WARWICK
THE UNIVERSITY OF WARWICK

Physics Research

Dear Reader,

Welcome to this exposition of research conducted by the Warwick Physics Department. In the following pages, you will find snippets of the research work that has been going on since mid-2015 here at Warwick. The selection is drawn from our "Research Nuggets" - short news items available from the main departmental web page. These nuggets aim to inform visitors to our web page, students, past and present, and our staff about the multitude of excellent impactful research that is being conducted in the Department. The selection is entirely organic: our academics and research students post about their research whenever they find it opportune to do so. Hence, the items you will see are neither an exhaustive account of all the research done across these years, nor are they a set of research items specially selected to be worthy. Rather, they represent a glimpse of what our staff thought to be exciting physics done by them at the time – they represent a true snapshot of the vibrant, diverse and international physics research that we are engaged in here at Warwick. We hope you will enjoy reading about this eclectic mix of topics that have kept us busy in recent years, ranging from fundamental problems in quantum measurements, to applications in functional materials and on to physics at the highest energy scales as well as the farthest distances. The links provided will get you to the original publications, if any, while some of the figures show the many styles adopted in contemporary science. If you still want to know more then please contact the original authors who we are sure will be more than happy to discuss their research.

Prof. David Leadley
Head of Department

Prof. Rudolf A Römer
Chair of Research Committee

July 2019

Abbreviation	Group	Explanation	QR
A&A	Astronomy and Astrophysics	The Astronomy and Astrophysics group are interested in stars and planets, how they form, live and how they die, and the exotic physical processes that they allow us to explore.	
CFSA	Centre for Fusion, Space and Astrophysics	The CFSA Group focuses on plasma physics applied to the grand challenges of magnetic and inertial fusion power, space physics, solar physics, and astrophysics.	
CMP	Condensed Matter Physics	The CMP Group carries out research across a broad range of fundamental and applied problems in solid state physics and materials science and quantum technology.	
EPP	Elementary Particle Physics	The Elementary Particle Physics Group carries out research into the fundamental particles of matter and the forces by which they interact.	
Theory	Theoretical Physics	The Theory Group works on problems in non-equilibrium biophysics, the dynamics of complex fluids, the electronic properties of materials, and quantum information science.	

A note on the cover image

The cover shows the polar lights (aurora borealis) over a dramatic northern village landscape and snow-covered mountains. As physicists, we also see how space weather from the sun influences the aurora, how the physics of phase transitions governs the water-ice transition, how the (multi-) fractal shapes of the mountains contain the minerals needed for modern functional materials and how understanding these phenomena helps improve life on our planet.

Spin-coherent dynamics and carrier lifetime in strained GeSn semiconductors on silicon

Maksym Myronov — CMP

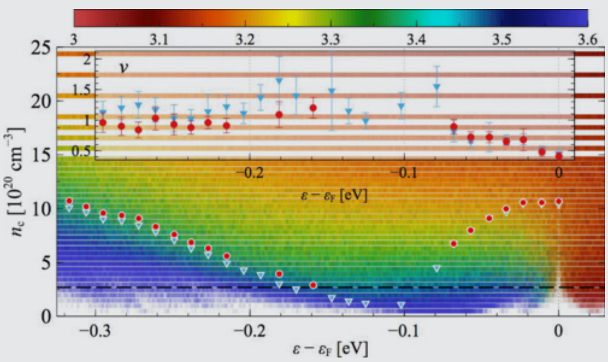
We demonstrate an effective epitaxial route for the manipulation and further enrichment of the intriguing spin-dependent phenomena boasted by germanium. We show optical initialization and readout of spins in Ge-rich germanium-tin alloys and report on spin quantum beats between Zeeman-split levels under an external magnetic field. While heavy Sn atoms can be readily utilized to strengthen the spin-orbit coupling, our experiments reveal robust spin orientation in a wide temperature range and a persistent spin lifetime that noticeably approaches the nanosecond regime at room temperature. In addition, time decay photoluminescence experiments evidence a temperature-induced monotonic decrease of the carrier lifetime, eventually providing crucial insights also into nonradiative recombination mechanisms.

