UNIVERSITY OF CAMBRIDGE

# CavMag

JULY 2012 Issue 8

News from the Cavendish Laboratory

## Inside...



# The Battcock Centre for Experimental Astrophysics

**We are delighted to report that construction will begin this summer of the Cavendish Laboratory's new Battcock Centre for Experimental Astrophysics, bringing all astronomers, astrophysicists and cosmologists from the Cavendish Laboratory and the Institute of Astronomy together on a single site.**

In 2009, we celebrated the opening of the Kavli Institute for Cosmology, which brought together the cosmologists and extragalactic astrophysicists of the Cavendish Laboratory, the Institute of Astronomy and the Department of Applied Mathematics and Theoretical Physics (DAMTP) in a specially designed Centre on the Institute of Astronomy site. It was always recognised that this was the first step in bringing together all the Cavendish astrophysicists with their colleagues in the Institute of Astronomy and DAMTP, in particular, in strengthening interactions between theoretical, observational and experimental astrophysicists.

This second phase of the consolidation of Cambridge Astrophysics, and the next phase of the Cavendish's redevelopment plan, are now being realised through the generosity of two major benefactors. We are most grateful to Cavendish Alumnus Humphrey Battcock and to The Wolfson Foundation for their gifts, which have been matched by the University to enable the new Centre for Experimental Astrophysics to become a reality by about September 2013. The ground-breaking ceremony will take place later this summer.

Humphrey obtained his first degree in Physics at the Cavendish and then took an MBA at the London Business School. From the very beginning of the present Cavendish Redevelopment Programme, Humphrey has been a very strong and enthusiastic supporter of our initiatives. In particular, he was host of a breakfast gathering at the Royal Society in 2010 for Alumni with an interest in supporting our redevelopment efforts – out of that event, the Winton Programme for the Physics of Sustainability was created. In addition, the event resulted in a number of generous gifts to the Laboratory's programme. In recognition of Humphrey's zeal in promoting Cambridge University's and the Cavendish's development programmes, it is most gratifying that the University has agreed that the new Centre for Experimental Astrophysics, an area in which he has a particular interest, should be named in his honour.

*Continued overleaf*

**Above:** An architect's impression of the Battcock Centre for Experimental Astrophysics. The white building on the left linked to the Battcock Centre is the Kavli Institute for Cosmology.

*Continued from overleaf*

We also acknowledge the generosity of The Wolfson Foundation in providing support for the construction phase of the new building. This gift continues the Foundation's long term support of astronomy in Cambridge, the original Hoyle Building of the Institute of Theoretical Astronomy and its associated astrophysics programme being provided by the Foundation. An appropriate form of recognition of this latest gift will be incorporated into the new building.

This is a key development for the redevelopment programme. As stated by James Stirling, Head of the Cavendish Laboratory,

> *"Investment in new facilities is absolutely essential if Cambridge and the UK are to maintain their international leadership in fundamental astronomy and astrophysics research."*

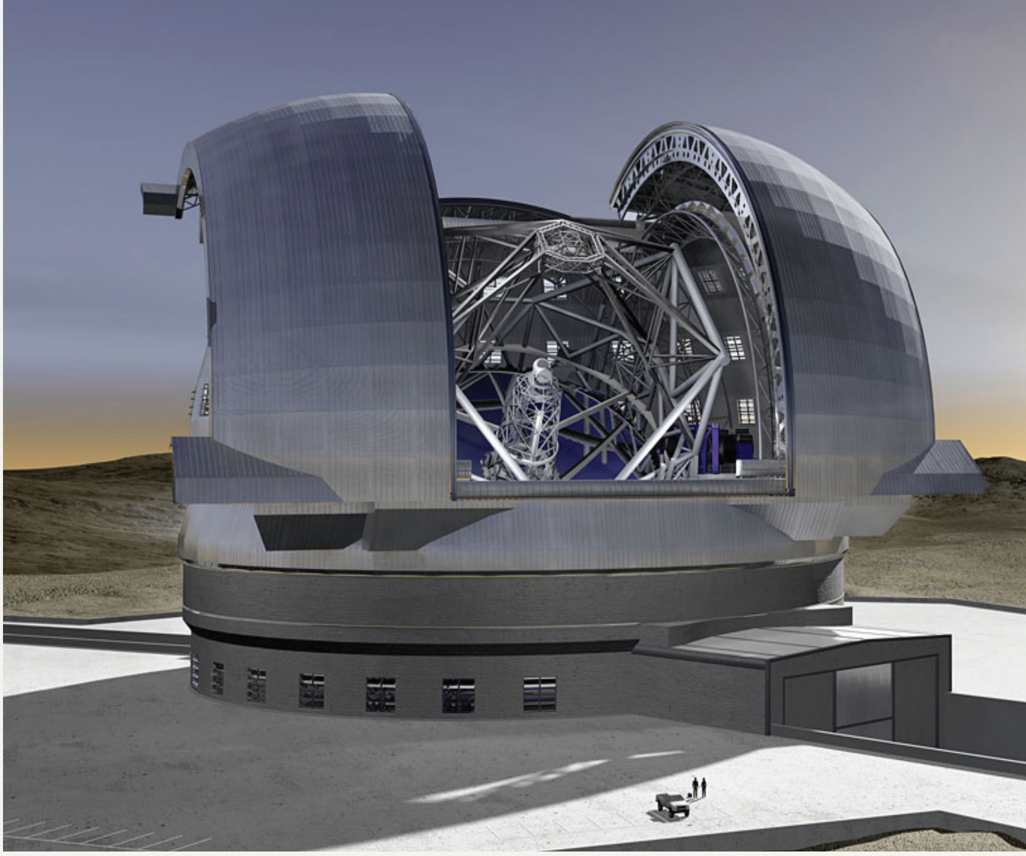
The Cavendish Astrophysics group, led by Paul Alexander, is expected to move into the new building in September 2013. The group members who will be moving are largely associated with Experimental Astrophysics, including the optical-infrared interferometry group led by Chris Haniff and the new activities led by the recently arrived Roberto Maiolino, who had been appointed to the Chair of Experimental Astrophysics in the Cavendish. Roberto describes his programme of experimental and observational research into the formation of galaxies in the following article. The new building will house offices and experimental design space while the implementation of major construction projects will remain on the main Cavendish site.

Rob Kennicutt, Plumian Professor of Astronomy and Experimental Philosophy, former Director of the Institute of Astronomy and now Chair of the School of Physical Sciences, stated:

> *"The Centre for Experimental Astrophysics will bring together world-class groups in astrophysical theory, observation, and instrumentation, and set the future path for Cambridge's continued pre-eminence and leadership in astronomy and astrophysics."*

This is a major milestone in the redevelopment of the Cavendish and exemplifies our determination to make bold steps in advancing research in collaboration with our colleagues in cognate disciplines. With the delivery of these facilities, it will be up to the astronomers to capitalise upon these wonderful opportunities and lead Cambridge Astronomy, Astrophysics and Cosmology to even greater levels of innovation and distinction.

**Malcolm Longair**



# How Galaxies Really Formed

**We are delighted to welcome Roberto Maiolino as Professor of Experimental Astrophysics. His research into the formation of galaxies will be central to Cambridge's endeavours in this key area of astrophysical and cosmological research.**

Understanding how the first stars formed out of pristine primeval gas clouds, how they enriched the Universe with chemical elements and how they were assembled and evolved into the galaxies that we observe in the local Universe is one of the major challenges of modern astrophysics. The investigation of the earliest phases of galaxy formation requires the use of observing facilities capable of detecting primordial galaxies in the early universe. In such galaxies the bulk of the starlight, as well as optical nebular lines associated with star forming regions, are redshifted into the near-infrared bands at 1-5$\mu$m as a consequence of the expansion of the Universe. Strong far-IR fine structure lines, which dominate the cooling of gas in galaxies, are also redshifted into the millimeter and sub-millimeter spectral bands. In recent years my main research interests have focused on extensive near-IR and sub-mm observations aimed at finding and characterising galaxies in the early Universe with the goal of understanding their nature and their mechanisms of formation.

I have exploited near-IR spectrometers on some of the largest telescopes in the world to map star formation, dynamics and the production of chemical elements in distant galaxies (Maiolino *et al*. 2008). These observations revealed an unexpected large population of massive galactic disks in regular rotation at an epoch when the Universe was only 10% of its current age (Fig. 2, from Gnerucci *et al*. 2011). This result contrasts with the expectations of many theories, which predict that the majority of galaxies should be interacting and irregular systems at such early times. Another puzzle is that these young galaxies have a deficiency of chemical elements in their central regions (Cresci *et al*. 2010), quite the opposite of what is observed in local galaxies where the central regions are more chemically enriched. This result may suggest that at early epochs massive flows of unprocessed gas are conveyed into the central region of galaxies diluting the concentration of chemical elements and boosting star formation at the same time.

These results show that our understanding of galaxy formation in the early universe is still quite immature. Observations of large samples of distant galaxies, extending to the epoch of formation of the first stars and probing the faint galaxy population are required to obtain a clear picture of the origin of galaxies. That is my motivation for dedicating substantial efforts to supporting major future observing facilities that are expected to play a key role in this field.
I am the project scientist of MOONS, a near-IR multi-object spectrograph in its design phase for the Very Large Telescope (VLT) of the European Southern Observatory. With 1000 fibers positioned in the telescope focal plane, MOONS will simultaneously take near-IR spectra of several hundred galaxies, which would take hundreds of nights with single-

**Fig. 1 (above).** Artist's impression of the European Extremely Large Telescope (E-ELT) on Cerro Armazones (Chile).

object spectrometers. The resulting sample of several thousands of distant galaxies in a few nights of observation will allow us to assess statistically the properties of distant galaxies and how these correlate with the large scale cosmic structures out of which they are forming.

