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Department of Physics Newsletter

UNIVERSITY OF OXFORD

HARMONI FOR THE EXTREMELY LARGE TELESCOPE

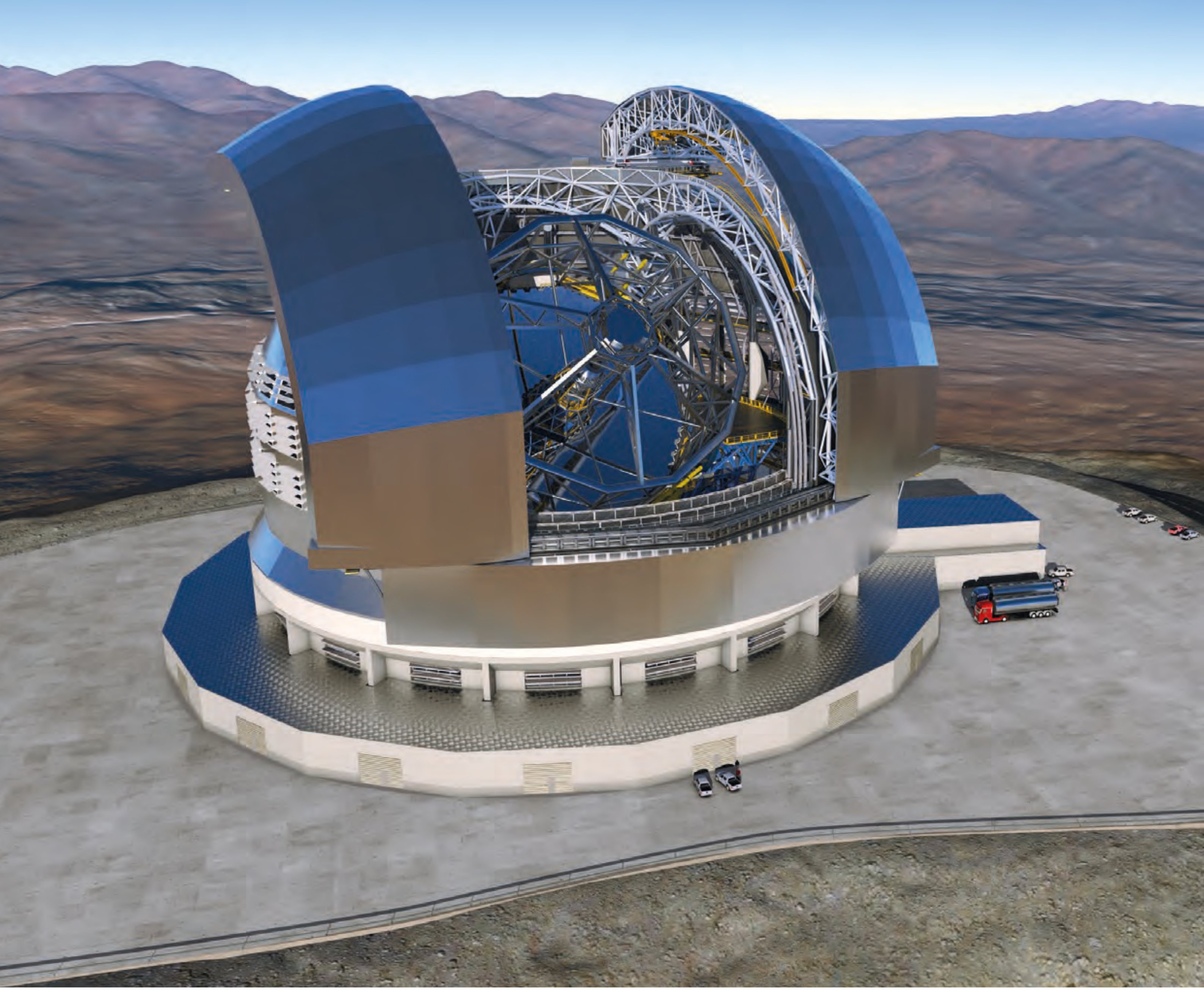
Hyper-spectral imaging

TOPOLOGY IN BIOLOGY

Mechanical control of the density of cell layers

MAKING THE INVISIBLE VISIBLE:

Ancient texts revealed



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IOP Institute of Physics Juno Champion

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TOPOLOGY IN BIOLOGY

MECHANICAL CONTROL OF THE DENSITY OF CELL LAYERS

Topological defects are mistakes in ordering which can only be removed by their reaching a boundary or by annihilation with other topological defects. They are found in many places: dislocations in crystals, cosmic strings and monopoles formed in the early Universe, magnetic skyrmions which are small swirling structures in chiral magnets that hold a promise for spintronics, and, comet- and star-shaped topological defects in nematic liquid crystals (Fig. 1). Now, in collaboration with colleagues from Paris and Singapore, we have identified topological defects in layers of cells, and demonstrated a link to cell death and the removal of unnecessary or pathological cells (Fig. 2).

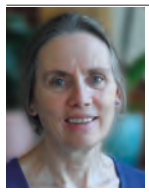
Fig. 1B shows a monolayer of Madine-Darby Canine Kidney (MDCK) cells as a model for the epithelium. Epithelial tissue lines blood vessel surfaces and many of our organs, for example the gut and the lungs. The MDCK cells gently move around (with velocities on the order of microns per hour) by pulling on the underlying substrate. The resulting force is then transmitted to neighbouring cells by intercellular contacts known as adherens junctions, leading to anisotropic cell shapes. When we created a map of the cells' long axes, shown in black in Fig. 1B, we found local nematic order where the axes lined up (see box below and Fig. 1). We were also able to clearly identify places where the order was disturbed and formed structures that looked exactly like the comet-like and star-like topological defects found in nematic liquid crystals.

TOPOLOGICAL DEFECTS IN A TISSUE

There is, however, a very important difference between the topological defects in liquid crystals and in cellular layers. In liquid crystals new defects do not appear once the nematic phase has been created. Rather, the existing defects slowly anneal out by annihilating in pairs of +1/2 (comet) and -1/2 (star) defects, rather like electric charges. But cell layers are alive, they continually use chemical energy from their surroundings in the form of ATP (Adenosine Triphosphate) to move and to divide. This energy also allows them to create topological defects, in pairs to conserve topological charge. The +1/2 defect then moves quickly away from the -1/2 defect until it encounters another -1/2 defect where it is annihilated. Over time, the rate of defect pair creation and annihilation balance, and the defect density within the monolayer reaches a steady state. The more active the cells the higher the defect density in the tissue (see Fig. 3A).

Cell layers produce topological defects: but do the defects have any biological function? Epithelial tissue removes dead and excess cells by extruding them from the layer, an important contribution to homeostasis, the active regulation of cell density. Breakdown of this control mechanism can lead to pathological processes such as cancer metastasis. Cell extrusion was thought to be initiated by chemical signalling. However, careful work by our experimental colleagues showed that there is a correlation between the sites of cell extrusion and the position of comet-like topological defects, suggesting that there might be a mechanical trigger.

Dr Amin Doostmohammadi



Prof Julia M Yeomans

To see the articles as published in *Nature*:

www.nature.com/nature/journal/v544/n7649/abs/nature21718.html

www.nature.com/nature/journal/v544/n7649/full/544164a.html

Nematic liquid crystals are formed by elongated particles that have long range (on a scale larger than individual elements) orientational order, but lack any positional order (see Fig. 1A). Nematics are therefore a state of matter between liquids (no positional or orientational order) and solid crystals (both positional and orientational order). As an intermediate state of matter, nematics have exotic features; they can flow like a liquid, while resisting orientational deformations like an elastic solid. The constituent elements do not have any polarity and are best characterised by a headless vector, the 'director', which lies along their axes.

In perfectly ordered nematics, all the directors align parallel to each other. However, in most real materials the structural inhomogeneities or boundaries and external fields (eg electric or magnetic fields, and shear flow), lead to a non-uniform director configuration. In a non-uniform director field topological defects separate regions with different orientations. They are mistakes in the arrangement of nematic particles that are manifest as singularities in the orientation field. A specific topological charge m, is associated to each singular point depending on the rotation of the director around it. Following a full rotation (2π) around a defect, the director angle changes by m×2π, where m can take half-integer (±1/2, ±3/2,…) and full integer (±1, ±2,…) values. In a two-dimensional nematic ±1/2 defects occur most frequently since they are energetically the most favourable. The +1/2 defect has a comet shape while -1/2 is three-fold symmetric. The difference in symmetry properties of topological defects leads, in active nematics, to distinct flow and stress patterns in their vicinity and can contribute to their biological functionality.

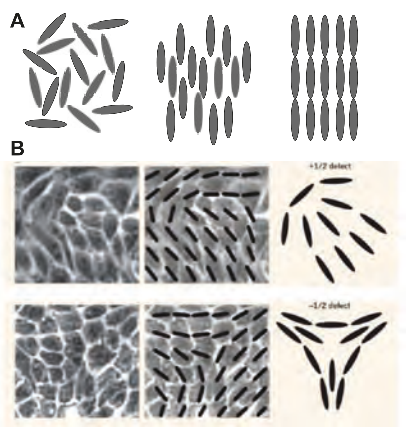
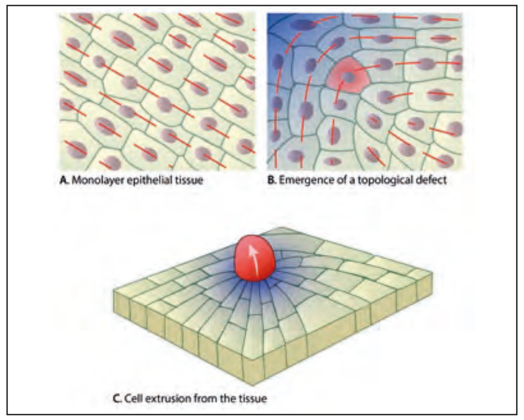
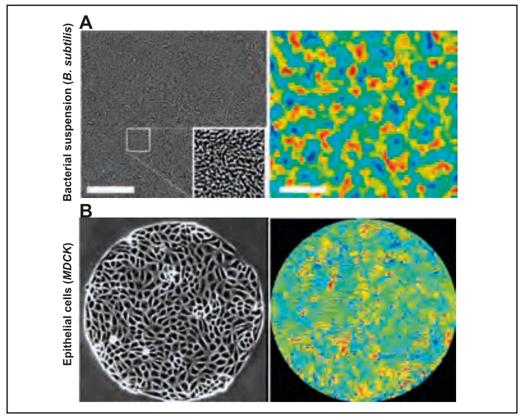


Fig. 1: Nematic liquid crystals: (A) Schematic representation of the particle configuration in (left) a liquid, (middle) a nematic liquid crystal and (right) a crystal. (B) A monolayer of epithelial cells (MDCK cells) shows the emergence of nematic topological defects. Black solid lines mark the director field based on the direction of elongation of the cells. Both comet-like (+1/2) and star-shaped (-1/2) defects are observed.



Right: Fig. 2: Defect-induced cell death and extrusion: schematic of the mechanical route to cell death (apoptosis) and cell extrusion.



Far right: Fig. 4: Active turbulence in living systems. (A) Dense suspension of *B. subtilis* bacteria and (B) a confluent monolayer of MDCK cells. In both systems, the colourmaps show the vorticity of the cell flow and solid blue lines illustrate streamlines. The flows of both bacterial suspension and epithelial cells are characterised by highly chaotic swirls and jets resembling turbulent flows.

CELL MONOLAYERS AS ACTIVE MATTER

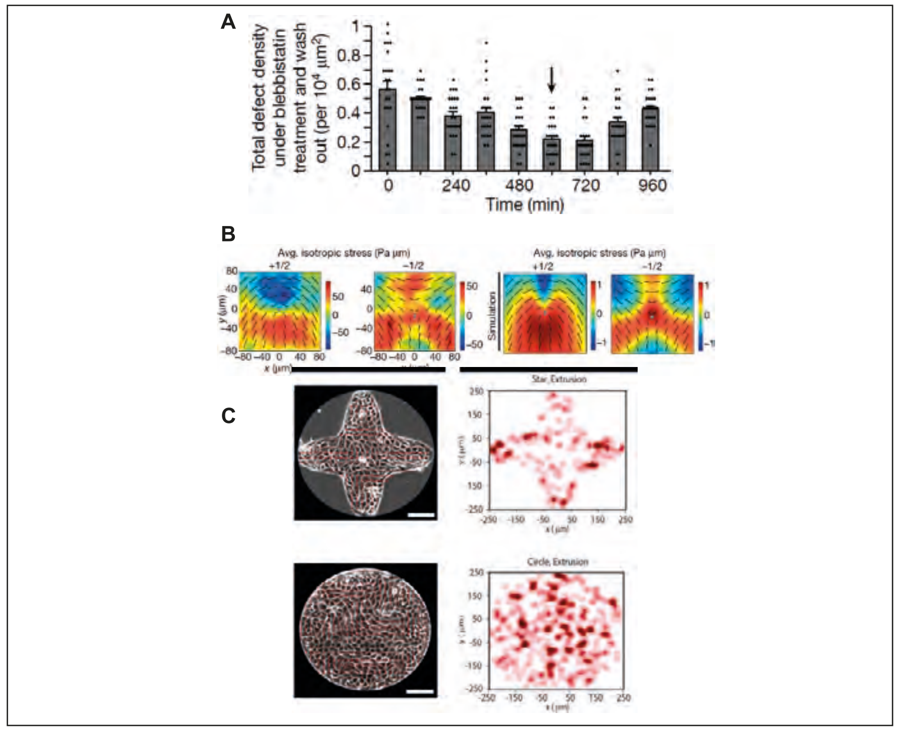
What makes the topological defects special sites for cell extrusion? To answer this question, we used a theory of active matter. Cells are an example of active matter, materials which use energy from their environment to perform work. Active matter is meant to exist out of thermodynamic equilibrium and it is providing many new insights into non-equilibrium statistical physics. In particular, continuous energy injection in active matter leads to chaotic flows in the form of swirling structures called active turbulence (Fig. 4). By using the active matter theory we calculated the stress and velocity fields around a +1/2 and -1/2 topological defect and compared them to the experimental measurements. Fig. 3B shows the close agreement between observations and simulations of active nematics. Further, the stress measurements showed the presence of compressive stress regions at the head of the comet defects, where experiments showed that cell extrusions predominantly occur.