Phys. Rev. B 99, 035202 (2019)

Resolution of the exponent puzzle for the Anderson transition in doped semiconductors

Rudo Roemer and Nick Hine — Theory

The Anderson metal-insulator transition (MIT) is central to our understanding of the quantum mechanical nature of disordered materials. Despite extensive efforts by theory and experiment, there is still no agreement on the value of the critical exponent ν describing the universality of the transition—the so-called "exponent puzzle." In this Rapid Communication, going beyond the standard Anderson model, we employ ab initio methods to study the MIT in a realistic model of a doped semiconductor. We use linear-scaling density functional theory to simulate prototypes of sulfur-doped silicon (Si:S). From these we build larger tight-binding models close to the critical concentration of the MIT. When the dopant concentration is increased, an impurity band forms and eventually delocalizes. We characterize the MIT via multifractal finite-size scaling, obtaining the phase diagram and estimates of ν. Our results suggest an explanation of the long-standing exponent puzzle, which we link to the hybridization of conduction and impurity bands.



Phys. Rev. B 99, 081201(R) (2019)

New ideas to measure the mass of the W boson

Mika Vesterinen — EPP

The Standard Model of particle physics provides an elegant description of the fundamental constituents of matter and their interactions. Two of the four basic forces of nature, namely the electromagnetic and weak forces, are combined into a unified electroweak theory. In the electroweak theory the mass of the W boson is predicted to a precision of one part in ten-thousand. If experiments measure a different value this would be a strong hint of new particles and interactions. Unfortunately, the W mass is extremely difficult to measure. The most precise measurements are expected to come from the study of leptonic W decays at the LHC, but a key challenge is to understand the structure of the colliding protons well enough. Measurements of the W mass have long been part of the program of the ATLAS and CMS experiments at the LHC, but they could eventually hit an irreducible limit due to the proton structure uncertainties. Researchers at Warwick, and collaborators from Oxford and Liverpool, looked into the role of the proton structure uncertainties in detail, and realised how a re-optimisation of the analysis method could help to reduce the uncertainties by roughly a factor of two. Work is now ongoing to apply the proposed method in the first ever measurement of the W mass with data from LHCb.