Major breakthroughs in this field will certainly be achieved through the James Webb Space Telescope (JWST See CavMag 5, pp 8-9), the successor of the Hubble Space Telescope. The JWST has a 6.6m deployable primary mirror optimised for near-IR observations - launch is scheduled for 2018. By exploiting the absence of background radiation and atmospheric absorption which plague ground-based near-IR observations, the JWST will achieve sensitivities orders of magnitude greater than any previous observatory. I am part of the science team responsible for the science requirements and exploitation of the JWST near-IR spectrometer (NIRSpec), which will be the first multi-object spectrograph in space. NIRSpec will have the sensitivity to detect and identify the first stellar populations formed in the Universe out of the pristine, primordial gas.

NIRSpec will not have the spectral resolution to investigate the physics and chemistry of the interstellar medium of primordial gas clouds but this will be feasible with the European Extremely Large Telescope (E-ELT, Fig. 1). This giant segmented mirror telescope with an aperture of 38 meters is scheduled to see 'first light' in 2022. I am the project scientist of SIMPLE, the near-IR high resolution spectrometer for the E-ELT. By exploiting the unprecedented photon collecting area of the E-ELT, SIMPLE will allow us to map the intergalactic and interstellar gas clouds through their absorption signatures against the stellar light of primordial galaxies. By measuring the relative abundance of various elements in the early Universe, the SIMPLE data will reveal the chemical imprint of the enrichment produced by the first generation of stars. Such chemical patterns will allow us to determine the properties of the first stars that populated the Universe.

The millimeter-submillimeter spectral region is a complementary, extremely powerful waveband for exploring the early Universe. The strongest emission lines in any galaxy are the far-IR fine structure lines, which are redshifted into the mm/submm bands at high redshift. The [CII] 158μm fine structure line is the strongest of these transitions. Since its first detection at high redshift (Maiolino *et al*. 2005), it is now routinely exploited by us and several other teams to detect and characterise distant galaxies, even those which are heavily obscured by dust and undetectable at optical/near-IR wavelengths. As an example Fig. 3a shows the [CII] map of the host galaxy of a quasar at a redshift z=4.4 (Maiolino et al. 2009, Gallerani et al. 2012). Beside the compact emission associated with the quasar host galaxy, the [CII] map reveals the presence of a companion galaxy with a 10 kpc length scale. This galaxy is completely undetected at optical and near-IR wavelengths because of heavy dust obscuration.

The [CII] line will be the key tool to discover and characterise primordial galaxies with ALMA (see CavMag No. 7). Once completed, ALMA will be orders of magnitude more sensitive than past facilities. Already with the first 18 antennae in operation, ALMA has been delivering ground-breaking results, with outstanding [CII] maps of distant galaxies (Wagg *et al*. 2012) and the detection of far-IR fine structure lines much fainter than [CII]. As an example, Fig. 3b shows the ALMA map obtained by us of the [NII] 205μm line, redshifted into the millimeter band in a galaxy at z=4.7 – the line is 20 times fainter than the [CII] 158μm transition (Nagao *et al*. 2012). The detection of this line indicates that surprisingly this primeval galaxy was already 'chemically mature' at an epoch when the Universe was less than 10% of its current age, a challenging result for current theories of galaxy formation.

ALMA has however a relatively small field of view, which is not suitable for surveying large areas of the sky, which is required to investigate the relation between galaxy formation and the environment. For this reason, we are developing, together with the Cavendish Detector Physics group, a totally new concept of millimeter-submillimeter 'on-chip' spectroscopy. Thanks to miniaturised filters along a waveguide, deflecting the radiation at different wavelengths to separate detectors, it is possible to develop very compact micro-spectrometers. An array of thousands of such micro-spectrometers can be located at the focal plane of large millimeter-submillimeter telescopes to obtain simultaneously thousands of spectra over a large area of the sky. This instrument will allow us to obtain an unprecedented and, most importantly, unbiased survey of star forming galaxies in the early universe.

**Fig. 2 (below)**. Maps of a star forming galaxy at z=3, obtained with the near-IR integral field spectrometer SINFONI at the VLT. *Left:* Distribution of the [OIII] 5007Å nebular line (redshifted to 2μm) tracing star formation. *Center:* Galaxy kinematics revealing a regular rotation pattern typical of local massive galaxy disks. *Right:* Map of the chemical composition, revealing a deficiency of chemical elements in the central region (from Cresci *et al*., 2010).

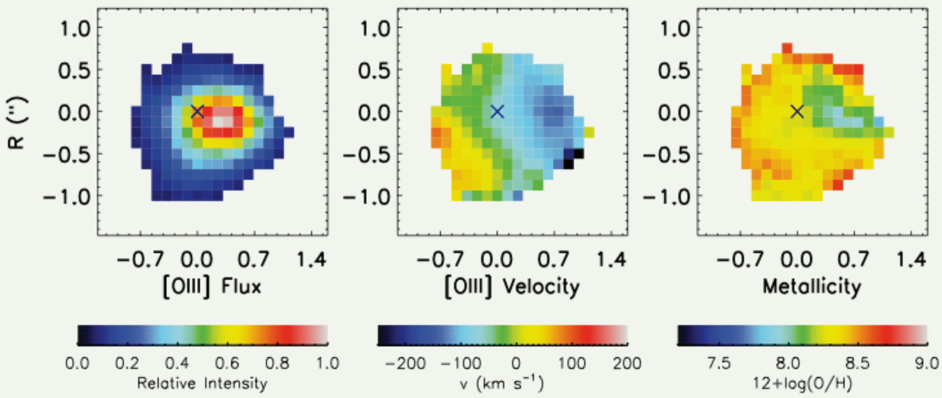
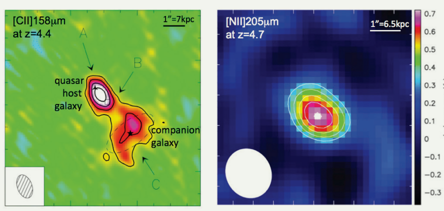



**Fig. 3 (below)**. *a)* Map of the [CII] 158μm fine structure line of a quasar host galaxy at z=4.4, revealing a companion galaxy that is undetected at optical/near-IR wavelengths (Gallerani *et al*. 2012). b) Map of the [NII] 205μm fine structure line in a distant galaxy at z=4.7 obtained with the first 18 antennae of ALMA (Nagao *et al*. 2012).





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# Two-for-One Solar

**Solar cells are an obvious way to harness carbon-free energy, but solar electricity is still too expensive to compete with conventional electricity generation without subsidies. Making solar cells more efficient will help, provided it can be done without increasing the cost of the cell. Neil Greenham describes a recent significant advance towards achieving this goal.**

The solar cells that you might install on your roof typically have efficiencies in the range 20-30%, and there are good physics reasons why it is difficult to exceed this. Solar cells are usually made of a single type of semiconductor, like silicon, which can only absorb photons with energies greater than its bandgap. The solar spectrum is broad and so some photons will not be absorbed. Higher-energy photons will be absorbed, but the energy in excess of the bandgap is rapidly lost as heat, so that only the bandgap energy is collected. The trade-off between these two losses places a fundamental limit on the efficiencies of solar cells.

Researchers in the Optoelectronics Group at the Cavendish have recently demonstrated a route that could get round this problem. In a paper published in Nano Letters early this year [1], they have shown that it is possible to collect two pairs of charges, instead of the usual one, when a photon is absorbed in the organic molecular semiconductor pentacene. Absorbing photons in organic materials generates neutral excited states known as excitons, which come in two varieties, singlet and triplet, depending on whether they have a total spin of 0 or 1. Absorbing a photon generates a singlet state, but in pentacene, where the triplet energy is less than half the singlet energy, this singlet state rapidly falls apart into two triplet states. This process of 'singlet fission' has been known for some time, but time-resolved spectroscopy measurements at the Cavendish have recently shown that the process is very fast (sub-picosecond), and hence likely to be efficient.

If these triplet excitons can be dissociated into charges then it is possible for a current corresponding to two electrons to flow in the solar cell for just one absorbed photon. However, this alone doesn't help improve the efficiency of a solar cell. Compared with a normal organic solar cell where singlet excitons are dissociated, the current is doubled but the voltage is halved, so there is no additional power. The trick is to combine two materials in the same solar cell – a layer of pentacene with a layer formed from nanoparticles of an inorganic semiconductor such as lead sulphide. The nanoparticles have a low bandgap, and hence are good at harvesting photons in the near-infrared region of the solar spectrum. The voltage produced by the cell is rather low, and this would normally be a problem since only a small fraction of the energy of the visible photons would be collected. In the new cell structure the visible photons can be absorbed in pentacene and can generate two pairs of charges, so although the voltage is low the energy of the visible photons is not wasted.

Although the early results clearly showed that singlet fission is contributing to the current in the solar cell, the overall efficiency of the cells was low, at less than 1%. Despite some overenthusiastic reports on the web that "Cambridge researchers have produced a 45% efficient solar cell", there is in fact a long way to go to improve efficiencies towards this new maximum limit and to apply the approach in practical cells. Existing strategies to improve efficiency use complex 'tandem' stacks of solar cells with different bandgaps. One attraction of the new approach is that the device structure is relatively simple, and should be possible to apply easily over larger areas. Work in the last six months has already improved efficiencies by a factor of five by tuning the device design, and better understanding of the physics of device operation is expected to lead to further improvements.

[1] Bruno Ehrler, Mark W. B. Wilson, Akshay Rao, Richard H. Friend, and Neil C. Greenham, Nano Letters, **12**, 1053 (2012).

**Neil Greenham**

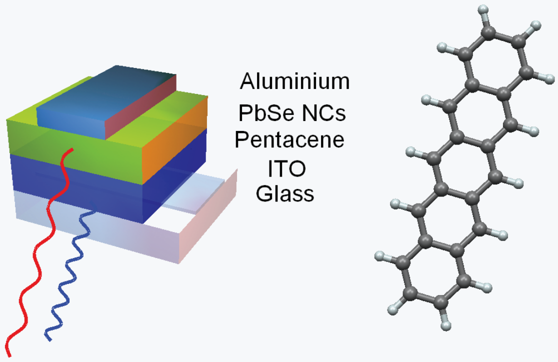



**Fig. 1.** The pentacene molecule (right), and the structure of the most recent fission-sensitised cells using lead selenide nanocrystals (left).