Our first guess was that this additional compression at the head of the +1/2 defects pushed the cell out of the layer. However, the mechanism turns out to be more complicated. The defect-induced stresses de-activate a death inhibitor protein YAP (Yes-Associated Protein) by pushing it from the cell nucleus to the cytoplasm. This then triggers cell death and the weakening of cell junctions so that the dead cell is ejected from the layer (Fig. 2).

TOPOLOGICAL CONTROL OF CELL EXTRUSION

Having worked out the mechanical route to cell death and extrusion, we then asked if a special arrangement of topological defects could produce controllable cell extrusion. To this end, our experimentalist colleagues cultured cells within a cross-shaped geometry with round arms (see Fig. 3C). As a result of the topology, we expect a larger number of comet-like defects within the four arms and experiments indeed showed that this was where the largest number of cell extrusions occurred. This suggests a novel way of controlling positions of cell death and extrusion in a tissue only by modifying geometrical constraints.

The topological defect-induced cell death and extrusion is a previously unknown phenomenon that not only reveals a purely mechanical cause for an important biological process, but also offers new links between tissue dynamics and the physics of liquid crystals. ■



Left: Fig. 3: Cells as active nematics:
(A) Experimental confirmation of the relation between cell activity and the number of topological defects. At time t=0 blebbistatin is added to the cells. This disrupts their motion (essentially sends them to sleep) and the number of defects starts to decrease. At t=600min the blebbistatin is washed out, the cells wake up and the number of defects starts to increase. (B) Patterns of isotropic stress (red: compression, blue: tension) around topological defects measured in experiments on MDCK cells (left) and from the theory of active nematics (right). (C) Geometric control of cell extrusion. In the left column red lines show the director field. The colour intensity in the right column corresponds to the number of cells extruded per unit area, showing that in a star-shaped geometry extrusions are mostly localised within the arms.

SCIENCE NEWS
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HARMONI FOR THE EXTREMELY LARGE TELESCOPE

The European Southern Observatory is building the world's largest visible and infrared telescope at Cerro Armazones in the Chilean Andes. With a primary mirror diameter of 39 metres, the Extremely Large Telescope (ELT) will have almost as much light collecting area as the combined area of all the telescopes built to date. The project has a €1.1 billion price tag, and is set to see first light in 2024. HARMONI, the ELT's adaptive optics assisted visible and near-infrared integral field spectrograph, is on track to become the work-horse first light spectrograph for the ELT. The instrument is designed and built by a consortium of six institutes from France, Spain and the UK, led by Oxford scientists and engineers.

FURTHER, FAINTER, SHARPER

Astronomers build large telescopes for two principal reasons – one is to collect as much light as possible to allow us to see fainter objects. Fainter usually means that the objects are further away (but not always, an important exception being planets around other stars), so the light has taken longer to reach us. This makes big telescopes work like time machines, we can look back in time to see the Universe as it looked when it was very young, and study its formation and evolution simply by looking at distant objects.

Distant galaxies are also smaller, both because they are still in the early stages of formation, and because they appear to have a smaller (angular) size in the sky. The second reason for building large telescopes is to take sharper pictures: the diffraction limit (stemming from the wave nature of light) dictates that the bigger the telescope, the finer its angular resolution, so the sharper the picture. With an increase in diameter of almost a factor of five over current telescopes such as the Very Large Telescope (VLT), the ELT will allow images to be a factor of five sharper.

However, achieving this exquisite resolution with ground-based telescopes is challenging because the turbulent earth's atmosphere gets in the way. Over the last three decades, astronomers have successfully implemented the technique of adaptive optics (AO) that compensates for atmospheric turbulence by including a deformable mirror (DM) in the light path to the instrument. The DM is a thin reflective glass shell equipped with several thousand actuators on its back, that can be pushed or pulled to change the mirror shape in real time, up to 1000 times per second. Sensing the turbulence using the light of a reference star, the AO system computes the correction to be applied to the DM, which then allows every object in the sky to be imaged sharply, in a small region of the sky surrounding the reference star. However, as there aren't enough bright reference stars in the sky, astronomers have now taken to using laser beacons that generate artificial stars (reference sources for AO) in the upper ionosphere, using lasers tuned to the sodium D2 line that excite sodium ions.

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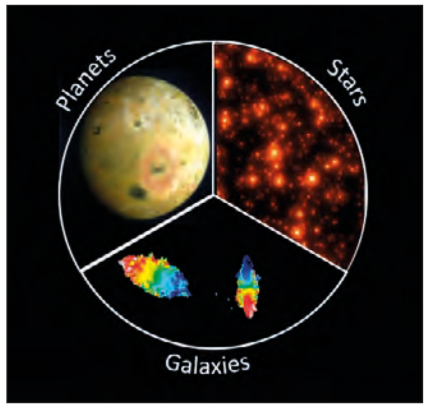
Prof Niranjan Thatte (Principal Investigator)

A NEW WINDOW IN THE UNIVERSE

The ELT will be the world's first adaptive telescope, where the adaptive optics components have been incorporated into the telescope itself. It will host a ≈5000 actuator deformable mirror, and six Laser Guide Stars that are projected from the sides of the telescope. The AO sensors will be incorporated in the instruments. Combining enormous gains in light gathering power with much improved spatial resolution, the ELT has the potential to truly transform our ability to observe the Universe in exquisite detail with unprecedented sensitivity. ■



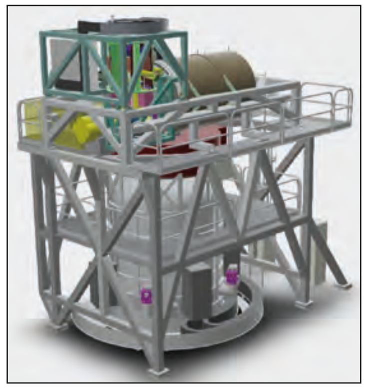


Fig. 4 (above): CAD model of the HARMONI instrument design at the end of the Preliminary Design Phase. The yellow rounded 'plus' indicates the point where light from the telescope enters the instrument, at a height of 6 metres. A 3.5 metre diameter upward-looking cryostat houses the main opto-mechanics of the integral field spectrograph. It is placed on a de-rotator to cancel field rotation from the telescope as it tracks the stars. The horizontal brown cylinder is a focal plane relay system.

Fig. 2 (left): Simulations showing the capabilities of HARMONI, the ELT first light spectrograph, in various key areas of astrophysics. HARMONI will be able to observe moons of outer planets in our Solar System with resolutions approaching that of space probes, take spectra of individual stars in nearby galaxies, and observe the motions of gas in very distant galaxies to infer their masses.

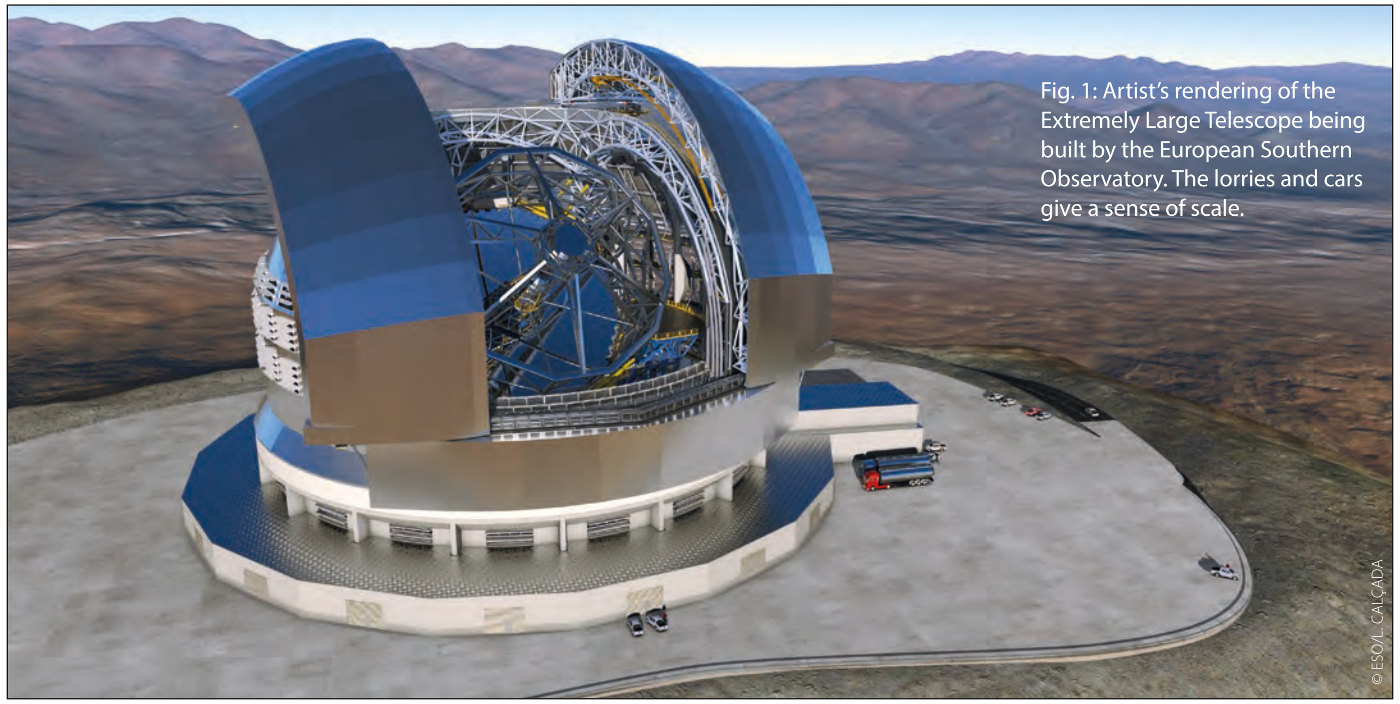


Fig. 1: Artist's rendering of the Extremely Large Telescope being built by the European Southern Observatory. The lorries and cars give a sense of scale.

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HARMONI: SIMULTANEOUS IMAGING AND SPECTROSCOPY

A telescope is only as good as the instruments that can harness the light collected by it. For centuries, astronomers have realised that they can extract substantial information from the light of distant objects by splitting it into various colours, obtaining a spectrum. By observing the emission and absorption lines of various atomic and molecular species, as well as their Doppler shifts, we can deduce a whole host of fundamental physical characteristics of the emitting (or absorbing) objects. For individual stars, we can infer their heavy element content ('heavy' implying elements not formed in Big Bang nucleosynthesis) and thus their age, since successive generations of stars are formed from gas that is 'enriched' by supernova explosions from earlier stellar generations. For groups of stars, or gas clouds, we can infer their motion through Doppler shifts, and thus infer the gravitational potential of the galaxy, which relates to its mass – allowing us to determine the dynamical masses of distant galaxies. Observing emission lines of gas allows us to infer the chemical composition of the gas, its pressure, temperature and ionisation state.

Ideally, we would like to combine spectroscopy with imaging, so that we can obtain a spectrum for every pixel of a two-dimensional image, so as to maximise the information we can glean from observations of extended objects, such as distant galaxies. HARMONI is an integral field spectrograph that provides this capability of simultaneous imaging spectroscopy. Assisted by adaptive optics, it will benefit from the sharp images and the huge light collecting area of the ELT. Integral field spectroscopy is very efficient, since no scanning is required to build up the 'data cube' – intensity as a function of position (two spatial coordinates) and wavelength for every point in a small part of the sky. In other words, HARMONI provides ≈4000 simultaneous images of size 214x152 pixels, each at a slightly different wavelength (or colour). One of four different 'scales' can be chosen on-the-fly, so that field-of-view and sensitivity can be traded with spatial resolution (ability to discern fine details).

The design of HARMONI incorporates use of an image slicer, an optical assembly of large numbers of tiny mirrors, some only 1 mm tall, each polished to a specific parabolic or spherical shape. Figure 3 illustrates the principle of the image slicer. A slicing mirror stack splits the image into many long, thin slitlets. Other mirrors re-align the light (still containing all colours) so the slitlets line up end-to-end, rather than one below the other, as in the original image. The pseudo long slit is then dispersed using a conventional spectrograph, that allows a spectrum of every pixel of the original image to be observed. The 'data-cube' is reassembled from the individual dispersed spectra. HARMONI follows the heritage of other integral field instruments such as MUSE, KMOS, SINFONI and SWIFT, where team members played key roles in their design and development.

