have set ourselves. We are looking forward to developing these plans further with our colleagues, the architects, the School of Physical Science and Estate Management.

David Peet and Malcolm Longair

Appointments, Awards and Prizes

Warmest congratulations to the following staff members:

Athene Donald has been appointed a member of Scientific Council of the European Research Council (ERC) by the European Commission (**see also page 11**).

Nicholas Hine and **Andrew Morris** have been awarded Winton Advanced Research Fellowships. Nicholas will work in the Theory of Condensed Matter Group and Andrew in the Nanoscience and Theory of Condensed Matter Groups

Sarah Teichmann has been appointed Principal Research Associate in the Physics of Medicine

Yingjie Peng, who joined the Astrophysics Group as a research assistant, has been awarded the ETH Medal, awarded to the top 5% of all dissertations in all research fields at the Swiss Federal Institute of Technology.

Cavendish Part III student, **Sam Bayliss** was awarded a 2012 SET Award for 'Materials discovery of solar-cell chromophores for co-sensitisation.'



Nicholas Hine



Andrew Morris



Sarah Teichmann



Yingjie Peng



Sam Bayliss

Retirees

We send all best wishes to the following long-standing members of the Department on their retirements:

Richard Hills	Professor of Astrophysics, following his return after 5 years secondment as project scientist for the ALMA project in Chile.
Richard Ansoorge	Senior Lecturer in the Biological & Soft Systems Sector and Academic Librarian for the Rayleigh Library.
Bob Barker	STO in the Astrophysics Group after 50 years of service to the Laboratory
Chris Moss	STO in the Electronics Workshop after 21 years of service to the Laboratory

Leavers

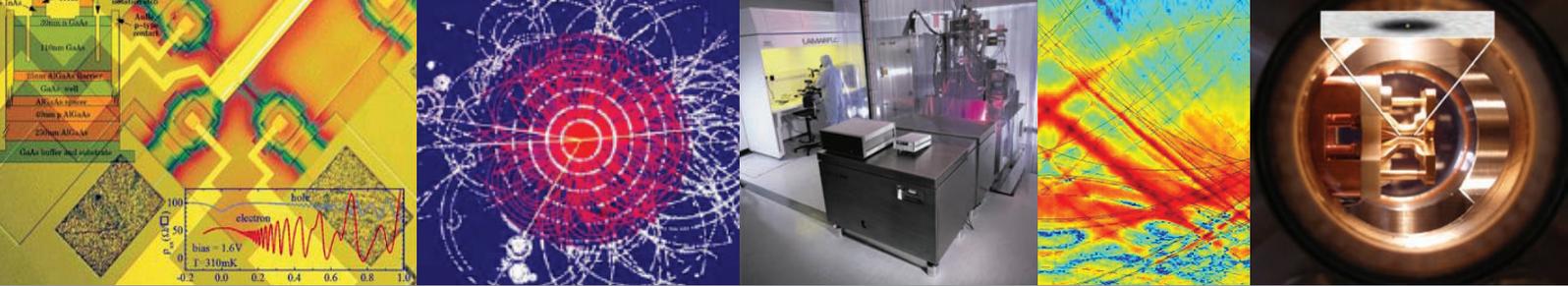
The following have moved on to higher things. We wish them all success in their future careers:

Peter Littlewood	Professor in the Theory of Condensed Matter Group and former Head of Department
Matt Burgess	Finance Manager of the Department
Stefani Gerber	Administrative Assistant in the Biological & Soft Systems Sector
Katherine Habib	Group Temporary Administrator in the High Energy Physics Group
Tracy Inman	Group Administrator of the Biological & Soft Systems Sector
Jerry Lewis	Administrator in the Graduate Students Office

Appointments

We are delighted to welcome the following new members of staff and returnees:

Daniel Corbett has been appointed Computer Officer in the TCM Group
Felicity Footer, High Energy Physics Group Administrator, and **Louise Mortimer**, Scientific Computing Group Administrator, have both returned from maternity leave
Steve Martin has joined the Outreach Team
Glynis Boxall has joined the Laboratory as Receptionist/Cashier
Charlotte King has been appointed Administrative Assistant, Central Administration
Imen Litim is the new Administrative Assistant in the Graduate Students Office
Daniel Sargent has been appointed Administrative Assistant in the Biological & Soft Systems Sector
Thomas Sharp has begun an Apprenticeship in Mechanical Engineering



Cavendish News, continued



25 Years Long Service

The following members of the Department reached their 25th anniversary with the University:

(left to right)

- Michael Payne** Professor of Computational Physics [2000]
- Alan Beckett** Senior Mechanical Workshop Technician
- Daniel Cross** Senior Chief Research Laboratory Technician

Fellowships

Congratulations to the following who have won research fellowships:

- Benjamin Beri** EU Marie Curie Intra-European Fellowship (TCM)
- Katy Brown** Royal British Legion Centre for Blast Injury Studies Research Fellow (SMF)
- Liam O'Brien** EU Marie Curie International Outgoing Fellowship (TFM)
- Jian Sun** EU Marie Curie Intra-European Fellowship (TCM)
- Liwu Zhang** EU Marie Curie Intra-European Fellowship (NP)
- Jeff Waggoner** Final Year of Max-Planck/NRAO Fellowship (AP)
- John Biggins** JRF, Trinity Hall College, (TCM)
- Richard Bowman** JRF, Queens' College, (NP)
- Luke Butcher** JRF, Jesus College, (AP)
- Chiara Ciccarelli** JRF, Gonville and Caius College, (ME)
- Malak Olamaie** JRF, Sidney Sussex College, (AP)
- Eileen Nugent** Lu Gwei Djen Research Fellowship, Lucy Cavendish College, (BSS)

If you would like to discuss how you might contribute to the Cavendish's Development Programme, please contact either Professor Malcolm Longair (msl1000@cam.ac.uk) or Professor James Stirling (HoD@phy.cam.ac.uk), who will be very pleased to talk to you confidentially. Further information about how donations may be made to the Cavendish's Development Programme can be found at:

www.phy.cam.ac.uk/development

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