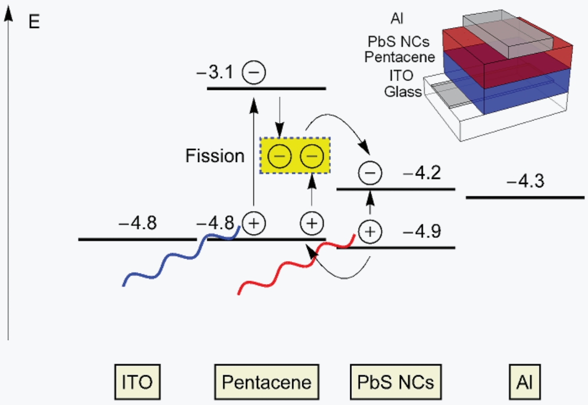
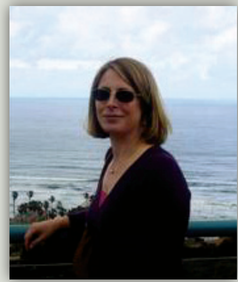


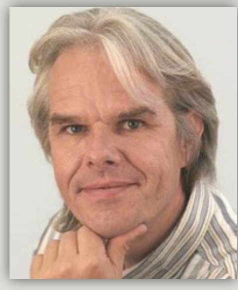

**Fig. 2.** Device schematic and energy diagram and the proposed working mechanism of the solar cells. The excited singlet state in the pentacene layer converts to two triplet states after about 80fs. These triplets are dissociated at the pentacene/PbS nanocrystal interface. At the same time the PbS nanocrystals absorb the infrared portion of the incident light.

**Below.** Bruno Ehrler, Ph.D. student at the Cavendish, who has developed the new solar cells based on singlet fission, collects the Innovation in Solar Technology award at the UK Solar Conference, 2012.

# Do you like butter?

**Silvia Vignolini, Beverley Glover and Ulli Steiner unravel the remarkable physics behind the old children's game of holding a buttercup under the chin**





Plants develop and adapt their morphology and anatomy depending on the light conditions in which they grow. They exploit light for photosynthesis, but use it also to signal to other species. The purpose of flowers is, of course, the attraction of pollinators. Their optical appearance was thought to be mainly pigment-based but it became evident very recently that the shape and the anatomy of the different petal tissues strongly affect their optical appearance.

It is now increasingly clear that flowers develop photonic structures that mould the flow of light. The resulting structural (spatially variable) colour and other effects such as strong glossiness are used by some plant species to create optical effects that stand out in the sea of colours of a spring meadow.

The exploration of the unusual optical properties of flowers and their relationship to the petal anatomy is the subject of a collaboration between Silvia Vignolini and Ulli Steiner at the Cavendish Laboratory and Beverley Glover at the Plant Science Department, combining the spectroscopic characterisation of flower petals with plant genetics and bee experiments. These investigations allow the disentangling of the optical response of the different petal tissues.

A striking example of how flowers employ photonics is the humble meadow buttercup *Ranunculus repens*. It is perhaps best known for the children's game of holding a buttercup under the chin. The resulting yellow reflection onto the chin is said to mean that the person likes butter (Figure 1), an effect that is unique to the buttercup and some closely related *Ranunculus* species. In a recent study, the Cavendish-Plant Science collaboration demonstrated that this optical effect arises from the unusual glossiness of the buttercup. The anatomy of the *Ranunculus* petal consists of a flat cuticle layer that is superposed on a highly diffusive starch background, giving it a similar

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**Fig 1 (above right)**. Picture of a *Ranunculus repens* flower. (Inset) Chin illumination by the flower in ambient sunlight.

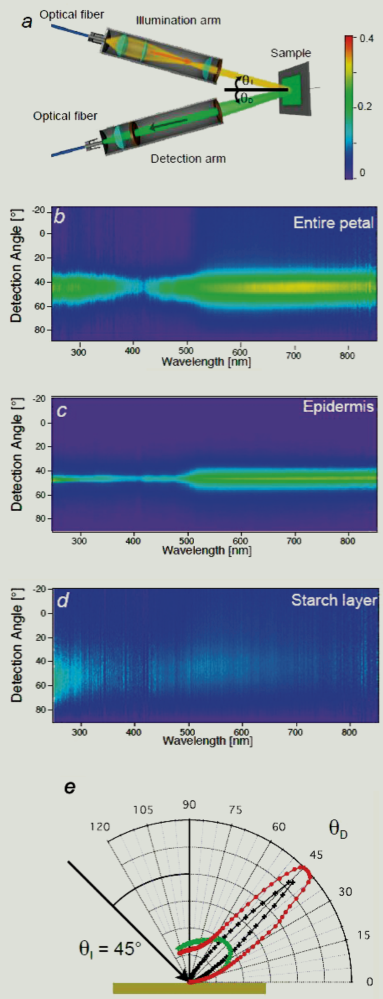
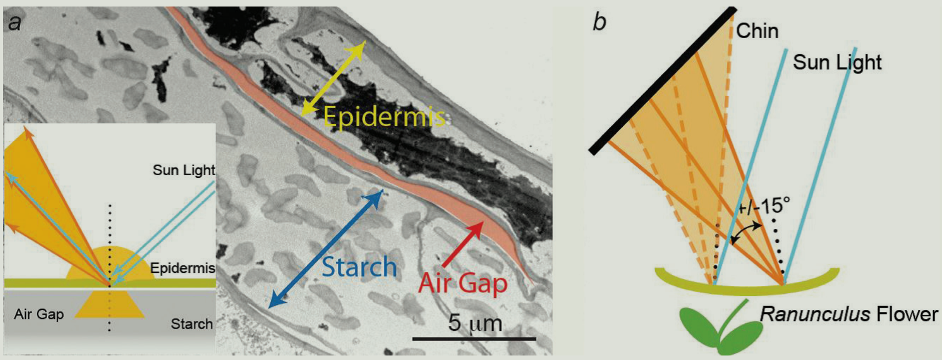



**Fig 2 (right)**. (a) Schematic of the optical goniometer set-up used in the experiment. Angle-resolved measurements of the scattered intensity from (b) the entire petal, (c) the epidermal layer only, and (d) the starch layer. The illumination angle was 45° with respect to the surface normal. (e) Reflectivity averaged over the 500–600 nm wavelength range of the entire *Ranunculus* petal (red), the epidermal layer (black), and the starch layer (green). The intensity scale is in arbitrary units.

**Fig 3 (below)**. (a) Cross-sectional transmission electron micrograph (TEM) of a *Ranunculus* petal, indicating its salient anatomic features. The inset is a schematic drawing of the reflection of light from the petal morphology. (b) Schematic illustrating the buttercup chin illumination effect.

All Figures are adapted from J. R. Soc. Interface, doi:10.1098/rsif.2011.0759



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combination of gloss and diffuse retro-reflection as that of coated photographic paper.

Nature has, however, a further trick up its sleeve. To compensate for the relatively low refractive index of the top epidermal layer, the buttercup enhances specular reflection by providing not one, but two planar reflective surfaces.

The highly transparent, pigment-bearing adaxial epidermal layer is separated from the lower starch substrate by a sparsely supported air-gap. The primary specular reflex of the petal surface is thereby supplemented by a secondary specular signal arising from the reflection at the lower-lying interface. The carotenoid-bearing film thereby acts as a colour filter, painting the secondary specular reflex yellow. The remaining transmitted light is finally backscattered by the starch layer, giving rise to a diffuse yellow background colour, enhancing the overall brightness of the petal.

The buttercup petal anatomy and its optical consequences can be readily tested by the layperson. Using a fine pair of tweezers and some patience, the epidermal layer can be peeled off a buttercup petal. Placed on a planar glass slide, it becomes evident that the yellow colour and the glossiness emanates from this layer only, leaving behind a diffuse white-looking petal remainder.

This is shown more quantitatively in Figure 2, where the optical response of the individual epidermal layers of *Ranunculus* petals were optically characterised using the goniometer setup of Figure 2a. The angular-resolved spectra in Figure 2b-d contrast the spectral response of the entire petal, the peeled-off top epidermal layer, and the underlying starch layer, respectively. For an incidence angle of 45°, the high intensity reflection at 45° corresponds to specularly reflected light. The reduced signal in the 350-500 nm-range arises from pigment absorption, giving the flower its yellow colour. Notice also the residual signal in this wavelength-range which arises from reflection off the top-most petal surface. While a strong reflection is seen for the top epidermal layer and the entire petal, it is absent in the starch layer, which shows only diffuse scattering at all wavelength into all angles. This is also observed in the polar graph of Figure 2e, where the pointed lobes in the 500-600 nm wavelength-band correspond to specular reflection, and the more circular signal is indicative of diffuse scattering.

The glossiness of the buttercup has intrigued scientists for more than a century, with a first seminal publication dating back to 1885. It required however the tools of the 21st century to describe fully its optics. The air gap shown in the cross-sectional TEM image of Figure 3a, separating the top-epidermal film from the lower-lying layer, is unparalleled in other plant species and it is the cause of the unusual buttercup gloss. The spectra of Figure 2 also show, apart from the yellow dip, the broadband nature of the gloss, extending far into the ultraviolet waveband. This is perhaps one of the more significant new findings, given the good vision of bees at ultraviolet wavelengths.

Figure 3b finally rationalises the taste for butter of children playing outdoors. The yellow chin reflection is merely a consequence of the mirror-like reflection arising from the unusual buttercup gloss, aided perhaps by the focussing of the reflected light by the curved assembly of the petals in the flower.