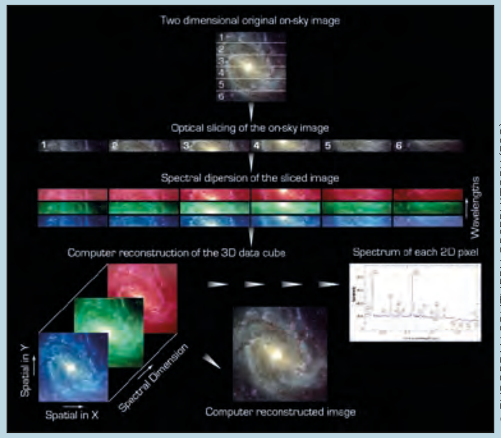

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Fig. 3: The principle of image-slicer based integral field spectrographs. The two dimensional image, containing light of all colours, is split into thin strips by the image slicer, which rearranges these strips so that they line up end to end, rather than one below the other. A conventional long-slit spectrograph then disperses the pseudo long slit, so that a spectrum of every spatial pixel of the input image can be observed simultaneously.

HARMONI's design and construction is being led jointly by the University of Oxford and the Science and Technology Facility Council's Astronomy Technology Centre (UKATC). Oxford scientists and engineers play key roles: N Thatte (Principal Investigator), F Clarke (Lead Systems Engineer), M Tecza (Instrument Scientist), M Pereira-Santaella (Project Scientist), V Ferraro-Wood (Project Administrator). Our scientists (D Rigopoulou, M Richardson, J Magorrian) are also taking the lead in defining the scientific observations that HARMONI will carry out during the first few years, and are making detailed computer simulations of predicted performance, so as to be ready for first light in 2024. The HARMONI project is just coming up to a major milestone, a Preliminary Design Review, in November 2017. Oxford Physics' state-of-the-art infrastructure, including new laboratories in the Beecroft building, will cement our ability to play this leading role in the design, construction and scientific exploitation of HARMONI at the ELT. ■

MAKING THE INVISIBLE VISIBLE: USING DARK-FIELD IMAGING TO REVEAL ANCIENT TEXTS

An international team of scientists from Oxford Physics, The University of Kentucky and the Diamond Light Source are harnessing particle physics to unlock some of the ancient world's longest kept secrets.

Using X-Ray Fluorescence technology at Diamond Light Source's I12 beamline, the team of physicists and computer scientists have established a way to image trace elements found in ancient inks, a technique called 'dark-field X-Ray tomography.' This innovative method, which relies on high energy fluorescence and a very sensitive pinhole camera, promises to open up thousands of otherwise inaccessible ancient texts for scholarship.

THE INVISIBLE LIBRARY

There are scores of ancient scrolls and manuscripts in libraries, museums and private collections which contain texts hidden within and behind extensive damage. Still more written material is locked away in rolled and folded documents which have become so fragile that they cannot be opened without being destroyed. This international 'invisible library' is estimated to contain hundreds of thousands of texts which – if only they could be read – would profoundly enhance, or even alter, our knowledge of world history and culture. Non-invasive advanced imaging techniques combined with specialised 'virtual unwrapping' software have made examining and even reading these highly fragile artifacts possible, but some of the most valuable items remain elusive.

The reasons are two-fold: First, different writing surfaces (from papyrus to parchment to animal skin) and their shapes (warped, wrinkled or rolled) hinder the detection of writing, effectively hiding it within their damaged composition and complex geometry. Second, many of the inks used to pen ancient manuscripts are not easily imaged. These more difficult-to-image inks, primarily used during the classical era, are made of plant-based elements (like carbon) that are applied to plant-based surfaces (like papyrus). The similarity in density and composition between such non-metallic ink and the underlying substrate makes textual detection seemingly impossible.

THE PHYSICS SOLUTION TO THE UNSOLVABLE PROBLEM

Recent experiments performed by the Oxford/University of Kentucky team have shown, however, that these 'invisible' inks can in fact be detected, if the right tools are brought to bear on the problem. The team, which is led by project PI Dr W Brent Seales from the University of Kentucky and co-investigators Alexy Karenowska from the University of Oxford and the Institute for Digital Archaeology, Dr Michael Drakopoulos from Diamond Light Source, and Drs Jens Dopke, Matthew Wilson, and Matthew Veale from the STFC, has been successful in producing first-of-their-kind images of writing on text from arguably the most important and iconic collection within the 'invisible library': the Herculaneum Scrolls.

The Herculaneum Scrolls represent the perfect storm of massive irreversible damage, extreme fragility, non-detectable ink, and challenging topology. They are, in short, the unreadable texts to end all unreadable texts. The story of these fascinating documents begins with the eruption of Mount Vesuvius in 79 AD. The pyroclastic flow from the great volcano completely consumed the city of Herculaneum, including a large ancient library containing thousands of papyrus scrolls. During the 18th century, labourers chanced upon the remains of this library – which has come to be known as the 'Villa of the Papyri' – and found its contents to be in a tantalizing state of preservation.

The intensely hot gas and rock from Mount Vesuvius that quickly enveloped the Villa flash-heated the scrolls, turning them into extremely fragile tubes of carbonised papyrus.

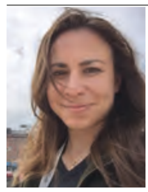
They were then buried beneath tons of volcanic rock, causing their already tightly wound layers to compact further still. The result was the preservation of intact, potentially legible scrolls but in material hardly less fragile than the flakes of ash one finds in the grate after a fire and with a dense and chaotic internal structure. Around 1800 scrolls from the site were eventually excavated, and Oxford's Bodleian Library is one of only four institutions in the world possessing these highly prized artifacts. The British Library in London, the Institut de France in Paris, and the Biblioteca Nazionale in Naples are the other three.

Since their discovery, scholars have been trying to find ways to access the written material inside the scrolls. By the twentieth century it had been established that there was no viable mechanical approach, and the search was on for an alternative. Obvious candidates were imaging technologies capable of resolving the internal structure, but these were frustrated by the fact that the soot-based ink that the scrolls are written in is almost identical in density and chemical composition to the carbon-based substrate on which they are written on.

Until recently, it was believed that the pigment used to write the papyri was pure carbon, making any tomographic imaging of text impossible. However, in 2009, Dr Seales' investigation of an intact scroll at the Institut de France revealed the surprising presence of lead and other heavy trace elements: possibly because the inks were mixed in lead or leaded vessels. It was this discovery that led Seales and his team to the synchrotron at Diamond and the development of the dark field imaging approach.

The new imaging instrument constructed by the team is a pinhole camera which captures the radiation emitted by the document or fragment under study after high-energy illumination from the synchrotron beam (Figure 1). This radiation or 'fluorescence' has a characteristic energy distribution which depends on the composition of the material that produces it. Regions of the sample which are inked – and therefore contain minute traces of lead – have a very slightly different emission signature from those which are not, and the two can therefore be differentiated. In order to configure and characterise the instrument, the team has made measurements both of original documents and papyrus 'phantoms' made using home-mixed lead doped inks. Data is collected using a highly sensitive sensor and can be displayed in the form of a map of the distribution of lead – and therefore ink – in or on the sample (Figure 2). On account of the very small concentrations of lead in the ink, the sensitivity required to produce these maps is higher than any other similar instrument developed to date. Ink distribution data can be combined with information about the geometry of a given fragment to produce a digital model of the whole structure – effectively allowing it to be 'digitally unwrapped'. The Kentucky team lead by Prof Seales specialises in virtual unwrapping technology. Previous work has included the digital reconstruction of the so-called En-Gedi scroll, an ancient Hebrew document written in metallic ink whose charred remains were discovered in Israel in 1970 (Figure 3a). Using micro-computing tomography data in combination with purpose-built software tools, the team was able to produce a complete digital map of the scroll completely non-invasively (Figure 3b). The new results at Diamond open up the application of these sophisticated techniques to documents written in inks previously thought to be completely unresolvable.

This work not only promises long-awaited information about the contents of these alluringly inaccessible written materials, but potentially significant insight into the science of ancient inks. The novel camera and technique paves the way for new kinds of component analysis and 'digital fingerprinting' of ancient pigments which may throw fresh light on the origins, ages, and relationships between documents. ■



Dr Alexy Karenowska (University of Oxford). See Alexy in Rome next year –page 17

See Alexy in Rome next year –page 17

Christy Chapman (University of Kentucky)

Group photo: Back row, L–R: Seth Parker, Jens Dopke, Matthew Wilson, Simon Bevan, Matthew Veale, Bryony Smerdon. Front row, L–R: Christy Chapman, Brent Seales, Michael Drakopoulos, Alexy Karenowska.

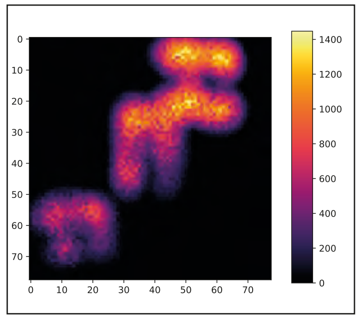


Fig. 2: An image of a fabricated sample of ink. Experiments show that the new camera can reveal trace elements found in ancient inks.

Fig. 3a: The scroll of En-Gedi, an ancient Hebrew manuscript discovered in Israel in 1970. Any attempt to unwrap the fragile charred mass of parchment would completely destroy it.

IMAGE COURTESY OF LEON LEVY DEAD SEA SCROLLS DIGITAL LIBRARY, IAA. PHOTO: S HALEVI

IMAGE COURTESY SETH PARKER, UNIVERSITY OF KENTUCKY

Fig. 3b: A digitally unwrapped rendition of the writing hidden inside the En-Gedi scroll. Scholars have identified the text to be an excerpt from the book of Leviticus. It is the oldest Biblical scroll ever to be found in the holy ark of a synagogue.

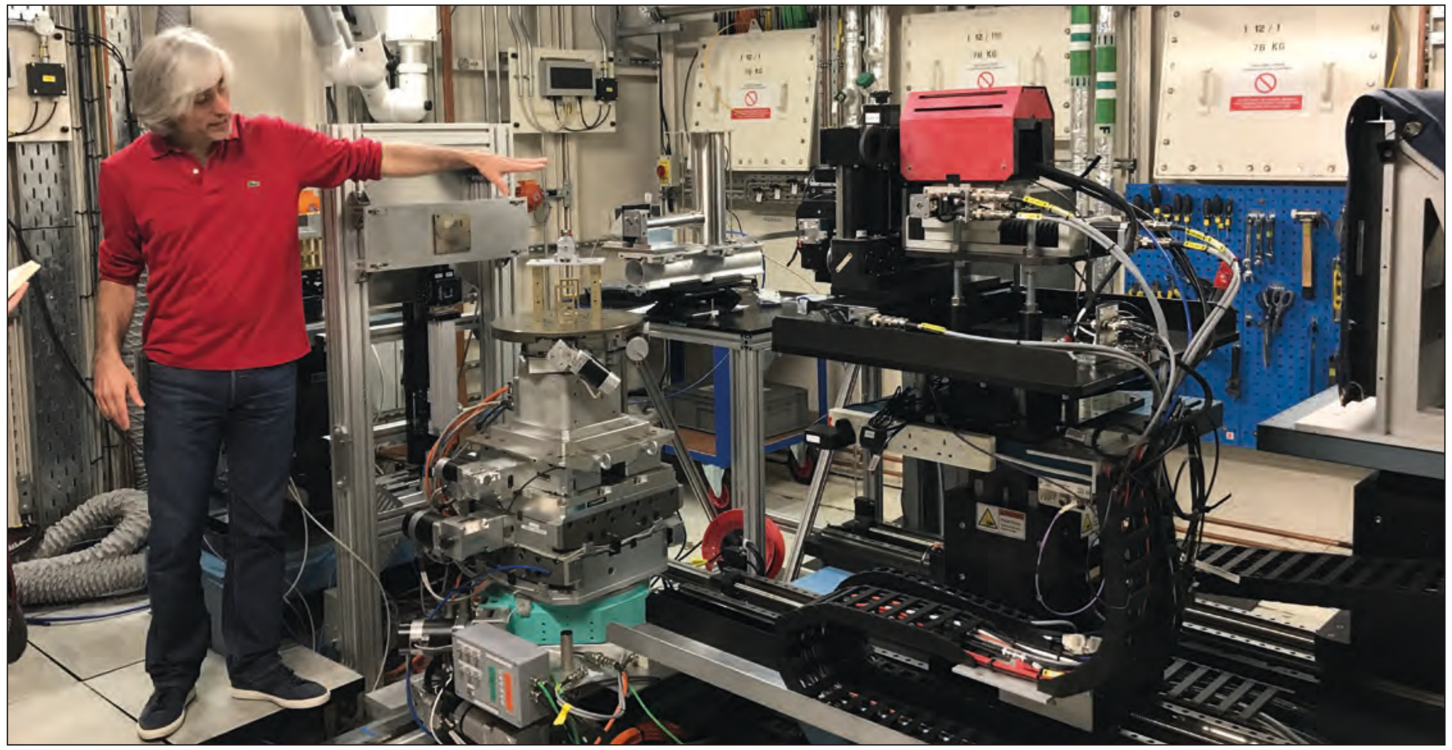


Fig. 1: The new camera was constructed on Diamond Light Source's I12 beamline under the supervision of beamline scientist Michael Drakopoulos.

SCIENCE NEWS
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COMMERCIAL SUCCESS FROM SOLVING PROBLEMS WITH PHYSICS

– by Dr Phillip Tait

By furthering the understanding of our world through the power of physics we create opportunities to make advances in society. Oxford physicists work with businesses to help turn our ideas and scientific inventions into technologies that solve problems faced by people every day.

To turn these ideas into reality, we work with existing companies that can provide complementary expertise and a route to market. If there is no suitable industrial partner, we can create a new company (spin-out) by raising external investment in exchange for equity in the new company. License deals with existing companies normally lead to royalty payments, which are shared between the academic inventors, the University and the Department of Physics. If a spin-out is formed, the academic inventor receives shares in the new company, which will usually then license the technology from the University, as well as the opportunity to act as a consultant to the spin-out.

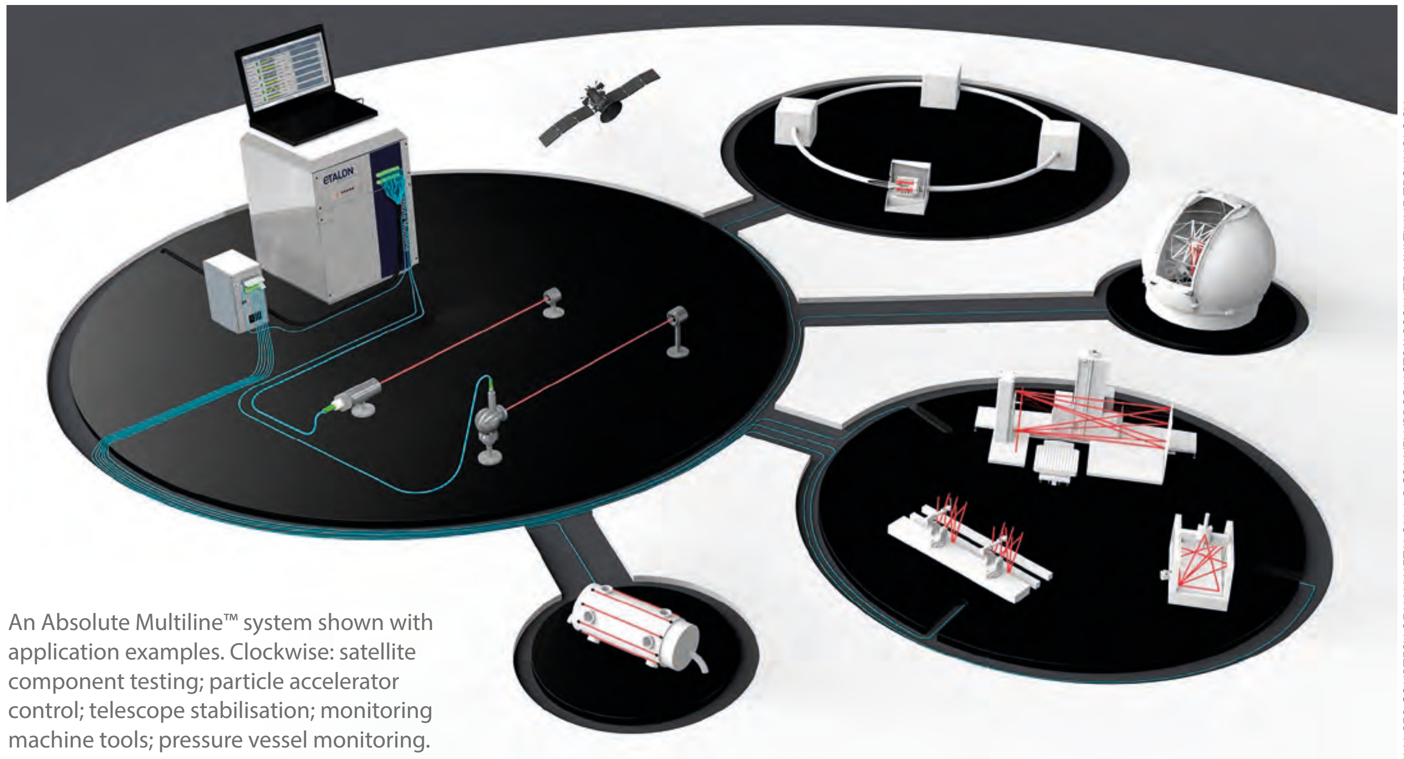
With support from Oxford University Innovation (OUI), a wholly-owned subsidiary of the University, Oxford Physics has commercialised many inventions over the years through both routes, allowing technologies from the department to solve problems across the globe. In fact, the University of Oxford's first ever spin-out company, Oxford Instruments plc, was founded in this department by Sir Martin Wood and Lady Audrey Wood in 1959 (see article on p. 16–17 of this Newsletter) to manufacture superconducting magnets. The company is now a leading provider of high technology tools and systems for research and industry, with annual revenue in excess of £350m. In this issue we'll show how collaborating with industry enables cutting-edge technology invented through our fundamental research to be integrated into products and sold to customers in wide ranging sectors of industry and academia.

www.physics.ox.ac.uk/enterprise

Partnering with industry for near-perfect distance measurement

Distance is one of the most fundamental properties humanity uses to describe the world and we have learned to measure it in an amazing variety of ways using everything from the length of your forearm to the wavelengths of photons. In modern industrial societies, length measurements are deeply embedded into all production processes and the requirements for range, resolution, speed and absolute accuracy are constantly growing. In everyday life, distances do not need to be measured with great accuracy in contrast to precision engineering and world class science where this is needed. High-precision machines and equipment such as telescopes or particle accelerators simply will not work unless their critical component positions are constantly measured to an incredibly high level of accuracy, with a tolerated error often measuring just a few microns over lengths of tens of metres. Professor Armin Reichold participated in the design and construction of an alignment system for the semi-conductor tracking detector of the ATLAS experiment at CERN and later led a project to develop a robotic survey instrument for the tunnels of the International Linear Collider (ILC), a proposed linear e+e- collider.

Prof Armin Reichold



An Absolute Multiline™ system shown with application examples. Clockwise: satellite component testing; particle accelerator control; telescope stabilisation; monitoring machine tools; pressure vessel monitoring.

IMAGES COURTESY OF WWW.ETALON-AG.COM/EN/PRODUCTS/ABSOLUTE-MULTILINE-TECHNOLOGY

The metrology challenges of these high-energy physics experiments led to the development of the Frequency Scanning Interferometry (FSI) technique, from its initial stages in ATLAS to a technique capable of simultaneously measuring hundreds of absolute distances up to 30m with accuracies below 5×10^{-7} at sampling speeds of up to 125 million samples per second (MS/s).

Foreseeing a wide range of potential applications of FSI beyond particle detectors and accelerators, Professor Reichold approached Etalon AG, a company that manufactures laser tracers to measure distances with extreme accuracy and the National Physical Laboratory to start a collaboration that would develop the technology into a commercially available instrument for scientists and engineers in research and industrial environments alike. The invention was patented by OUI and licensed to Etalon, who now manufacture and sell the FSI technology under the brand name 'Absolute Multiline'. This product is considered a pioneering solution to precision absolute measurement. Unlike conventional interferometers, the FSI laser beam can be interrupted at any time and measurements resumed when the break is over.

THE ABSOLUTE MULTILINE TECHNOLOGY PROVIDES THE FOUNDATION FOR MACHINES AND STRUCTURES THAT ARE SELF-MONITORING. THEREFORE, IT CAN BECOME A BUILDING BLOCK IN THE FUTURE CONCEPT OF INTELLIGENT PRODUCTION.

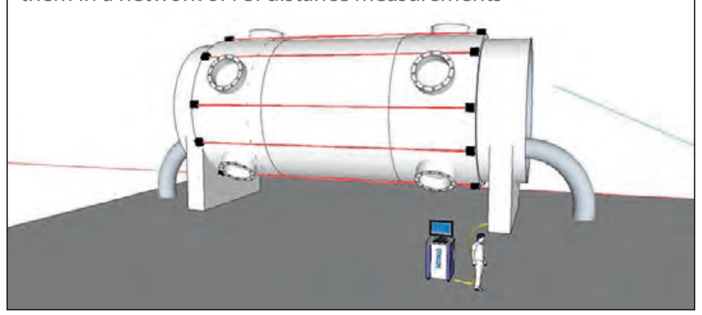
Dr-Ing. Heinrich Schwenke, CEO Etalon AG

The technology has found applications such as continuous monitoring of large machining centres, automatic detection of deformations and vibrations of (thermo-) mechanical systems such as generators, turbines or telescopes and automated metrology monitoring of robots based on reference lines. The distance between the sensors and the system electronics can be several kilometres, making it possible to conduct measurements under extremely rough environmental conditions and to distribute measurements via a fibre optic network across an entire campus. Based on the collaborative work, the Absolute Multiline technology has already generated turnover for Etalon of approx. €1.5m, and they predict that figure will reach €2.5m – €3.0m over the next three years. Thanks to the collaboration, FSI technology is now used in a wide variety of applications beyond physics experiments, such as micro-chip lithography, calibration of computer controlled industrial (CNC) machines, power production plants and material research laboratories. The technology is also on its way into car production plants, space simulators, air craft manufacturing, national metrology institutes and many other applications.

As the research continues, ideas are shared to further improve the technology for commercial and scientific applications. Many scientific facilities such as the current and next generations of telescopes (KECK, GMT, ELT) or accelerators (HL-LHC) could benefit from the ability to continuously monitor mirrors or accelerator components with low latency. This requires the next step in FSI technology. With this capability CNC machines could not only be calibrated but also controlled in operation. With Etalon and a new collaborator VadaTech UK, Prof Reichold is currently working on extending FSI to be able to measure distance to fast-moving targets, which will open up another market of much larger size: control of high-precision CNC machine tools. ■

The original research and ongoing collaboration has been supported by grants from STFC and EPSRC.

Pressure vessels can be monitored for deformation by encasing them in a network of FSI distance measurements



Accurate, rapid and long distance measurement have such a vast range of applications in industry and research with large variations in requirements that it is impossible for a single academic from particle and accelerator physics to find them, let alone develop reliable instruments that can be used in all these areas. But with the right commercial partner the full range of applications can be addressed.

Prof Armin Reichold, Department of Physics, University of Oxford

INVENTION, INNOVATION, IMPACT

The technologies needed to provide solutions to the challenges facing society today and in the future will require the power of modern physics. It's a very exciting time for the department as our staff and students are making new discoveries that will be deployed in growing and emerging industries as diverse as quantum computing, small satellite instruments and new photovoltaic materials. With expert support from the department and the wider University, our inventions can be further developed in partnership with industry to make an impact far beyond the laboratory. In the next issue of the newsletter we'll describe how we created a new company to take super-resolution microscopy from an Oxford Physics laboratory to the hands of scientists in universities and companies around the world.

NOTES FROM THE HEAD OF PHYSICS

Prof John Wheater, Head of Department

Research is inherently risky – by definition one does not know the outcome when one starts. It is therefore necessarily the case that some research ultimately disappears from view pretty much without trace. Research projects can be misguided in subtle ways, just too hard for the techniques of the time, or demonstrate beyond doubt that some notion doesn't work or is not true in which case it soon disappears from the conscious collective memory. Before we get too gloomy, however, the good news is that much of the research done in the Physics Department over the years has turned out to give new insight into the workings of nature, to be directly useful in the wider world, or to have required the development of techniques or devices that are useful, and often more than one of these. An excellent example is the work on materials at low temperature and in high magnetic fields of the 1950s and 1960s. The demand for higher magnetic fields made their provision using room temperature magnets progressively more challenging. Martin Wood, who was at the time a Research Officer in the Clarendon, responded by building the first superconducting magnet outside the USA. These became the signature product of Oxford Instruments (OI), and are now ubiquitous in MRI scanners. OI was our first spin-out company in the modern sense and is one with which the department works closely to this day. The event marking Sir Martin and Lady Audrey Wood's ninetieth birthdays to be held in a few days' time, as I write this, is a fitting tribute to them and their many contributions to the development of advanced technology in the UK.

PROFESSOR MICHAEL BAKER

The passing of Professor Michael Baker, whose obituary appears in this Newsletter, breaks one of our last links with the immediate post-war years in the Clarendon Laboratory. Michael was associated with the department for nearly seventy years; first as a student, then following three years spent in Harvard, as a staff member and finally as an emeritus who came in regularly until shortly before his death. His work on defects in crystalline materials, and especially in diamond, paved the way for many technologically important applications; even today new applications are emerging, for example in the use of diamond for quantum devices.

THE BEECROFT BUILDING

The last few months have seen the transformation of the Beecroft Building from a shell into something close to the hugely complex system of the completed project. A visit to the interstitial servicing levels of the laboratories is a real eye-opener; all the equipment that is needed to provide the state-of-the-art environment control that we are aiming for does fit, just as shown on the plans, but there is not a lot of space to spare. Hitherto I have been able to report that the project was on schedule but now we have dropped a little behind. It is ironic that the cause of the delay has not been all that complicated equipment for the labs, but a fire at the timber factory which has delayed the delivery of such mundane items as doors. Anyway, the supply has now resumed, the delay is not too bad, and we expect to take possession of the building in the second week of February. We plan to hold the formal opening in summer 2018.

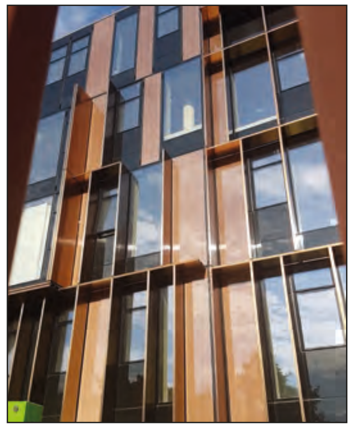
OXPEG AND THE FUTURE

This October the first two graduate students funded through our OXPEG (Oxford Physics Endowment for Graduate students) campaign will join the department to work in Particle Physics and Climate Physics. In October 2019 at least a further three students will join us through the generosity of alumni in responding to the OXPEG campaign. Whatever the future holds, and these are uncertain times indeed, the education of the next generation to the highest standards must be a crucial part of it. Please help us extend that opportunity to as many bright and motivated young people as possible; a giving form is enclosed with this Newsletter and the Development Office is always happy to discuss other ways of supporting us. Please email Hannah Curwell-Parry at hannah.curwell-parry@devoff.ox.ac.uk.