# Tackling Malaria

**Pietro Cicuta is a University Lecturer and a member of the Biological and Soft Systems Sector. He has been involved with the Physics of Medicine Initiative since its foundation.**

My area of research is in biological physics, building on my interests in soft materials and physical chemistry. I develop experimental techniques aimed at opening up new research areas. One aspect of this is the automation of video microscopy platforms – our objective is to push back the frontiers of live cell imaging.

*P. Falciparum* is the deadliest strain of human malaria, a disease for which there is no vaccine and increasing drug resistance. The World Health Organisation (WHO) data show that in 2010, "malaria caused an estimated 655,000 deaths, mostly among African children". 210 million people have malaria, and it is the prime reason for economic underdevelopment in vast areas of the world. A few years ago, through one of those chance encounters that makes working in Cambridge so rewarding, I teamed up with malaria biology experts Teresa Tiffert and Virgilio Lew in the Physiology department in Cambridge as part of the Physics of Medicine initiative.

Malaria is a very complex disease, and most people are familiar with the fact that a certain species of mosquito can carry the parasite. Another part of the disease takes place however once the parasite has entered the human blood stream. The parasites, known as merozoites in this phase, grow within red blood cells, multiplying for many hours, and then egress, infecting neighbouring cells. This cycle repeats over days, vastly amplifying the number of parasites. This is the stage of the disease which causes the most severe and potentially lethal symptoms such as internal bleeding. Attacking the egress/invasion process is a potential target for drugs or vaccines.

Studying the moment when a parasite enters a new red blood cell has proved technically very difficult to investigate in the laboratory. Through the work of PhD student Alex Crick and post-doc Jurij Kotar we have found a means of doing this. We can now record multiple egress and infection events at a high frame rate. This is possible thanks to an automated system that finds and recognises mature schizonts, meaning cells full of parasites about to egress, in an imaging chamber and then triggers high speed recording of the pre-egress and egress stages. This platform can run for a few days unsupervised, collecting an unprecedented body of data on this elusive stage of the progression of the disease (Fig. 1).

We aim to elucidate the role of the red blood cells targeted for invasion by the merozoites: an irreversible apical contact is the necessary preliminary step for parasite penetration. The existing video recordings show that the random contact between a merozoite and the red cell surface results in a sequence of rapid, vigorous and dynamic shape changes of the red cell which reverts to biconcave quiescence as soon as the merozoite is seen apically aligned, poised for penetration (Fig. 2). The mechanism of this unique motile response aimed at aiding invasion, and not seen in any other context, is unknown. Intervening with optical forces at just the right time in the penetration stage will allow us to measure the binding force between a merozoite and a red blood cell. Red blood cell mechanics, which we have studied carefully in recent years for the case of healthy erythrocytes, can be monitored optically throughout the maturation stages.

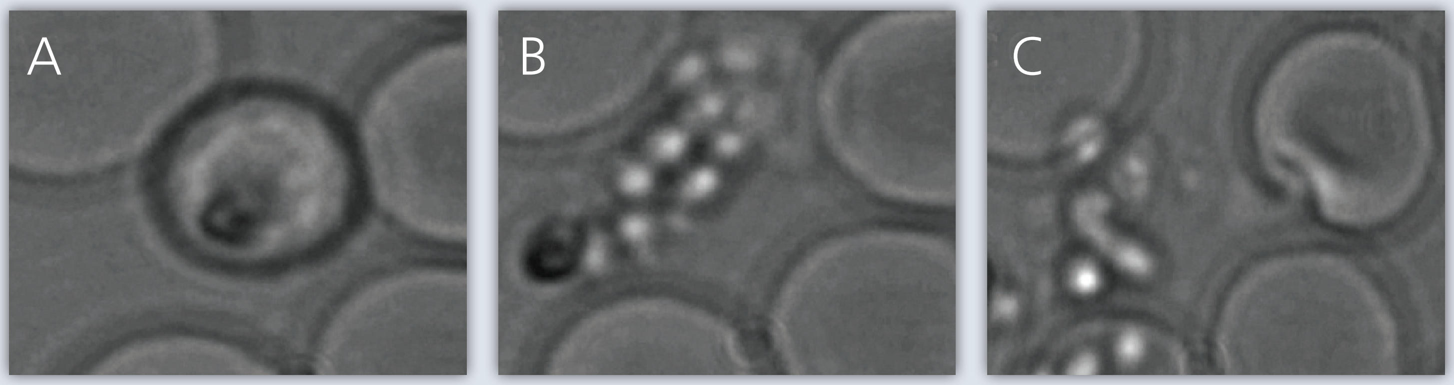



**Fig. 1**. Our unique automated imaging platform allows us to gather high frame rate videos of rare processes, with no human intervention. These selected frames show A: a pre-rupture infected cell (schizont); B: explosive egress with merozoite dispersal; C: first deformation response on merozoite-red blood cell contact (upper right cell).

Understanding an infection process through imaging is challenging because the relevant dynamics takes place on very different time-scales. Typically some biological processes occur very fast, for example, receptor clustering and binding can occur over fractions of a second, whilst other aspects, for example changes in the gene expression, take fractions of hours. With two biological entities interacting, each can be characterised by different timescales. The challenge is to capture enough data at the 'fast' end with the well-known limitations set by camera acquisition times, low light, and ultimately drowning in raw unprocessed data, while at the same time monitoring the systems at the 'slow' end, again without drowning in unnecessary data and overcoming the difficulties of manually running experiments for more than 24 hours.

The automation we have developed addresses these issues, and improves the way that live cell imaging is carried out. We culture and deliver cells through microfluidic chemostats and channels designed in-house. Then we use video recognition software to enable the rare events to be identified, automatically recorded, probed/perturbed by optical forces if necessary, and ultimately statistically significant data to be recorded. We code software tools to perform on-line image analysis to inform the physical hardware actions, and to collect data efficiently. Optical tweezers are integrated into the microscope, to move cells and measure adhesion forces. Ultimately we are aiming to facilitate a major leap forward in the type and quality of data that can be obtained by these systems.

In an extended collaboration with Julian Rayner (Wellcome Sanger Institute) and Clemens Kaminski (Chemical Engineering) we plan to develop further our imaging to include fluorescent markers in order to elucidate cell biological processes that have not been measurable up to now. The hope is to inform the design and the screening of possible drugs and vaccine candidates for malaria.

The Physics of Medicine building in which I work is ideally organised for the work described here, as well as hosting a community engaged in interdisciplinary biophysical research. For example, we have bio-chemical characterisation facilities and areas for safe handling of biological organisms including Hazard group 2 and Hazard group 3 such as *P.Falciparum*. I am also a member of the Nanoscience Center, with full facilities for microfluidic device fabrication.

You may wonder why a physics department should get involved in the areas of biology and medicine. It becomes obvious once one gets involved: biology and medicine are an endless source of challenges, and these are what drive a scientist. It is also clear that through our physics competences and approaches we can have a real and direct impact. Physics as a subject is defined by posing frontier questions, which change over time. As we often say, "Physics is what physicists do". We work at an intersection of what the community is able to address given tools and resources, and what society and science need from us. Through new technology, as well as modelling approaches and the tremendous work from the biological side in bringing so much of that subject onto a quantitative basis, many of the central questions in biology are also becoming part of today's physics.

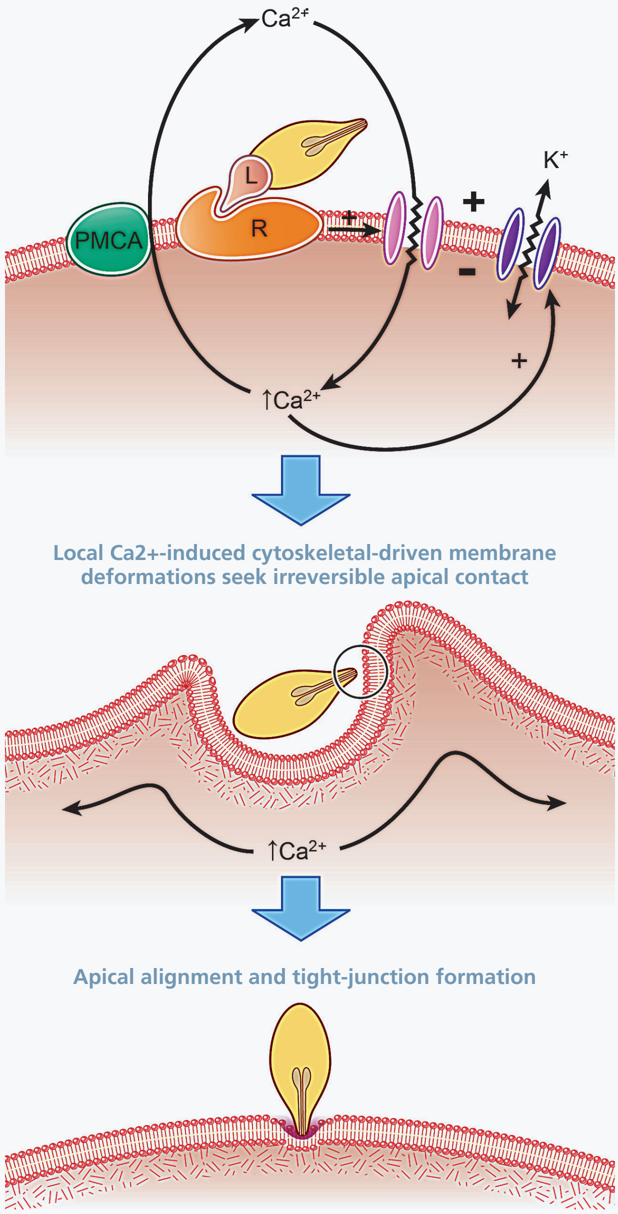



**Fig. 2.** How does a parasite orient itself to make its way through a membrane into the red blood cell (pink)? This cartoon depicts our hypothesis, whereby the parasite causes a calcium spike, which results in a contraction of the red blood cell membrane, leading to optimal orientation. Current work is aiming to verify this idea.