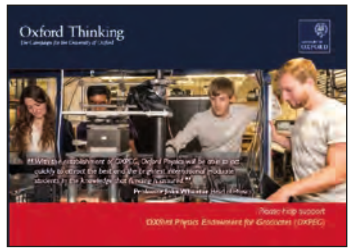
It is now a full five years since I described the building project in the very first of these notes which appeared in the second Newsletter; the Physics Department first took part in the University Alumni Weekend; and we started to develop our alumni events programme. During that time, we have funded the building; become a fixture at the Alumni Weekend; and established a portfolio of events that, together with the Newsletter, are clearly enjoyed by a great many people. We are always open to suggestions, and if you have ideas or wishes for alumni events, or features in the Newsletter, please drop a note to Val Crowder at alumni@physics.ox.ac.uk or the Editor at newsletter@physics.ox.ac.uk. If you haven't been to any of our events and have the opportunity to, then please give it a go – you will find a warm welcome and I am sure you will have a good time. As ever, we will be endeavouring to keep the standard up, and I look forward to seeing many of you over the coming year. ■

Lady Audrey and Sir Martin Wood

Clarendon Laboratory before the building of the Beecroft started



A detail of the new Beecroft Building



Our OXPEG campaign. See donation form on page 11 for more details.

PLEASE CUT HERE AND POST TO THE ADDRESS AT THE BOTTOM. THIS FORM IS ALSO AVAILABLE ONLINE

Oxford Thinking

The Campaign for the University of Oxford

UNIVERSITY OF OXFORD

Oxford Physics Endowment for Graduates (OXPEG)

OXPEG is an endowed fund that will provide scholarship support for the most outstanding graduate students, regardless of their country of origin, to study for a DPhil degree in the Department of Physics.

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Full details on how your data are held and used are set out in our Data Protection Statement at **www.campaign.ox.ac.uk/data-protection** or you can request a hard copy from our Database Team. Some sensitive personal data may be held in DARS. If at any time you have any queries about the use of your personal data in DARS or wish to change the content or extent of use of your personal data, please contact the Database Team, quoting your alumni card number (if you have one), at the address given below, or email **database@devoff.ox.ac.uk**, or telephone **+44 (0)1865 611600**.

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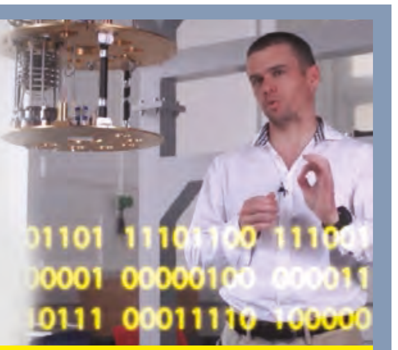


www.physics.ox.ac.uk/blog/alumni/2017/04/13/new-video-full-circle

Giving to Physics

Oxford Physics is one of the largest and most eminent Physics departments in Europe. Oxford physicists are probing new ways to harness solar energy, modelling the earth's atmosphere to predict future climate, exploring the potential of quantum physics to revolutionise information technologies and executing calculations that reveal the fundamental structure of space and time. They participate in many large-scale international physics projects – including the Large Hadron Collider, European Extremely Large Telescope and Square Kilometre Array.

Oxford Physics has established the Oxford Physics Endowment for Graduates (OXPEG) as its main funding priority and has set an ambitious target to establish an endowment providing scholarship funding for 25 graduate scholarships. With a fund of this scale, the department can be confident of having the resources to attract the best possible candidates from the UK and internationally. As well as being a launchpad for their careers, graduate students contribute enormously to the work of the department, in terms of ideas and overcoming technical challenges.

Donors who give £1,000 or more to Oxford Physics are eligible to become a member of The Henry Moseley Society. For further information about this or how to support Oxford Physics, please contact Val Crowder: email alumni@physics.ox.ac.uk.

Please note that all donations will be held as expendable endowment in the OXPEG fund, which has been established for the purposes of supporting graduate scholarships in the Department of Physics.

To make a gift, visit www.campaign.ox.ac.uk/physics

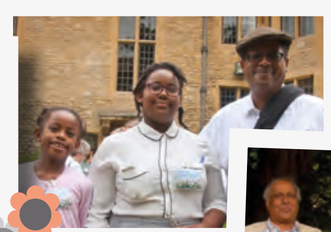
On that page, you will see links for those who would like to donate from the USA, obtain information about leaving a gift in your will and more information on tax-efficient giving.

Thank you!

Physics Alumni Garden Party

On Sunday 25 June we hosted our annual Physics Alumni Garden Party, at the beautiful venue of Rhodes House. More than 100 guests enjoyed a fascinating talk by Dr Alexy Karenowska, followed by afternoon tea and drinks. The event was hosted by Prof John Wheater, Head of Physics, with the participation of DPhil student Marco del Tutto and a demonstration of VENu (featured in the Spring 2017 Newsletter). It was a lovely occasion enjoyed by all, young and old, and a perfect time to find old mates, see friends again, or meet your tutor from more than 30 years ago!

Prof Dame Jocelyn Bell Burnell will be guest speaker at the 2018 Alumni Garden Party to be held at Mansfield College in June. Keep an eye on our website for further details.



L–R: Guest speaker Dr Alexy Karenowska; Guests looking at 3D archaeological images; Prof Wheater (second from right) talking to guests

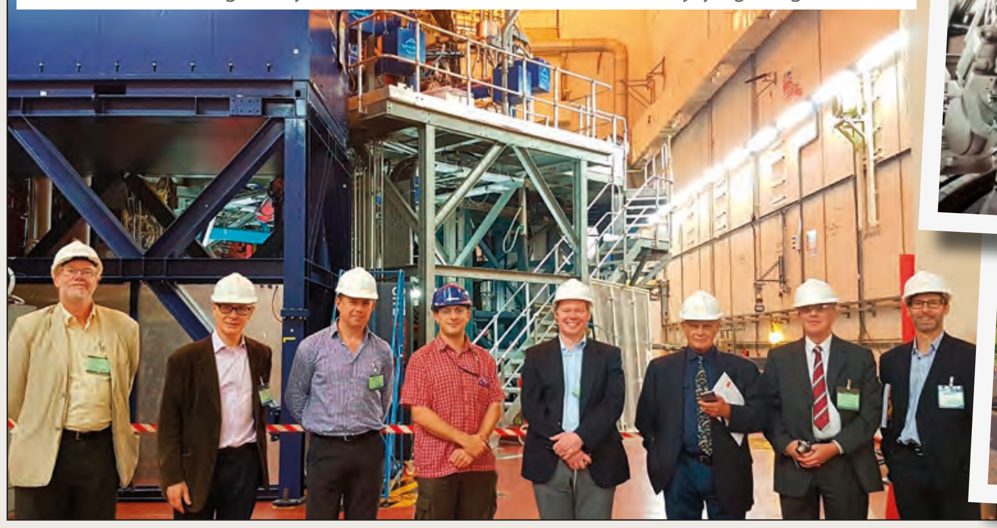
The Henry Moseley Society Special Event 2017

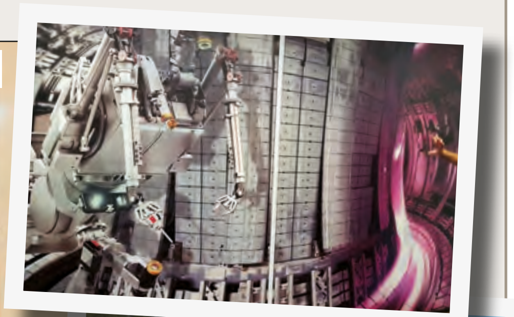
We hosted the Henry Moseley Society Special event, this year, at Culham Centre for Fusion Energy, on 9 June. Members of the society arrived at Culham in specially organised coaches. Prof Roger Cashmore (Chairman of UK Atomic Energy Authority) and his team welcomed all and after an informative introductory talk, the guests were taken in groups to see the Joint European Torus (JET) – the world's largest and most powerful tokamak, and focal point of the European fusion research programme; the control room; and other areas of the fascinating and complex installations at Culham.

Thanks are due to Pauline, Roger, Chris, Jamie and Sam for their time and dedication. Afterwards, the group enjoyed a wonderful dinner at a nearby restaurant, with plenty of time for catching up and planning next year's event.

If you would like to learn more about the Henry Moseley Society, and the many ways it supports the activities of the department, please write to Val Crowder: alumni@physics.ox.ac.uk

Guests were able to get very close to JET. Some of the members enjoying the guided visit





MERRITT MOORE HAS WHAT IT TAKES

You may remember our DPhil candidate Merritt Moore from our Autumn 2015 Newsletter (page 22). Merritt took part in the BBC series 'Astronauts: Do you have what it takes?' which aired in August/September 2017.

Follow Merritt @physicsonpointe

Roger Davies elected EAS President

The European Astronomical Society (EAS) held their annual European Week of Astronomy and Space Science (EWASS) in Prague, Czech Republic, in June. Roger Davies, Philip Wetton Professor of Astrophysics, and student of Christ Church, was elected as President of the EAS for a four year term. One of his first duties was to toast Czech Astronomy, as the Czech Astronomical Society is celebrating its centenary this year.

The EAS was founded in 1990 and acts at a European level on behalf of the astronomical community. Twenty-seven national societies are affiliated to the EAS; it collaborates with European intergovernmental research organisations like CERN, ESA and ESO.

EWASS typically attracts 1000–1200 participants, and awards a range of prizes and medals which recognise excellence in astronomy. The next EWASS will be held jointly with the Royal Astronomical Society's National Astronomy Meeting in Liverpool from 3–6 April 2018.

Prof Henry Snaith hosted PSCO In Oxford

The Perovskite Solar Cell and Optoelectronics (PSCO) conference was held at the Mathematical Institute in Oxford. 400 delegates attended, to present and discuss recent advances and challenges in metal halide perovskite semiconductors for solar cells and other optoelectronic phenomena. The conference was a resounding success; the energetic three days reflecting the fast-paced advancement of research in the field. To visit the conference website: www.psco-conference.org. To see more about Prof Snaith's work: www.physics.ox.ac.uk/research/photovoltaic-and-optoelectronic-device-group.

Top: PSCO opening lecture at Oxford Maths Institute
Bottom: PSCO social dinner at Oxford Town Hall

PHYSICS POSTDOCS CAREERS EVENT 2017

Dr Jordi Mur-Petit

The Dennis Sciama Lecture Theatre was filled to capacity in January for the Physics Postdocs Careers Event 2017. This annual event, organised by the department, aims to raise awareness among post-doctoral research assistants (PDRAs) of the varied career options that physicists successfully pursue, both in academia and beyond. To this end, the Physics Postdocs Liaison Committee (PDLC) set up a panel comprising internal speakers and external guests, to share experiences and address concerns which postdocs from all sub-departments had submitted in advance.

In a post-event survey, participants valued the 'opportunity to ask questions and listen to non-department-, non-university-based people' who offered 'both a variety of viewpoints, but also some common useful messages (eg benefits of project management skills; the need for flexibility regarding career goals and opportunities)'. More than 40% of participants agreed the event had changed their vision of their future career options.

The PDLC is already preparing the next Careers Event – if you're interested in taking part, or know someone who would be, then please get in touch. ■

Whether in academia or outside, it's worth learning at least a bit on project management.

There are actually many options outside of academia that still ask for relevant physics knowledge (not only the way of thinking).

I became more aware of job options as policy advisor; this opens a range of job opportunities I was not aware of.

Panellists (L–R): Lukas Genever (Churchill Frank), Dr Ruzin Ağanoğlu (Leoni Fiber Optics), Dr Andrew Pontzen (UCL), Dr Rosalind West (DfID), Prof John Wheater (Head of Physics), Dr Phillip Tait (Knowledge Exchange/Physics), Dr Michele Warren (Grants team/Physics); absent from picture: Dr Rachel Bray (Careers Service)

2017 LEAVERS

Every year, we wish all the best to our Leavers with an informal reception. It's a great opportunity to learn about all the ways in which you can stay connected to the department and the physics community. Pictured: some of the Physics Leavers 2017. Congratulations! Please keep in touch!

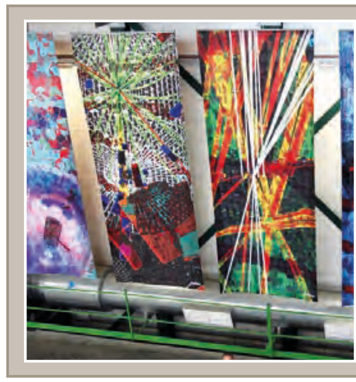
A chance to see the northern lights with Prof Martin Bureau

© WADHAM COLLEGE

Martin Bureau will join an Oxbridge alumni astronomy trip to Norway next March, where he will present a series of lectures. Martin's research centres on the formation and evolution of galaxies, mainly through detailed studies of nearby systems, across the whole electromagnetic spectrum.

Acting as 'Star Expert', Martin's lectures will include: 'Big Toys: Light and Telescopes'; 'The Dark Side of the Force: Dark Energy and Dark Matter'; and 'Universal Recycling: Stellar Nurseries and Graveyards'. Prof Bureau is a Lindemann Fellow and Tutor in Physics at Wadham College. For more details contact Christine Fairchild at the central Alumni office: enquiries@alumni.ox.ac.uk or www.hurtigruten.co.uk/uk/astronomy-tour.

XAVIER CORTADA – SCIENCE AND ART



Visitors to the Denys Wilkinson Building will have enjoyed seeing the fantastic work of artist Xavier Cortada. The now permanent displays are copies of those made at CERN thanks to Prof Ian Shipsey, who commissioned the original artwork during his time as one of the two CMS Collaboration Chairpersons. CMS is one of the two experiments that led to the discovery of the Higgs particle. Ian strongly supported the Arts@CMS project and Cortada was one of the participating artists. See more of his work @xcortada / www.cortada.com.

DEPARTMENT SUMMER PICNIC

In June, the entire department gathered in the beautiful University Parks for a BBQ and picnic lunch. This was a great time to catch up with colleagues and to enjoy lunch with families and friends.

FORTHCOMING ALUMNI EVENTS

The department offers a series of special lectures, events and other opportunities for alumni to engage and stay connected. The most up-to-date information can be found on the website at www.physics.ox.ac.uk/events.

ALUMNI EVENT AT THE ROYAL SOCIETY

10 November 2017 'Cloudy with a chance of sapphires: the important role of clouds for climate – from Earth to Exoplanets'. Hosted by Prof David Marshall (Head of AOPP) and senior members of the department. Talks, discussion panel, Q&A, followed by a reception and networking opportunities.

THE HINTZE LECTURE

13 November 2017 This is a public lecture, all welcome. This year's speaker will be Prof Brian Paul Schmidt AC, FRS, FAA (Nobel Prize in Physics 2011). *Martin Wood Lecture Theatre, Oxford.*

THE PARTICLE PHYSICS CHRISTMAS LECTURE

2 December 2017 This year's speaker will be Prof Sir Tejinder Singh Virdee, FRS. Hosted by Prof Ian Shipsey, Head of Particle Physics, including a full day of talks, Q&A, lunch and networking opportunities. *Martin Wood Lecture Theatre, Oxford.*

SAVE THE DATE! 2018 EVENTS...

NEW BEECROFT BUILDING INAUGURATION

TBC We are working on a series of events to celebrate with alumni and friends.

EUROPEAN ALUMNI WEEKEND: 'MEETING MINDS' – ROME, ITALY

16–18 March 2018 The Physics Department will participate in the event with many activities for alumni in addition to events organised by Central University Alumni Office. Dr Alexy Karenowska will be one of the main speakers during this event. Join us in Italy if you can! More details available soon. www.alumni.ox.ac.uk/Rome2018

NORTH AMERICAN ALUMNI WEEKEND: WEST COAST

6–7 April 2018 Let us know if you are planning to attend. Prof John Wheater and other members of the department will be there, and they'd love to meet you. www.alumni.ox.ac.uk/north-america-2018

OXFORD MAY MUSIC

3–7 May 2018 Help Oxford May Music, a unique festival of science and music founded by an Oxford physics professor. Leading scientists and musicians will entertain. See www.oxfordmaymusic.co.uk for details on becoming a Friend.

All these events are free, but we have limited capacity so tickets will go on a first come, first served basis. To avoid disappointment, visit our website regularly for updates. **To book your place, please visit www.physics.ox.ac.uk/events.** We update the list all the time, so please check regularly. If you have any questions about the events, please contact Val Crowder: alumni@physics.ox.ac.uk.

MARTIN WOOD IN THE CLARENDON LABORATORY

Written by Lady Audrey Wood for the Physics Newsletter, Autumn 2017

Martin's arrival in the Clarendon was serendipitous. Following his National Service as a Bevin Boy down the coal mines, the National Coal Board paid for him for four years in the engineering school at Cambridge, and two years at Imperial College studying mining engineering. Feeling obliged to go back into the mining industry as a very junior management trainee, he was working in a Midland's pit when an advisor told him he was really free to work elsewhere without feeling guilty. He had enjoyed the coal face, but the bottom rung of the management ladder in the huge coal industry was not a good place to be in 1955. An old family friend in Oxford told him that Professor Alexander Thom was looking for a young engineer in the Engineering School. He accepted the job, put in his resignation to the Coal Board, and prepared to move to Oxford.

MOVING TO OXFORD

Two weeks before we were due to come to Oxford, Martin got an urgent phone call from a mortified Professor Thom, to say that the University Chest would not give him the money for the position. If Martin still wanted to come to Oxford, he would find him some tutoring, and some engineering drawing classes to teach, so he would have a little income.

By the time we got to Oxford, Alexander Thom had learned that the Physics Department was looking for an engineer, and he sent Martin over the road to see Nicholas Kurti. They got on very well together. They went all over the lab, and saw the old 2MW DC generator that once powered the trams of Manchester; the large cooling-water tank on the roof; and the research rooms, with magnets trailing huge cooling hose pipes and fed by heavy power cables, and the research equipment towering above the magnets. Martin saw the workshops where the magnets were made, and learned of the responsibilities of the job. As they were shaking hands at the door Nicholas remarked 'I think we will just have to see the other candidates' – Martin had no idea it was an advertised job. It probably wouldn't happen now!

WORKING IN THE CLARENDON LAB

So, in the Autumn of 1955 Martin arrived in the Clarendon Lab to look after the engineering installations, to learn about the high field magnets and then design and develop new ones and oversee their manufacturing in the workshops. The magnets were mainly stacked, strip-wound copper pancakes, insulated with fishing line nylon. Martin's main innovation here was to put them in fibreglass cases instead of the old heavy metal ones. Later, he inherited a half made 'Bitter' magnet, like the ones in MIT. This one didn't really suit the old generator, requiring rather thin copper disks and insulation. The many cooling holes in both disks and insulation were hard to keep aligned, as the disks were stacked up, each overlapping the one before at its slot. Martin took the stack home, to work with a long file on the holes, in peace. I found him sitting in our son's playpen with the stack, while Jonathan romped around the rest of the room. This magnet achieved a higher field than the pancakes, but was always more difficult to maintain. The disks are beautiful and adorn many a wall belonging to a physicist or an engineer.

In the 1950s, new universities were being established in various towns and cities. Academics from Oxford went to set up some of the new Physics departments, and wanted to continue their lines of research using high magnetic fields. Some of the equipment they wanted was not available commercially, and a couple of them asked Prof Brebis Bleaney whether they could get the Clarendon technicians they knew to make a few parts or magnet coils in the workshops after hours. By the end of the decade this had become an embarrassment to the department, impacting the work of one or two resident researchers. Martin suggested to Nicholas that he might start a company to do this work instead of the Clarendon workshops. Nicholas's reaction was 'What can I do to help you?' Nicholas was originally from Hungary, where universities worked much more with industry than in the UK at that time. Brebis Bleaney had also worked with industry during the war, and didn't have the same apparent horror of mixing with industry that some of the academics had then. He gave the idea his blessing. But Nicholas insisted that his approval only held if Martin stayed on in the Clarendon developing new magnets.


Magnets team is best in its field

From the Clarendon Archives

Top: Martin testing the Magnet for the first time

Bottom: The first Superconducting Magnet, April 1962, in Martin's hand

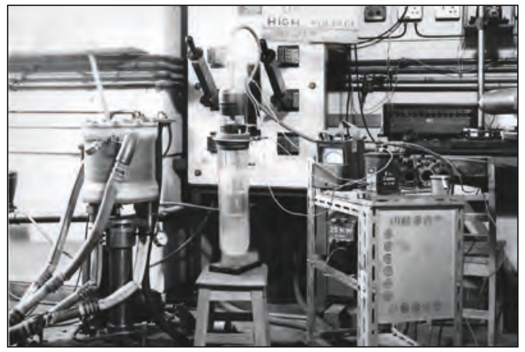
The Martin Wood Complex at the Department of Physics hosts the Martin Wood Lecture Theatre and the Audrey Wood Conference Room. More than 10,000 people a year use these facilities for lectures, meetings and other events.

THE START OF OXFORD INSTRUMENTS

Oxford Instruments was born in 1959. For two years it served this purpose of helping the new universities to set up high magnetic field facilities. A lot was consultancy on what was available, and on how to get things like magnet hoists made locally; designs for systems; and a few parts made in the garden shed with the help of retired Clarendon technician Joe Milligan. We also made two big stacked pancake magnets in those two years, one for the Royal Radar Establishment in Malvern, and one for Harwell to go in a reactor.

In the Clarendon, Martin developed a new sort of magnet, the Polyhelix magnet, with six or seven concentric nesting helices. This design suited the generator better than the Bitter magnet, and the first one achieved a field of 10T. In November 1961 Martin gave a paper on this magnet at the First International High Magnetic Field Conference in MIT. It was at this conference that superconductors emerged as possible replacements for copper in high field magnets. The company knew nothing about liquid helium – necessary for superconductors – and cryogenic equipment to contain it, but we decided to try this brand-new technology of superconductivity. We got hold of some of the first superconductors available and Martin designed and wound an experimental magnet. Nicholas Kurti and other Clarendon colleagues were very interested and lent him a glass cryostat and a little liquid helium. In the Spring of 1962 Martin tested it with all of them watching. As the magnet cooled, the resistance went down steadily, but suddenly it dropped to zero. The magnet coils became superconducting. The magnet had been wired up to a car battery through a rheostat, and then, as Martin very slowly wound up the current until it reached 17 amps, just above the design current, its coils returned to their normal, non-superconducting, state with a pop and rapid boil-off of the remaining liquid helium. This was the first superconducting magnet of many made and still being made by Oxford Instruments. They came in a great variety of sizes and shapes, often for particular experiments, and they led on to high field analytical NMR magnets, and on further to whole-body MRI magnets in 1980.

Martin left the Clarendon to concentrate on the fast-growing company in 1969, 10 years after the company started. But he and Oxford Instruments' scientists have been in touch with the laboratory ever since. ■



Testing the first superconducting magnet. The superconducting magnet can be seen inside the glass cryostat (centre, bottom). Further left is one of the old water-cooled magnets, with copper coils inside a fibreglass case, with the cooling water hoses attached. Clarendon Laboratory, Oxford, March 1962.

The Sir Martin Wood Prize is awarded annually by the Millenium Science Forum to a young researcher from a Japanese University Research Institute who has performed outstanding research in the area of condensed matter science.

The Sir Martin Wood China Prize (sponsored by Oxford Innovation) for research in physical science is awarded to promote and recognise the novel work of young scientists working in the fields of low temperatures or high magnetic fields in China.

MARTIN & AUDREY WOOD

1956	1959	1962	1972	1980	1982	1983	1986	1987	1994	2000	2004
Martin was first appointed as an Engineer by the Department of Physics at Clarendon Laboratory	Oxford Instruments is born, the first University of Oxford spin-out company and still one of the most successful	Martin Wood made the first superconducting magnet outside the USA. Awarded Queen's Award for Technological Innovation for developing superconducting magnets and the Harwell dilution refrigerator	Awarded Queen's Award in 1972 for Exports	Awarded Queen's Award for Technological Achievement in superconducting magnets for NMR spectroscopy	Royal Society Mullard Award	Awarded a second Queen's Award for Exports	Commander of the Order of the British Empire, Order of the Rising Sun, Knighted	Fellow of the Royal Society	Honorary Fellow of the Royal Academy of Engineering	The Martin Wood complex at the Department of Physics was officially opened	Honorary doctorate from University of Oxford

HOW TO MAKE A SUPERNOVA

– by Dr Jena Meinecke

Physicists are using lasers to recreate some of the most violent events known in our Universe – from supernova explosions to galaxy cluster mergers and much more. Researchers from the Oxford Centre for High Energy Density Science (OxCHEDS), the Atomic and Weapons Establishment (AWE), and Imperial College were recently awarded an exhibition stand at the Royal Society's Summer Science event, held on 3–9 July, to show the public 'How to Make a Supernova' using the most powerful lasers in the world.

As thousands of visitors approached the stand, they were transported into the world of laboratory astrophysics, where high-energy lasers recreate the violent conditions found in the Universe. A large mural of the night sky, lit up with the supernova remnant Cassiopeia A, greeted guests as they learned how a team led by Professor Gianluca Gregori created a scaled version of this remnant in the laboratory. Colin Danson, the AWE exhibit sponsor, said 'We were very excited to be at the Royal Society showcasing some of the cutting-edge research undertaken by the preeminent scientists through the AWE Orion academic access programme. The collaborative effort of the three institutions allowed over 40 people to act as exhibitors throughout the week.'

Visitors explored the nature of plasma, both in the laboratory and in space, with a variety of demos, games, and crafts. A giant plasma ball anchored the exhibit, and was even featured on BBC, as children conducted electricity with their bare hands. Interactive laser games and astronomy-themed crafts were featured alongside large optics and targets from the Orion Laser (AWE) itself. The highlight of the event was the air vortex demonstration, in which a large bin was filled with smoke and visitors hit the sealed back, like a drum, to create beautiful vortex rings that mimicked a shock wave seen on the leading edge of a supernova explosion. The goal: knock down as many cups, or cosmic clouds, as possible! This brought out the inner child in many, while demonstrating some real physics behind supernovas.

'The Royal Society Summer Science Event was a wonderful opportunity to inspire future generations of physicists, while engaging the public in the up-and-coming field of laboratory astrophysics,' explained Dr Jena Meinecke, lead organiser through OxCHEDS. 'Hopefully the passion and enthusiasm of our collaborative team has inspired students to consider further education and careers in physics.'