# Shedding Light on Quantum Information Networks

**Mete Atature, recently promoted to a Readership, draws inspiration from the ancient Greek Antikythera mechanism in the search for a functional quantum computer.**

More than 2000 years ago a mechanical construction of connected gears was built to compute the exact occurrence of periodic phenomena based on the motion of the heavenly bodies. Coined as the first computer, the Antikythera mechanism could perform only a few selected tasks, such as predicting the dates of past and future eclipses as well as the Olympic Games, but it did so with immense accuracy (Fig.1). The grand challenge was to use simple mechanical elements to achieve unprecedented long term accuracy for its predictions. Arguably, the key to its success was an ingenious pin-and-slot mechanism for implementing Hipparchos' epicyclic Lunar theory which takes into account the slow precession of the Lunar orbit. The Greeks already had a sophisticated understanding of Astronomy and Mathematics, but building the Antikythera mechanism bridged the chasm between the predictably simple and the unpredictably complex.

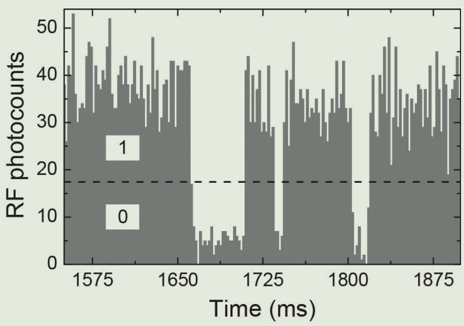
The quest for quantum computing carries similar overtones. The absence of a readily available building block forces researchers to cooperate across disciplines for higher level control over matter. The scalability challenge causes a further obstacle for the implementation of quantum computing concepts. The search for a single physical system to answer all demands, that is, the ultimate quantum bit, has given way to a quantum information network utilising the specialised strengths of disparate physical systems, *stationary qubits*, interconnected by the transfer of quantum mechanical information, *flying qubits*. To this end, quantum dot spins and photons shine as potential candidates for building such an architecture. On the road to realising a quantum information network there are a number of grand challenges for quantum dot spins and photons. To this end, our research group in the Atomic, Mesoscopic and Optical Physics group (AMOP) of the Cavendish Laboratory took on two challenges on the way to realising a quantum information network: the ability to measure spin projection in a single attempt with high fidelity and generating single photons of ultra-high coherence.

The main obstacle for optical measurement of a single spin has been the intricate dynamics between measurement and back-reaction. While optically exciting a quantum dot, the spin state of the confined electron is altered in the process, which is a major hindrance for any application within quantum information science. In order to circumvent this problem, the AMOP group engineered an alternative system comprising two separate quantum dots in close proximity. Here, the optical transitions of the additional quantum dot act as a local sensor for the nearby qubit. When probed resonantly, these transitions generate a stream of single photons conditional on the electron spin state. Fig. 2a shows a continuous measurement of the state of the qubit as it goes through spin jumps in real time. These results from the AMOP Group indicate 96% measurement fidelity for a single electron spin [from A. N. Vamivakas *et al.*, *Nature*, **467**, 297 (2010)].

The second challenge is perhaps common to all single photon sources, that is, the generation of highly coherent flying qubits. Single photons from solid-state sources usually have finite coherence, which hinders the construction of a decoherence-free quantum network. To date, demonstrations of photon indistinguishability and coherence have revealed the dramatic effects of these fundamental limitations. The members of the AMOP group tackled this long-standing problem by dramatically altering the way a single photon can be generated – instead of relying on spontaneous emission of a photon, where the generated photons embody all dephasing dynamics of the excited states, they utilised an alternative fully coherent scattering process, where the scattered single photons are now generated in the image of the excitation laser [C. Matthiesen et al., *Phys. Rev. Letts*, **108**, 093602 (2012)]. Fundamentally different from spontaneous emission, these coherent photons sustain phase-correlation with the excitation laser down to milliHz spectral stability – more than a billion times better than before!

These results immediately open a number of exciting directions for the near future. Individual photons can now be amplitude and phase tailored by the excitation laser, and single photons from separate quantum dots can be forced into mutual coherence within a quantum circuit. In the longer term, ultra-coherent photonic cluster states can be generated using single spin transitions, and we could even envisage coupling qubits defined by disparate species via shared photonic interconnects, that is, a hybrid quantum network. There is still a long way to go and many things to resolve, but we are a step or two closer to figuring out the gears, the nuts, and the bolts for an Antikythera mechanism of the quantum world.

**Fig 1 (top)**. The Antikythera mechanism and a glimpse into its inner workings. *The original photos and the figure courtesy of the Greek Atomic Energy Commission, Professor Rien van de Weijgaert and Carsten Schulte, respectively.*



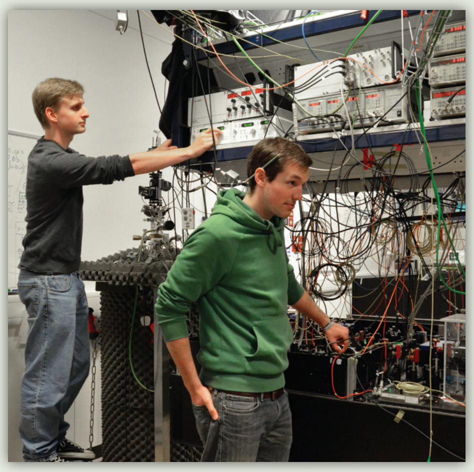



**Fig 2. (a)** Continuous measurement of a spin qubit. **(b)** Members of AMOP in the quantum computation laboratory.

# Sculpting Quantum Matter with Light

**Jeremy Baumberg and Natasha Berloff demonstrate how quantum phenomena can be observed on the macroscopic scale opening up remarkable future possibilities.**

Quantum Mechanics is counterintuitive but as physicists we become familiar with it, working far outside our normal human experience, with individual atomic-scale particles. Much of the history of the Cavendish has been punctuated by the development of new ways of exploring quantum systems through probes that extend our senses into this domain. What would it be like, however, if we could directly watch quantum mechanics in action, sitting on a table in front of us? As undergraduates, we drew wavefunctions with graceful oscillations and nodes, but might we literally create a box to confine them and see quantum evolution in front of our eyes?

In our recent collaboration with the experimental team at the NanoPhotonics Centre, we are exploring a system which allows us to do just that. We investigate the properties of a 'quantum liquid' which spreads out in sheets hundreds of microns wide but which, unlike normal liquids, possesses a global macroscopic quantum phase over distances visible to the naked eye. In 1937, Pyotr Kapitsa, after whom our building is named, discovered the peculiar properties of quantum liquids and more recently Brian Josephson showed how electrons in superconducting states could dance to the same tune. But in our recent work, the particles making up the liquid are not the 'fundamental' or 'natural' ones, such as helium atoms or electrons in lead, but are created inside semiconductors built into nano-structures of exquisite precision.

Designing and growing stacked layers of selected atomic species such as gallium, arsenic, indium and aluminium, we can control where electrons move and how they interact with light. In our devices, we sandwich the electrons into thin sheets, in which they absorb and emit light of a specific colour. Around these 'quantum wells' we grow extremely shiny mirrors which efficiently trap light in between them, but only of a colour set by the micron-sized gap between the mirrors because of the need to recirculate the light to return in phase after each round trip. By matching the colour of this microcavity light and the electronic emission, radiated photons from relaxing electrons are immediately returned back into the semiconductor, re-exciting electrons into an identical state. So energy continually oscillates between light and matter. This coherent mixture of electrons and photons forms a new quasiparticle called a 'polariton', with completely new properties that we can control through clever design.

The photon component of polaritons makes them thousands of times lighter than electrons, billions of times lighter than typical atoms, and achieves sufficient densities to form polariton Bose-Einstein condensates (BECs). In a BEC the quantum phase of the bosonic particles synchronises and creates a single macroscopic quantum object. This was first achieved with atoms at ultra-cold temperatures, on the scales of nanoKelvins. The achievement of a polariton BEC in 2006 by a team at the Cavendish [1] was followed by a blossoming of experimental activity eventually allowing us even to reach room temperatures [2].

version of the simple quantum harmonic oscillator states (Fig.1) but now on the scale of tens of microns across and so easily seen through a magnifying lens [3]. Creating arbitrary configurations of condensates on the fly, we can trap polariton condensates and start to teach them tricks. For instance we can create polariton interferometers which respond exquisitely sensitively to their environment. We have achieved a long held dream of creating macroscopic quantum states which we can tweak and prod on the human scale.

One of our major goals is the creation of such condensates at room temperature and by electrical excitation creating truly quantum devices. We have found that by stacking double sheets of electrons inside these structures, we can enable the polaritons to undergo quantum mechanical tunnelling which can be measured electrically [4]. And we have devised new ways of coaxing polariton condensation at higher temperatures. No fundamental limits now stand in the way of quantum devices operating in the palm within the next few years.

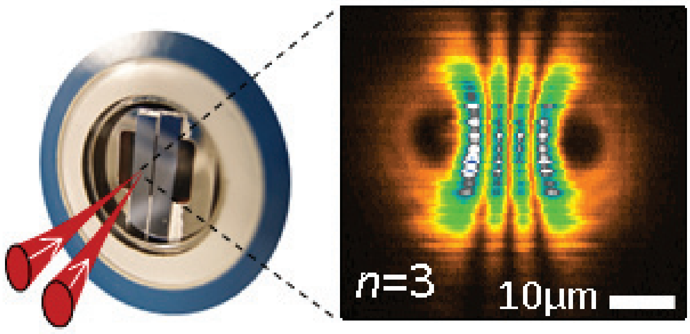



**Fig.1**. Two CW pump lasers focussed 20μm apart onto the microcavity (black holes on right image) create a trap for the polariton condensate in between. Photon emission shows the spontaneously formed n=3 quantum harmonic oscillator state [3].