> In school, I didn't know this research field existed and now I'm using the biggest lasers in the world to mimic supernovas. You could too!
>
> *– Dr Jena Meinecke*

More information about the science behand the stall can be found at www.physics.ox.ac.uk/makeasupernova. ■

PHYSICS IN PRIMARY SCHOOLS

Researchers from the department have long visited local primary schools to help inspire interest in physics from a young age, often schools where their own children are pupils. However, we have more recently been developing a primary programme aimed at targeting primary schools in areas of Oxford with the lowest progression rates to university and in 2016/17 we worked with The Oxford Academy to provide workshops on magnetism for schools in the East of Oxford.

We are also working with established partnerships of schools to develop and deliver new activities. In June we ran a day in the department for 87 pupils from 12 schools across Abingdon and Chipping Camden through the Ogden Trust Primary Partnerships scheme (www.ogdentrust.com).

We hope to develop these relationships further to provide a solid foundation in physics education as students progress into secondary school.

OXFORD PARTICLE PHYSICS MASTERCLASS 2017

– by Dr Sam Henry

The Particle Physics sub-department ran an exciting activity day in March for a group of more than thirty students from local schools. The particle physics masterclass gave the Year 12 group the chance to delve a bit beyond their course syllabus and experience first-hand what it is like to work as a particle physicist for a day, analysing data from the Large Hadron Collider.

The day kicked off with an introductory lecture by Oxford physicist Alan Barr, whose usual work involves hunting for dark matter and other new particles with the ATLAS detector at CERN. He explained all about fundamental particle physics: how the Universe is made of elementary quarks and leptons which interact through four fundamental forces. Tony Weidberg then explained how physicists study quarks and leptons, with a small particle detector set up as a demonstration, and slides of the much larger ATLAS detector.

> IT WAS AN EXTREMELY ENCOURAGING AND FRIENDLY ENVIRONMENT

This was just a warm-up for the main activity. After a tutorial by Oxford graduate students Beojan Stanislaus, Aidan Reynolds, Santiago Paredes Saenz and Francesco Giuli, the group moved to the computing laboratory, where they used ATLAS event display software to examine real data from the experiment. The challenge was to identify the particles from the electronic signals – or tracks – recorded by the detector. The students learned to recognise the characteristic signatures of photons, muons and electrons, and looked for signs of particles, such as the Z boson, as well as unknown ones.

Over lunch they had the opportunity to talk with researchers and graduate students about working at CERN and the latest research on topics like the Higgs Boson and the asymmetry of matter and antimatter in the Universe. After completing the analysis work, there was time to combine the results and discuss what they had found with the rest of the group, before joining a video conference hosted at CERN where they discussed their findings within an international team of researchers. Other student groups from institutions in France, Spain and Germany logged on to present the results of their analyses and ask questions to the team at the Large Hadron Collider. This exciting conclusion to the day gave the group a snapshot of life within an international particle physics collaboration. The ATLAS group at Oxford are part of a global collaboration of more than 3000 scientists and engineers.

We were pleased to see that the students enjoyed the day, and nearly all said the event had increased their interest in physics. Perhaps some of the group will return to Oxford as students or researchers, and may one day work on building, running and analysing the data from future particle physics experiments.

Thanks are due to Cigdem Issever, Sue Geddes and Sian Tedaldi who organised and ran the event and everyone else who helped behind the scenes. The particle physics masterclasses are part of a programme run by the International Particle Physics Outreach Group. We plan to run the event again over two days in 2018, to give even more students the opportunity to experience particle physics research. ■

SUCCESS FOR THE BRITISH TEAM AT THE INTERNATIONAL PHYSICS OLYMPIAD

After a rigorous selection process and some short bursts of intense training, the British Physics Olympiad (BPhO) team, comprising five talented young physicists at the end of their school careers, gained excellent results at the International Physics Olympiad (IPhO). The team achieved two gold, one silver and two bronze medals between them and showed particular aptitude for maintaining their composure when faced with very difficult theoretical and experimental questions during two five hour sessions.

The IPhO brought together 395 talented students from across the globe (86 countries) to Yogyakarta, Indonesia from 16 to 24 July 2017. The IPhO aims to celebrate Physics and friendship in equal measure, and the friendships made over the course of those eight days will long remain.

The BPhO is a charitable trust, run by volunteers, that aims to support and develop students' problem-solving skills. The department has supported the BPhO since 2008 with office administration and paper marking. We also organise training camps held at Oxford, and events for teachers across the UK. More information about the BPhO can be found at www.bpho.org.uk. ■

L–R: Euan Tebbutt (Twycross House School), Weida Liao (Churston Ferrers GS), Robbie King (King's College School Wimbledon), Robert Waddy (Devonport HS for Boys), Callum Brennan-Rich (Liverpool Bluecoat School) receive their medals at the closing ceremony of the IPhO. Well done team!

Follow Simon on @simon_rp84

FIVE MINUTES WITH... DR SIMON R PROUD

Postdoctoral fellow, Department of Atmospheric, Oceanic and Planetary Physics

Tell us a bit about your background

I was born in Canterbury and spent much of my childhood in Edinburgh. I moved to Leicester to study Physics and Space Science before moving to Copenhagen for my PhD studies. After graduating I stayed in Copenhagen for a postdoc, living there for almost ten years in total. In 2015 I moved to Oxford to work in the Earth Observation Data Group (EODG) at Oxford Physics.

When/how did you decide to become a physicist?

I've always been fascinated by two things: mechanical devices, and how the world around us works. Physics is often a mix of these, so it was a natural choice for me. I also love that physics covers such a wide range of regimes and scales, such as photon scattering right up to the dynamics of hurricane formation in the case of my research.

Why is it important to study physics?

Studying physics is important because physical principles affect every aspect of our daily lives, especially in an age filled with so many high-technology gadgets. Physics has the potential to improve our wellbeing, keep us safe and entertain us. It also allows us greater appreciation of our Universe, satisfying human curiosity.

Can you explain the work you do?

I devise techniques that can be used to transform satellite images of the Earth into data that describes the land and ocean surfaces, pollution in our atmosphere and the properties of clouds. My work focuses on a computer algorithm named ORAC (Optimal Retrieval of Aerosol and Cloud) that can retrieve the temperature and height of cloud tops, as well as an estimate of the size of liquid water droplets or ice crystals contained within. This information is important for use in weather forecasts, climate models and within industry, for example in producing live data regarding the location of potentially hazardous storms around the planet. I also spend some time in the laboratory, taking measurements that allow us to better quantify the light scattering and absorption properties of dust, volcanic ash and ice crystals.

What are the current challenges in this field?

One of the biggest challenges is the level of uncertainty in our assumptions and measurements. We need an accurate model of the Earth's surface to remove any effects it has upon the satellite measurements and hence retrieve only atmospheric components in our data. We typically assume surface parameters, which are often based upon a model produced from satellite data that assumes atmospheric parameters. This results in a vicious circle, where neither atmospheric nor surface scientists are entirely sure that their assumptions are correct. I think the next major leap forward will be to create a method that can jointly retrieve accurate estimates of both surface and atmospheric properties.

What interests do you have besides physics?

Walking in the hills is my main interest, especially in the Scottish Munros, and I try to do so as frequently as possible. I'm also a huge fan of mountaineering and have been lucky enough to visit the Himalayas several times, on one of which I met my now-wife, who shares my love of the outdoors. I also love to fly, and can occasionally be found bumping my way across the skies of Oxford in a Cessna.

What scientific breakthrough would you like to see in your lifetime?

It would be great to see advances that allow efficient interplanetary travel... we really need innovative ideas for spacecraft propulsion and there seem to be a lot of clever ideas in that area just now. I'd also like to see breakthroughs in how we generate and store electricity: new battery technologies that allow high power density would transform our lives.

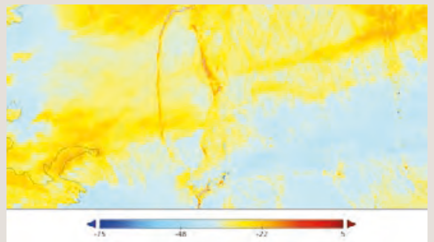
What are your plans for the future?

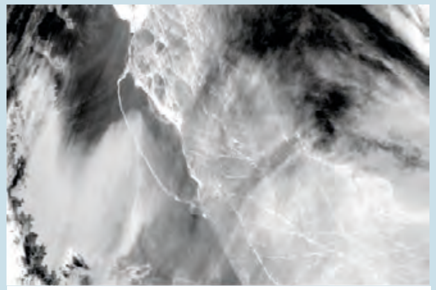
I'd like to work on the boundary between research and industry, as satellite technology has brilliant potential for use in daily life – something that isn't being fully exploited yet. I think it's an important part of being a scientist not just to research a theory or technology, but also to explore how we can use our work in other contexts.

What are the main positives of working at Oxford?

The best part of working at Oxford Physics is the wide range of people you meet. It's excellent to be able to attend a seminar on an unfamiliar topic, learn new things and meet researchers from an entirely different field. Not only is it interesting but it benefits us as scientists, by giving us a fresh perspective and new ideas. ■

Data produced by Oxford Physics showing the temperature of the Earth's surface. The newly-formed A-68 iceberg is slightly to the left of centre, separated from Antarctica by a thin line of red, indicating warmer sea water.





The first view of A-68 after it broke free from the Larsen-C ice sheet

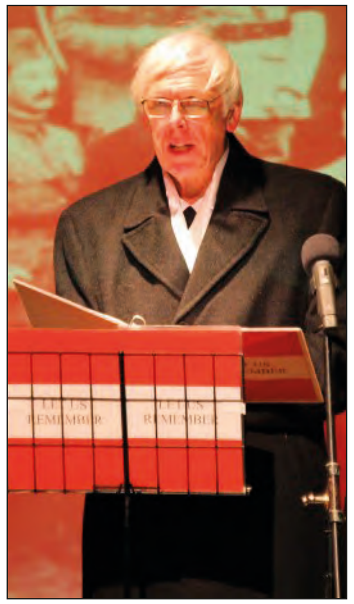
Oxford Physics scientists have used satellites to document the creation of Iceberg A-68, one of the largest icebergs ever recorded, which appears to have split from the Larsen-C ice shelf in Antarctica on 11 July. The constant darkness of polar winter means it can be hard to monitor the Antarctic ice sheets, but data from specialist satellite sensors that see using reflected moonlight[1] allow us to peer through the gloom and watch the Iceberg break away.

A special technique, known as ORAC[2], created by the Earth Observation Data Group[3] at Oxford Physics and researchers at RAL Space[4] transforms these satellite images into information about the Earth and its atmosphere – giving insight into clouds over Antarctica and enabling us to retrieve clear pictures of the new iceberg.

1 https://earthdata.nasa.gov/viirs-dnb
2 http://proj.badc.rl.ac.uk/orac/
3 http://eodg.atm.ox.ac.uk/eodg/
4 https://www.ralspace.stfc.ac.uk/Pages/home.aspx

LETTER TO THE EDITOR

*Letters are welcome and should be addressed to **newsletter@physics.ox.ac.uk***



Above: Dr Jeans in Performance of 'Let Us Remember'.

Below: in rehearsal for 'Some Sunny Day'.

DR ANTHONY F JEANS, JESUS, 1960

It was fascinating to read Christopher Rose-Innes's account of his journey from leading physicist to sculptor. In my experience, many physicists are deeply engaged with the visual and performing arts as practitioners, collectors, sponsors and supporters. (Engagement with literature seems less common – C P Snow and J Robert Oppenheimer being exceptions.)

My own career led from nuclear physics research through the scientific equipment business, teaching and management in Further and Higher Education, vocational education and training with the Fire and Rescue Service and the Offshore Petroleum Industry to my own consultancy business in education, training and development and in retirement, to the role of producer, director, designer and author for an amateur community theatre company.

In the 1980s, as one of the Vice Principals of Gloucestershire College of Arts and Technology (the HE programmes of which now form part of the University of Gloucestershire), I was based in the Art School in Cheltenham. The day to day contact with staff and students engaged in foundation and degree courses in Fine Art and Fashion was a revelation and the experience of exhibitions and fashion shows opened up new horizons.

In the last few years, with a colleague (who had been the Head of a local primary school), we have mounted successful productions of 'Murder in the Cathedral', 'A Midsummer Night's Dream' and 'The Rivals' and, with my wife as collaborator, we have constructed and written commemorations of WW1 in 2014 ('Let Us Remember') and WW2 in 2017 ('Some Sunny Day'). These have been for Charlton Kings Community Players (www.charltonkingscommunityplayers.com).

It has been very rewarding to develop a concept, manage the process, specify the set and the costumes, cast the show, create the illusion through lighting, music and projected images and then allow the actors to develop their roles within the overall framework. It is a remarkable experience, on the first night, when the house lights go down, the stage lights come up and the actors begin to deliver the concept which has been worked on for many months.

I have found as a physicist, working in very varied contexts with people from different disciplines and with a very wide variety of roles, that the experience gained from study of the subject and involvement with physics research provides an unlimited source for engagement. Physics is widely recognised as having profound conceptual and philosophical aspects while at the same time dealing with the real world and requiring intensely practical action in conducting research, using equipment, managing projects and process and applying numerical analysis.

'THE EXPERIENCE GAINED FROM INVOLVEMENT WITH PHYSICS PROVIDES AN UNLIMITED SOURCE FOR ENGAGEMENT'

Thus I have found it possible to gain understanding and respect from people from all kinds of academic backgrounds – philosophy, theology, arts and humanities, social sciences, engineering, other sciences, mathematics, computing, business, management etc.