Our recent work published in *Nature* and *Science* this year is based on producing samples so uniform that the polaritons can skate sideways at will inside their sheets, unfettered by imperfections, allowing the direct study of the two-dimensional quantum liquids they form. Shining light from above onto a spot on the surface excites polaritons, which diffuse out sideways and condense into a BEC when they are dense enough. Above this threshold a single quantum phase describes the wavefunction of all the polaritons together. Now we can easily inject two condensates in close proximity and watch them interact. One discovery has been the spontaneous emergence of patterns and dynamics in these condensates, which is only possible because they are not closed systems since polaritons continually decay into light escaping through the slightly leaky mirrors. We see coherent packets of polaritons oscillating back and forth, forming a precise


Jeremy Baumberg heads the NanoPhotonics Centre (jjb12@cam.ac.uk). Natasha Berloff works on the mathematical modelling of quantum fluids, from liquid helium to BECs of atomic and solid state condensates and is a reader in Mathematical Physics in the Department of Applied Mathematics and Theoretical Physics (N.G.Berloff@damtp.cam.ac.uk).



[1] Kasprzak, J *et al*., 2006. Nature, **443**, 409. Bose-Einstein condensation of exciton polaritons.

[2] Christopoulos, S. *et al*., 2007. Phys.Rev. Lett., **98**, 126405. 300K polariton lasing in semiconductor microcavities.

[3] Tosi, G. *et al*., 2012. Nature Physics, **8**, 190. Sculpting oscillators with light within a nonlinear quantum fluid.

[4] Cristofolini, P. *et al*., 2012. Science, **336**, 704. Quantum Tunneling with Cavity Photons.

# Cavendish Industrial Engagement Forum with BP

**The Cavendish Laboratory recently staged the first of a series of engagement days with companies, as part of the Laboratory's initiative to develop closer contacts with industry.**

In partnership with Cambridge Enterprise, the first Cavendish Industry Engagement Forum was held with BP. The primary purpose was to give Cavendish post-doctoral researchers and PhD students experience of considering industry issues through structured discussions over a day. BP put forward four themes in areas crucial to their business, and participants were divided into groups to look more closely at possible ways of tackling these.

James Stirling, Head of the Cavendish Laboratory, said:

> *"The Industry Engagement Forums are an important part of our strategy both to forge closer links with industry and to enhance the broader skills training that we provide for our students and postdocs. We are delighted that BP agreed to be our first Forum partner. We have longstanding and very productive links with the company, and we were particularly impressed by the positive way in which they engaged with the event."*

Feedback from the delegates was, overwhelmingly, that they had learnt a good deal about BP's activities, had gained a broader perspective on the needs of industry, and had greater realisation that a career outside of academia could be just as rewarding as pure academic research. They also gained more understanding of the type of work that is done by scientists in industry and realised that the BP experts shared similar views and outlooks. The day also gave researchers and postgraduate students the opportunity to meet others in different research groups across the Cavendish Laboratory.

Outcomes at the end of the day were three research topics, which will be discussed and developed further with BP.

Andy Leonard, Vice President, BP Cambridge, said:

> *"Today was something of an experiment for all of us. There was a terrific level of energy throughout the day and I think it was engaging for all those who participated. I believe we succeeded in highlighting the role that physics can play in addressing difficult challenges in our business and that there are numerous ways to apply physics expertise in jobs within the oil and gas business. Out of the four themes, three great innovative ideas were generated and these will be progressed further over the next few weeks. The Forum was a real success. It is a format we will use again."*

Seventeen Cavendish post-doctoral researchers and PhD students took part, as well as three academics, nine BP colleagues and representatives from Cambridge Enterprise. The event was facilitated by Amy Mokady, Director of the Cambridge University i-Teams Programme. Cavendish participants came from a number of research groups: Biological and Soft Systems, Astrophysics, High Energy Physics, Thin Film Magnetism, Theory of Condensed Matter, and Surfaces, Microstructure and Fracture.

Please contact Michael Simmons, Cavendish Laboratory Knowledge Exchange Coordinator, on **mps48@cam.ac.uk** or **01223 746626** if you would like to discuss taking part in a future Forum, or to arrange a meeting to explore possible areas for collaboration.

**www.phy.cam.ac.uk/research/KE**

**Michael Simmons**

Glyn Edwards of BP, left, and Sam George (Astrophysics) presenting a summary of their group discussions at the end of the day

Discussing one of the target themes during the Cavendish-BP Forum. Left to right Richard Brierley (TCM), Sander Gaemers (BP) and Jurij Kotar (BSS)

# The Teaching Office and the Teaching Support Team

In a department so dominated by excellence in research, it is easy to overlook the vital part that undergraduate teaching has to play and the number of people who help support it with such dedication. It often comes as a surprise to visitors from abroad that the Cavendish is not a pure research institute, but is a University department with equal responsibilities for teaching and research. The teaching programme necessarily results in very demanding roles for the staff, the teaching office and the teaching support team. The statistics alone give some impression of the size of this task. We have, at any one time, around 800 undergraduate students and 70 academic staff directly involved, as well as an army of graduate students and post-docs helping with third and fourth year supervisions and project work.

The Teaching Office is at the heart of the undergraduate teaching activity and provides a single point of contact for students, academics and support staff. Staff and students all require accurate and timely administration of records, work and examinations as well as the coordination of lectures, classes and management meetings. The logistical problems of the course timetables can be appreciated from the fact that in the final year of the course, for example, students can choose from 8 major topic lecture courses of 24 lectures, and then from 16 minor topic courses of 12-16 lectures. No two days are ever the same in the Teaching Office, which is inevitably often driven by interruptions and immediate demands and which can at times be a challenge to manage, given the need also to progress longer term tasks.

It is only in recent years that the central coordination of the complete undergraduate teaching programme has come about, but its importance has become clear and enormous benefits derived from it. In days gone by the classes staff provided some administrative support along with the teaching academics, but it became clear that things could be done better and more efficiently by establishing a dedicated centralised Teaching Office. This has grown in importance, and continues to develop its role and scope as individuals see the benefits to themselves and/or their students. This is particularly true of some of our academics who, it is fair to say, are not always the most organised people and clearly appreciate a little bit of steering and gentle encouragement!

Undergraduates have a heavy load of physics lectures to attend, as well as practical laboratory sessions, during the first three years of the Natural Sciences Tripos. We have three main laboratories, which during the course of a year provide and maintain a huge selection of experimental equipment, as well as supporting a growing number of outreach activities in which undergraduates are encouraged to participate. Many of the lectures also require the provision of demonstrations, which are always much appreciated. These also break up and enliven the otherwise somewhat theoretically-biased lectures. Julia Riley is the current entertainment gold medal holder having made several holes in the roof of the Chemistry lecture theatre with water propelled rockets!

The examination period in the Easter term brings with it a very large workload. We host around 20 exams in the second year laboratories and each one requires very careful planning and coordination. The job of collecting completed scripts and restocking paper supplies for over 200 places involves plenty of exercise. It is also our responsibility to provide encouragement and support when students find themselves overwhelmed with stress and worry.

The current team consists of Helen Marshall (Teaching Office Administrator), Harry Druiff, Richard King and Mark Smith (classes) and our latest part time staff, Helen Jobson and John Flynn who have fitted in brilliantly. The recent staff changes have given us an opportunity to take a fresh approach to much of what we do and we very much hope that we can maintain our reputation for helpfulness to all our customers. Our aim is to stay ahead of the daily demands through a greater understanding of what is likely to be required by whom and when. It is also becoming easier to plan further ahead and understand what resources we will have available at any given time. This, along with our flexible team, means that we are well positioned to develop even further the roles of the support staff and the Teaching Office to serve the needs of students and staff into the future.

It is fair to say that, if things are running smoothly, we are doing a good job. If they are not, then we are still doing a good job and someone else must have messed up!!

**Helen Marshall**

**Fig. 1 (top).** The Teaching Support team. Front row, left to right: Helen Marshall and Helen Jobson. Back row, left to right: Mark Smith, Richard King and John Flynn. Inset: Harry Druiff.

Lisa Jardine-Wright

## School Workshops

### Electricity & Electronics

On 29 and 30 March 2012, 120 students, aged 14 to 16, 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. During the afternoon the students built a dark detecting torch to take away from a practical session developed by the Cavendish. The resources from this and all other workshops are available on our website.

**A second workshop on this topic is scheduled on the 12th and 13th December 2012 for 11 to 13 year olds**. The practical workshop involving making a dark detecting torch to take away will again form the central element of the afternoon but the introduction and additional sessions will be changed appropriately for younger students. Places have filled up very rapidly and so we can only accept reserve bookings for the workshop, which can be made online from the school workshop section of our outreach page.

## Cavendish Physics Teachers Residential 2012

From the 30th June to 2nd July 2012, 20 A-level physics teachers from across the United Kingdom visited Cambridge for a residential workshop kindly hosted by Robinson College and sponsored by the Ogden Trust. This course focused on the following objectives:

- Many talented students are unable to attend the student Senior Physics Challenge (SPC) as we do not have the spaces to host them. This opportunity enables teachers to take the SPC back to school and into the classroom by providing them with all the resources and background materials, including current information about admissions, SPC course notes, example sheets and experimental ideas.
- To provide an opportunity for first-hand experience of the Cambridge collegiate system and physics research in Cambridge. The programme included a session on Cambridge admissions with directors of studies in physics and admissions interviewers.
- We discussed ideas and concepts with teachers to understand students' conceptual difficulties and bridge the gap between A-level and university physics.
- There was the opportunity to observe the Senior Physics Challenge students in action.

This residential course was piloted in 2011 and proved extremely useful and popular.