At the same time, because physics research requires teams with different skills, including people who need to do very basic tasks such as cleaning and record keeping, there is the opportunity to form working relationships across the piece. This also embraces people who are intelligent and skilled but also very focused on practical matters, as for example, members of the Fire and Rescue service.

On the world stage, the UK scores very highly in the quality of its offerings both in the arts and in the sciences. Theatre, music, literature, visual arts etc are very successful both in popular culture and in high art. Scientific research in many areas is at the leading edge and the number of Nobel prizes that come to this country is remarkable. There are some wonderful examples of synthesis thus the film industry in the UK has been widely recognised and sought after for its technical expertise.

In a time of political uncertainty, these areas of strength need supporting to form the basis of future prosperity and the open society. There should be common interest in the arts and science communities for securing continuing support for excellence in performance, production, fundamental and applied research, teaching and learning in the universities and attracting the best and brightest across the world to contribute.

Dr Anthony F Jeans, Jesus College 1960–68
MA DPhil MInstP CPhys FRSA
(DPhil in Nuclear Structure Physics 1967) ■

CELEBRATING THE LIFE OF **GIANA KURTI**

Giana was born on 15 April 1913 at the Red House, Chilwell, Notts, to Brigadier General Charles Tyrell Shipley and Joyce Shipley (née Carmichael). She had an older half-sister, Sally, and an older half-brother, Moses. They moved house in England frequently and in 1922 moved to Italy for three years. Giana's first experience of school was boarding at the Poggio Imperiale in Florence, where she developed a love for the language and literature of Italy.

From 1926–27 the family visited South Africa, where her mother had been born. On their return to England, she attended St Mary's School, Calne. Unusually, despite having 'no aptitude for sport', Giana was made Head Girl. She also 'discovered she was good at exams' and got a scholarship to Lady Margaret Hall, where she read Italian.

After her father's death in 1933, she moved to London and took various secretarial jobs, including at The Times Book Club. She went to theatre and ballet performances, and took dance classes. She started working for MI5 before the war, and during her employment was based in Wormwood Scrubs Prison and Blenheim Palace. After the war she spent six months in Rome, seconded by MI5 to the British Embassy.

Giana and Nicholas Kurti were married on 24 September 1946; her ease and elegance complementing his bombastic brilliance. The first Edinburgh Festival took place in 1947; the arrival of her first daughter, Susannah, in 1948. Her second daughter, Camilla, was born in 1952.

In the 1950s and 1960s there were family summer holidays on the Gower Peninsular in Wales, and in Europe: Brittany, Arcachon, Strobl am Wolfgangsee, Budapest, as well as holidays associated with conferences: Lake Como 1956, Crete 1967, St Andrews 1968 where she witnessed Russian scientists apologising to Czech colleagues for the invasion of their country; and from 1992 at the International Workshop on Molecular Gastronomy at Erice, Sicily, where she put into practice her knowledge of Italian.

Two sabbaticals in the USA (Berkeley 1956–57, and New York and Berkeley 1963–64) enhanced Giana's ability to connect with people, forming deep and lasting friendships that sustained her throughout her life. This gift was also evident in the way she developed independent friendships with people she knew through Nicholas' involvement with Brasenose College, the Clarendon Laboratory, The Royal Society and visiting Hungarian scholars.

Their round the world trip in summer 1964 was an experience that she appreciated enormously and made a lasting impression.

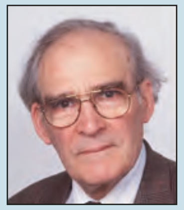
Italy and its culture gave her great pleasure: the Oxford Italian Association; visits to exhibitions of Italian art; Italian classes which led her to host the Italian Conversation group until Summer of 2016; and holidays in Italy with Susannah. Giana's love of English history and culture was enhanced by National Trust properties visits, and short breaks in English cities and towns, from York to St Ives, with daughter Camilla.

In Oxford, her activities included volunteering at the University Newcomers Club and Summertown Oxfam Shop; going to theatre and dance at the Playhouse and outings with the Friends of the Ashmolean and Wolvercote Horticultural Society.

Nicholas and Giana's generous hospitality extended to friends and family of all ages from all over the world. After Nicholas' death in 1998, Giana continued to enjoy this contact, making visits in England and Hungary, and welcoming everyone to the house in Blandford Avenue. ■

This text has been kindly provided by Susannah Kurti, daughter of Giana and Nicholas, and is a reproduction of the notes from the farewell event that took place at Jurys Inn, Oxford, on 3 July 2017.

IN MEMORIAM: **PROF MICHAEL BAKER**



It is with great sadness that the Physics Department announces the death of Professor John Michael Baker on 10 August 2017 at the age of 86.

Michael came up to Oxford in 1948 as a pupil of Brebis Bleaney at St John's College, and was awarded a BA in physics in 1951. He then became Bleaney's graduate student at St John's and later at St Anthony as a Senior Scholar, and gained a DPhil in 1954. Following a period at Harvard as Fulbright Scholar and Research Fellow, in 1957 he was appointed a University lecturer in the Physics Department and an Official Fellow and Tutor at Merton College. Michael was Head of Condensed Matter Physics from 1993 to 1997 and was awarded the title of Professor in 1996. He retired in 1998 with the title of Emeritus Professor and Emeritus Fellow of Merton College.

Michael's principal field of research was magnetic resonance, and his techniques of choice were electron paramagnetic resonance (EPR), electron nuclear double resonance (ENDOR – a technique which he pioneered in Britain) and, later, muon spin relaxation spectroscopy. Michael used these methods to investigate the nature of defects in a variety of materials, including in quartz, III-V semiconductors, oxides, fluorides, ferroelectrics and metalorganic crystals. This body of work, collected in more than 150 publications, led to his election to a Fellowship of the International Electron Paramagnetic Resonance (ESR) Society in 2011. Michael was particularly proud of his work on diamond, which was definitive in elucidating structures of intrinsic and impurity-related defects. This research was essential for the exploitation of synthetic diamond in optical and electronic applications, including very recent breakthroughs in quantum information processing. Until a few weeks ago, Michael was a regular presence in the department (he continued to publish papers until the late 2000s), and was well known and loved by generations of academics and students in the Clarendon laboratory.

Michael's funeral was held at Merton College Chapel on 11 September on a beautiful sunny afternoon. Michael's ashes will be buried in the Grove Meadow, at the west end of the Chapel at Merton. A memorial service will be held in the Chapel on 10 February 2018 at 3pm. ■

www.merton.ox.ac.uk/news/professor-john-michael-baker-1930-2017

COMINGS, GOINGS & AWARDS...

COMINGS...

ASSOC PROF SIDDARTH A PARAMESWARAN joins the Theoretical subdepartment of Physics. His work focuses on quantum mechanical systems of many particles that are strongly interacting, far from equilibrium, or both.

The department is proud to announce the four new Oxford Physics University Research Fellows: **DR JAMES FROST** (Particle Physics), **DR ADAM INGRAM** (Astrophysics), **DR RALPH SCHOENRICH** (Theory) and **DR SUZIE SHEEHY** (Particle Physics). The newly appointed fellows will be working on a wide range of research areas including detecting the particles that make up dark matter and how they interact by using data from the Large Hadron Collider; probing strong field gravity by mapping accreting black holes; unravelling the structure and history of the Milky Way and other galaxies; and exploring new pathways for the next generation of high intensity hadron colliders.

GOINGS...

DR MICHAEL VANNER, Departmental Lecturer and PI for the Quantum Measurement Lab. Michael has accepted a permanent position at Imperial College London to start a new experimental group that will study fundamental physics and quantum technologies with quantum optomechanical systems.

DR ROXANNE GUENETTE, STFC Rutherford Fellow. Roxanne studies neutrino oscillations and cross-sections using Liquid Argon detectors. Her main activities are on MicroBooNE, SBND and DUNE. She is now an Assistant Professor at Harvard University (USA).

JOHN MACALLISTER, Physics IT support group. After 42 years with the group John has now retired. His recent responsibilities have included user and system support throughout the Clarendon laboratory. His friendly personality, dedication and flexibility in assisting with all types of rapidly changing technology will be hard to replace. We wish John a long, relaxing and happy retirement.

MALCOLM BRADBURY, Senior Administrator of the Department. Malcolm retired from his post after 11 years of dedication, enthusiasm and hard work. We wish him a happy retirement.

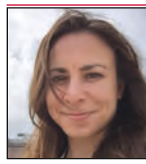
AWARDS

TIMOTHY CROTHERS was awarded the David Ryan Prize 2017 for the best presentation by a second year student at the annual poster session.

CHICO CAMARGO has won an Early Career Researcher award in the Vice-Chancellor's Public Engagement with Research Awards. Chico is the host and writer of a fortnightly show, Top Models, where he engages people with the mathematical models used in science, and how they connect the natural and the social sciences. He has produced more than 20 films; his YouTube channel, BláBláLogia, won the 2016 YouTube 'NextUp' prize.

PROF STEVEN BALBUS has won an MPLS Teaching Award for his 'exceptional ability to integrate research and teaching'.

ILEANA ANDREA BONILLA BRUNNER and **CHRISTOPHER DAVIES** have been jointly awarded the Nicholas Kurti Prize 2017 for the best presentation and distinguished work by a third year postgraduate student.



DR ALEXY KARENOWSKA has won an Early Career Researcher award in the Vice-Chancellor's Public Engagement with Research Awards, for her work on a public science project focused on the documentation, preservation, and restoration of at-risk cultural heritage sites across the world. Working with UNESCO and the Government of the United Arab Emirates, she developed the means to study, document and preserve heritage materials through optical, radio and X-Ray-based techniques and the application of 3D printing technologies. In 2016 Dr Karenowska led a team to create a 13-tonne replica of the Triumphal Arch from Syria's Palmyra site using a combination of photogrammetry-3D-based computer modelling and state-of-the-art 3D machining in stone. She managed the installation of this structure on Trafalgar and has overseen the installation of the same arch in New York, Dubai and Florence. Approximately 2.1 million people of all ages have visited the public installations.

Did you know? The Careers Service is for life…not just during your time in Oxford! For more information contact Dr Michael Moss: michael.moss@careers.ox.ac.uk or visit www.careers.ox.ac.uk

PROF GUY WILKINSON has won the James Chadwick Medal and Prize 2017, for his outstanding contributions to the experimental study of heavy quarks and CP violation, most especially for his leadership of, and his decisive contributions to, the LHCb experiment at CERN.

PROF HENRY SNAITH was awarded the IoP James Joule Medal and Prize for his pioneering discovery and development of highly efficient thin-film organic-inorganic metal-halide perovskite solar cells.

JUSTIN BALL was awarded a 2017 EPS DPP PhD Research Award for his study of the effect of plasma boundary shape on driving intrinsic rotation in the tokamak, and more generally on the confinement properties.

PROF TIM PALMER was elected a Foreign Member of the Italian Accademia dei Lincei which was founded in 1603 and is the oldest such academy in the world.

PROF DAVID MARSHALL (Head of AOPP) has been elected a Member of the Academia Europaea. Professor Marshall is a Physical Oceanographer interested in understanding how and why the ocean circulates, how the ocean circulation might change in the future in response to anthropogenic climate forcing, and how the ocean circulation has varied in the past.

PROF DANIELA BORTOLETTO has been awarded an MPLS Equality and Diversity Award in the best Initiative category for the development of the annual Conference of Undergraduate Women in Physics and for engaging and inspiring undergraduate women from across the United Kingdom.

The European Physical Journal *E-Soft Matter and Biological Physics (EPJE)*has awarded **PROF RAMIN GOLESTANIAN** the 2017 EPJE Pierre-Gilles de Gennes Lecture Prize. Prof Golestanian was selected for his outstanding theoretical contributions to the physics of microswimmers and their hydrodynamic interactions which have led to a series of discoveries in the field of active matter.

PROF KATHERINE BLUNDELL was appointed OBE for services to astronomy and the education of young people. Prof Blundell's research interests span a broad range of topics. She has published extensively on the evolution of active galaxies and their life cycles, on the accretion of material near black holes and the launch and propagation of relativistic jets. She is the founder of Global Jet Watch, a network of five observatories in strategic locations around the world: one each in South Africa, Chile and India and one on each side of Australia. Four of the five are sited at boarding schools where students, particularly girls, are encouraged to use the telescopes in their learning. After local bedtime at each location, she operates the telescopes remotely, over the internet, to gather more data on black hole systems in our Galaxy.

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PROF PAOLO RADAELLI was awarded the Cavaliere dell'Ordine della Stella d'Italia (Knight of the Order of the Star of Italy) by the President of the Italian Republic. This high distinction, which qualifies as a second civilian honour of the State, represents a particular honour on behalf of all those Italians abroad or foreigners, who have acquired special merit in the promotion of friendly relations and cooperation between Italy and other countries and the promotion of ties with Italy. Professor Radaelli has made major contributions to Italy. Of his 194 scientific publications, 43 are the result of collaborations with Italian institutions.

PROF DAME JOCELYN BELL BURNELL was awarded the IoP President's Medal for her outstanding contributions to physics through pioneering research in astronomy, most notably the discovery of the first pulsars, and through her unparalleled record of leadership within the community.

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We hope you enjoyed reading this issue of the Physics Department's newsletter. To contact the newsletter editor, Prof Dimitra Rigopoulou, please email **newsletter@physics.ox.ac.uk**. For latest news on developments at the Oxford Physics Department, see **www.physics.ox.ac.uk/about-us**. To contact the alumni office, email **alumni@physics.ox.ac.uk**. For events and lectures, **www.physics.ox.ac.uk/events**.