## Senior Physics Challenge

From over 300 applications of the highest calibre AS-level students, co-director Anson Cheung and I selected 66 students from all over the United Kingdom to participate in our physics access and admissions initiative called the **Senior Physics Challenge**. The summer school took place over four nights from the 2 to 5 July 2012, during which the students attended lectures on kinematics and special relativity and practical laboratory classes on dynamics and optics. There were also admissions talks and the chance to discuss physics and socialise with like-minded students of a similar age. The aim of the four days of intensive tuition was to develop problem-solving and experimental skills and to demystify the transition from A-level (or equivalent) to university physics.

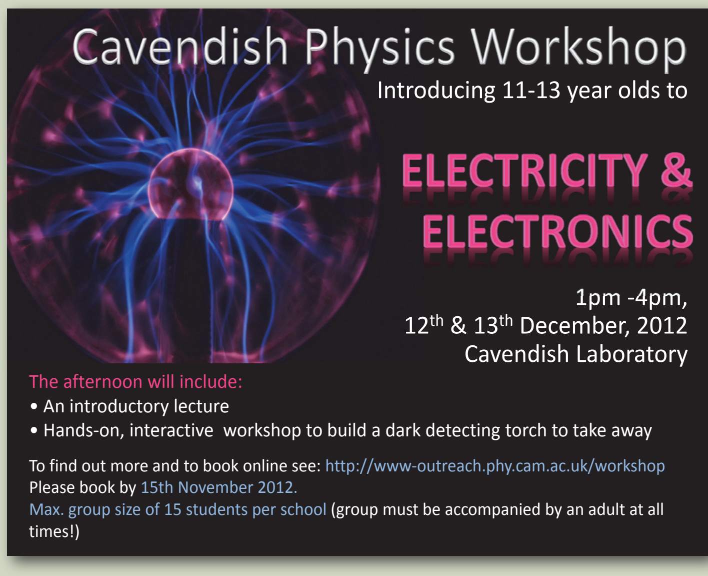
Participants were hosted to dinner and accommodated by a number of Cambridge colleges, this year including Churchill, Corpus Christi, Fitzwilliam, Newnham, Pembroke, Queens', Robinson, St John's and Trinity. Student application is initiated by teacher recommendation. Any interested teacher may register online to receive updates and notification of the next application round. To find out more please see our website.

## Undergraduate Open Days

From 2:00pm on the 5 and 6 July 2012, the Cavendish Laboratory opened its doors to the next wave of potential undergraduates. These open afternoons are designed to coincide with the Cambridge University central admissions open days but are stand alone activities to which any year twelve (AS-level or equivalent) students and their families are invited to attend.

In the first two years of the Natural Sciences Tripos, physicists spend the majority of their time in lectures, which are held in the centre of Cambridge, whilst time in the Cavendish Laboratory is primarily spent in practical sessions. One of the aims of our open afternoons is to introduce potential students to the variety of experiments that they will undertake as physics undergraduates, and to provide them with an opportunity to speak with graduate demonstrators and supervisors. This year Julia Riley gave an example of a first year lecture on special relativity and, as an experienced admissions tutor, followed the lecture with an opportunity for parents and students alike to ask any admissions questions regarding entry to study Natural Sciences in Cambridge. There was a museum tour and talk about the history of the ground-breaking physics performed at the Cavendish Laboratory.

The same format will be followed next year. There is no need to register or book for these open afternoons but further information can be found on our website.



## Physics at Work 2012

Bookings for the 28th annual *Physics at Work* exhibition opened a couple of months ago, and all the spaces are now taken. This unique exhibition runs for three days, this year from 18th until 20th September, with two sessions each day (morning sessions begin at 9am and afternoon sessions at 1pm). During each half day session school groups will see six different exhibits, selected by the organisers to include both internal and industrial exhibitors, and show the many varied ways in which physics is used in the real world. We are delighted to welcome both seasoned and new exhibitors to the event once again this year, bringing our total number of exhibits for 2012 to twenty-four.

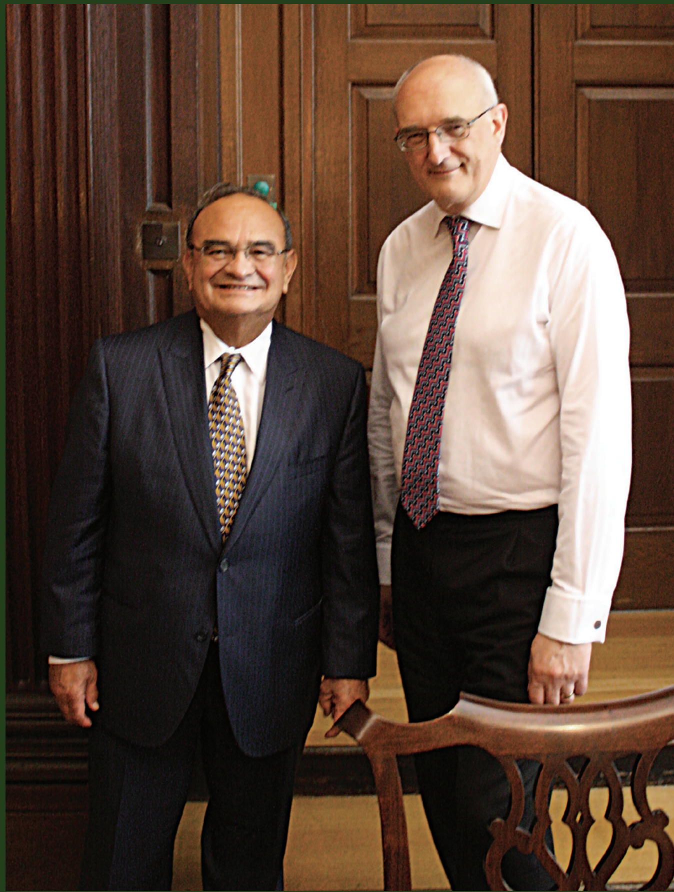
The exhibition is targeted at 14 -16 year olds with some schools bringing their *gifted and talented* year 9 students and others bringing year 12 students who are considering potential careers in physics. Schools are welcome to bring as many students as they are able (given a student to teacher ratio of about 15). On arrival at the Cavendish a given school party will be split into groups of approximately 15 students with 1 accompanying teacher. Map in hand each group is then led to their first exhibit to follow their own tailored route around the Cavendish.

Schools travel from all over London and the South East to attend this event. Although all places are now taken, we are accepting reserve bookings, which should be made online on 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, and further information can be found at their website:

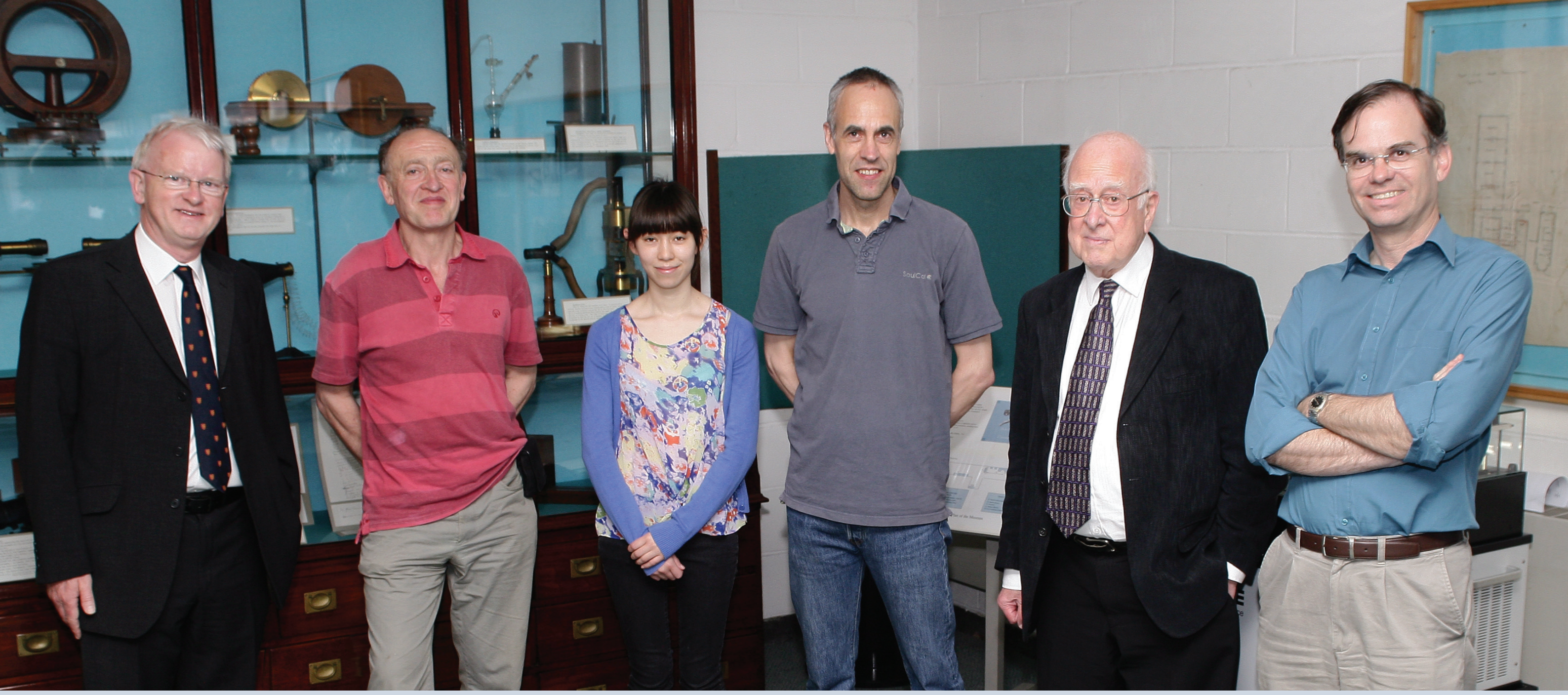
**www.cam.ac.uk/admissions/undergraduate/events**



**President Lopez with Sir Leszek Borysiewicz**

## President Daniel Lopez of the New Mexico Institute of Mining and Technology visits Cambridge

We were delighted that President Lopez was able to visit the Cavendish in June to discuss the future of the Magdalena Ridge Observatory project, in particular, the completion of the first phases of the optical-infrared interferometer which promises to be the world's leading instrument for extremely high resolution imaging of all classes of compact astronomical objects. The Cambridge efforts are led by Chris Haniff and David Buscher who have made major technological contributions to the project, particularly in the design of the telescopes and the many aspects of systems engineering. In particular, the crucial interferometer delay lines will enable images to be taken of bright objects with 50 times sharper angular resolution than the Hubble Space Telescope. During President Lopez's visit, he met the Vice-Chancellor, Sir Leszek Borysiewicz, who reaffirmed Cambridge's full commitment to the project. The immediate goal is to complete a fully functioning 4-element optical-infrared interferometric array over the next four years.



Peter Higgs with members of the High Energy Physics Group visiting the Cavendish Museum.
**From left to right:** James Stirling, Maurice Goodrick, Fehn Chua-Short, Steve Wotton, Peter Higgs and Andy Parker.

# Peter Higgs receives the title of the degree of Doctor of Science, honoris causa, of the University of Cambridge

*MOST fecund Muse, whom all adore,*
*Come help me now, I thee implore,*
*To sing and praise a trinity*
*Of men whose bright posterity*
*Illuminates the path we tread:*
*The first was he upon whose head*
*That local apple fell and gave*
*To Newton fame beyond the grave.*
*The second drew on gravity*
*To show through relativity*
*Whole warping universes bent*
*And folded back to pay time's rent.*
*Now third in line (though not renown)*
*We have this man, whose scarlet gown*
*Will light the lands beyond the Wall*
*Because he saw the root of all.*
*The briny thickness of the sea*
*Restrains and binds the arms of he*
*That seeks to swim against the tides -*
*His progress slows, slows more, then dies.*
*Yet heaving swells, both fore and aft,*
*Do not slow down a well-formed craft*
*Maintained well by crew and boatswain.*
*And so it is with what goes on*
*In the great vacancies of space:*
*Where wave-like light still wins the race*
*Against more massy forms of stuff*
*Which give off energy enough-*
*By crashing through, out, down, across*
*To give birth to the seeds of force*
*Named for this man - him, over there.*
*And this is why, quite everywhere,*
*To prove aright this good Professor*
*Men in labs smash things together.*

It is not often that your editor will allow poetry to appear within the covers of CavMag, but, with the award of the degree of honorary Doctor of Science to Peter Higgs of the University of Edinburgh, he relents and transcribes the address made by the University Orator, Dr Rupert Thompson of Selwyn College, on the auspicious occasion of the award of the degree. Peter's most famous contribution was understanding how the introduction of a new elementary particle, subsequently named the Higgs boson, would enable particles to acquire mass. Peter visited his colleagues in the High Energy Physics Group and enjoyed a tour of the Cavendish collection of historic apparatus and photographs.

Those who prefer the original Latin version, which was declaimed on the occasion of the award of the degree, can find it in the Cambridge *Reporter.* Both the Latin and English versions include outrageous puns on the term 'boson', while also giving the Margaret Thatcher cocktail-party explanation of the role of the Higgs boson (see: www.hep.ucl.ac.uk/~djm/higgsa.html).

**On Wednesday 4th July 2012, just two weeks after Peter Higgs was awarded his Honorary Degree, scientists at CERN announced the first clear evidence for the existence of his boson.**

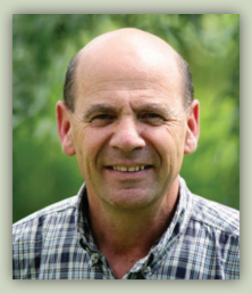
*Distinguished Chancellor, members of the University, I present to you*

**PETER WARE HIGGS, F.R.S., F.R.S.E., Hon.F.Inst.P.,**

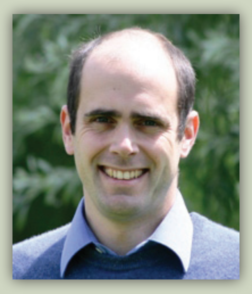
*Professor of Theoretical Physics Emeritus in the University of Edinburgh,*

*that he may receive the title of the degree of Doctor of Science,* honoris causa.

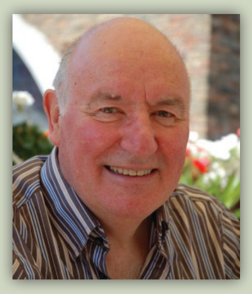
## PROMOTIONS, AWARDS AND PRIZES



**Mark Warner** has been elected a Fellow of the Royal Society



**Michael Kohl** has been awarded the Thomson Medal and Prize of the Institute of Physics for his pioneering experimental work in Bose-Einstein condensates and cold Fermi gases.



**Malcolm Longair** has been awarded an Honorory Degree of Doctor of Science of the University of Edinburgh for his "significant contributions to Physics and Astronomy at the University of Edinburgh and generally in Scotland".

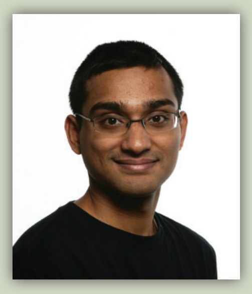
**Suchitra Sebastian**, a Royal Society University Research Fellow in the Quantum Matter Group, is recipient of the IUPAP Young Scientist Medal 2012. The IUPAP Young Scientist Medals in the field of magnetism are presented every three years, at the International Conference on Magnetism. She has also been awarded the Moseley Medal and Prize of the Institute of Physics for her important discoveries in frustrated quantum magnets, heavy fermion systems and high temperature semiconductor.

**Athene Donald** has been awarded an Honorary Doctorate of Science from the University of East Anglia.

**Robert Smith** of the Atomic and Mesoscopic Physics Group has been awarded a five year Royal Society University Research Fellowship to commence 1st October 2012.

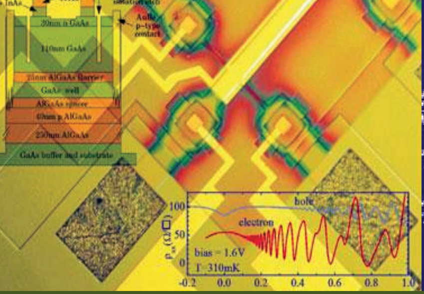
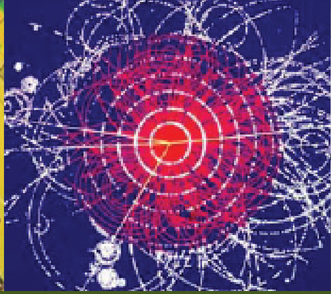
**Erika Eiser** of the Biological and Soft Systems Sector and **Zoran Hadzibabic** of the Atomic, Mesoscopic and Optical Physics Group are promoted to personal Readerships with effect from 1st October 2012.

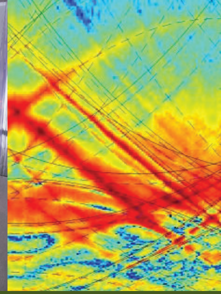
**Farhan Feroz** of the Astrophysics Group and **Marco Koschorreck** of the Atomic, Mesoscopic & Optical Physics Group have been awarded Early Career Fellowships from The Leverhulme Trust.



**Vijay Narayan** of the Semiconductor Physics Group has been awarded a three year Herchel Smith Fellowship commencing 1st April 2012.

**Richard Friend** has been appointed to the Council of the Engineering and Physical Sciences Research Council (EPSRC), from 1st April 2012 for a period of four years.




## Cavendish News, continued

**Lisa Jardine-Wright,** the Department's Outreach Officer, is to be awarded the IOP's Philips Award for her outstanding contributions to educational and outreach activities (see page 12).

**Neil Greenham** has been awarded the Royal Society's Kavli Medal and Lecture in recognition of his exceptional work on hybrid materials combining polymer semiconductors with inorganic nanoparticles, and their use in printable solar cells. (see his article on Page 4).

**Michael Pepper** and **Jocelyn Bell-Burnell**, both fomer members of the laboratory, have been awarded Honorary Fellowships of the Institute of Physics.

Two former Cavendish PhD students are to receive Institute of Physics awards, namely
**Dr Meera Parish**, the Maxwell Medal and Prize and
**Dr Henry Snaith**, the Paterson Medal and Prize.

**New Academic Staff Appointments**

**Professor Roberto Maiolino** appointed to the Professorship of Experimental Astrophysics has joined the Department (see his article *How Galaxies Really Formed* on Pages 2-3).

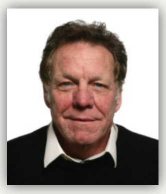
**Austin Lamacraft** joined the Laboratory on 1st July as a University lecturer in the TCM Group.
**Claudio Castelnuovo** will join the Laboratory on 1st October, also as a University lecturer in the TCM Group.

**New Assistant Staff Appointments (Since April 2012)**

**Hilaria (Teri) Bartlett** appointed Group Administrator to the Condensed Matter Research Groups in the Mott Building, primarily for Semiconductor Physics.
**Jacqui Tighe-Doyle** appointed as Nano-DTC Administrator.
**Nick Beaumont**, Cleaner.
**Monika Nierodzinska**, Cleaner.

**The following members of the Assistant Staff have reached the 25th Anniversary of their appointments with the University:**

**Kelvin Fagan** (Senior Photographic Technician).



**Douglas Heftel** (MBE Facilities Technical Manager, Semiconductor Physics Group).

**David Sawford** (Chief Electronics W/shop Technician, Detector Physics Group).

It is with profound sadness that we report the death of **Tom Duke**, formerly Reader in Biological Physics in the Department, at the tragically early age of 48. He moved from Cambridge to a Professorship at University College London in 2007.

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**

# Contacts

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