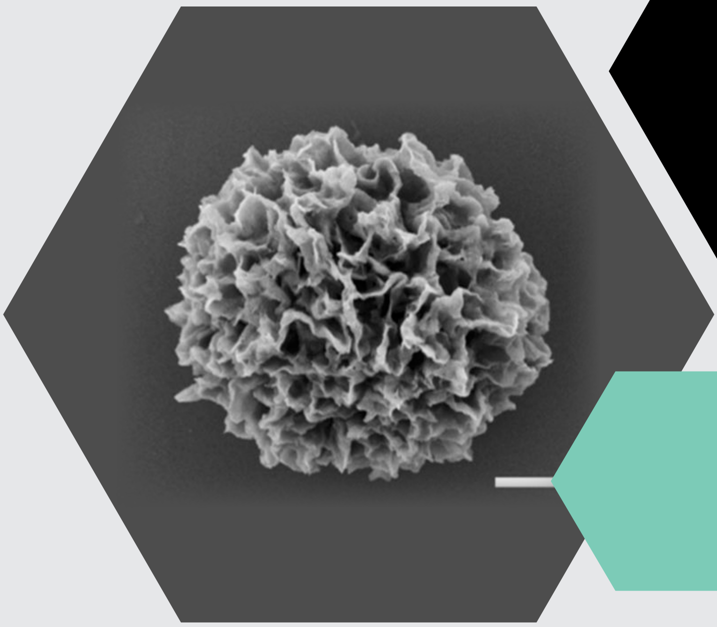
https://arxiv.org/abs/1902.04323

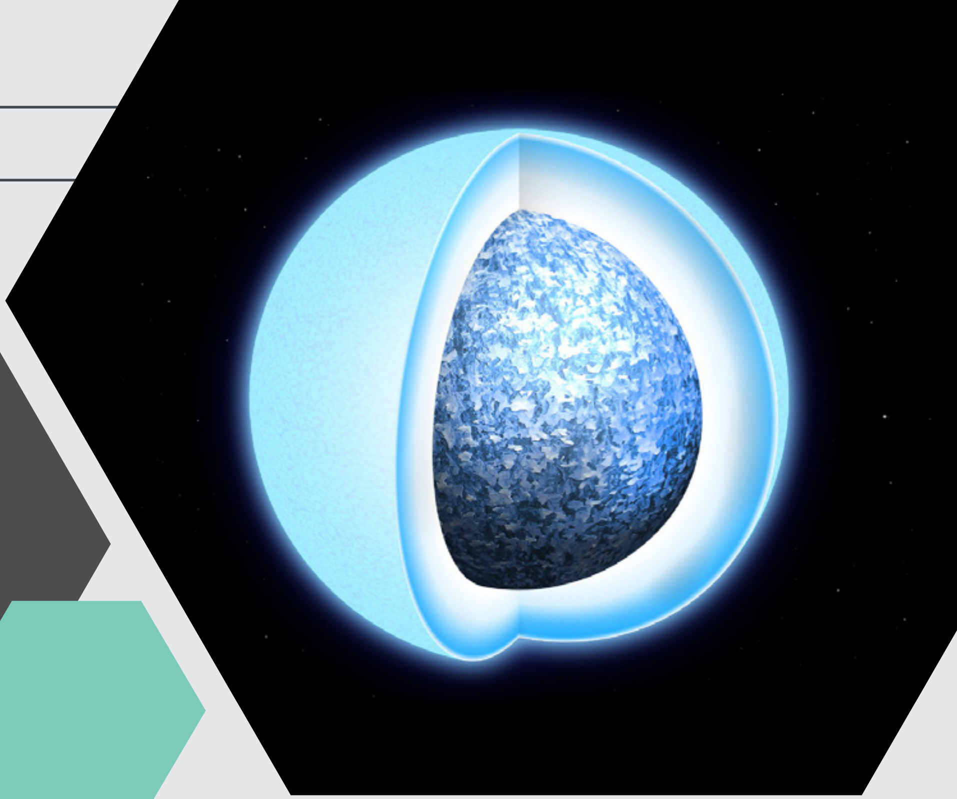
Research on attachment of antifreeze proteins to nanoparticles

Marc Walker — CMP

Antifreeze proteins (AFPs) have many potential applications, ranging from cryobiology to aerospace, if they can be incorporated into materials. Research led by the group of Matthew Gibson (Department of Chemistry), including contributions from Warwick's XPS Facility Manager Marc Walker (Physics), has led to several interesting developments in this area.

Langmuir (2019),
Polym. Chem. (2019)





Creating and investigating magnetic DNA nanoflowers

Paul Goddard — **CMP**

A team including researchers from the University of Oxford, Suez University, and Paul Goddard of Warwick Physics investigated conditions for chemically modifying existing nanoflowers through substitution of Mg2+ with Mn2+, Co2+ or Zn2+ and characterized the resulting particles. The team produced nano- and micro-scale hybrid DNA-inorganic materials that can be prepared in a range of shapes, show enhanced stability against DNA degradation and can be manipulated using an external magnetic field. The tuneable and selective properties of these materials suggests applications in drug delivery, sensing, biocatalysis, energy, and separation technologies.

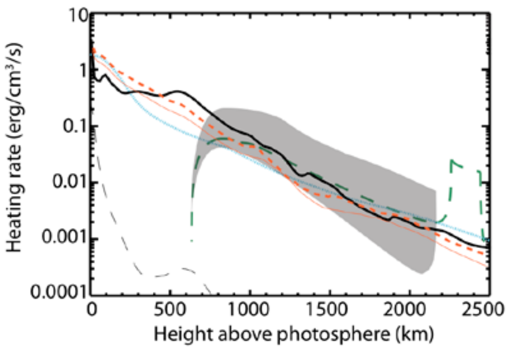
Nucleic Acids Research, 46, 7495 (2018)

Gaia reveals how Sun-like stars turn solid after their demise

Pier-Emmanuel Tremblay — **A&A**

In this study, the Warwick-led astronomers analysed more than 15 000 stellar remnant candidates within 300 light years of Earth and were able to see these crystallising white dwarfs as a rather distinct group in colour and intrinsic brightness. The cooling of white dwarfs lasts billions of years. Once they reach a certain temperature, the originally hot matter inside the star's core starts crystallising, becoming solid. The heat released during this crystallisation process, which lasts several billion years, seemingly slows down the evolution of the white dwarfs: the dead stars stop dimming and, as a result, appear up to two billion years younger than they actually are. That, in turn, has an impact on our understanding of the stellar groupings these white dwarfs are a part of.

Nature 565, 202–205 (2019)



Identifying the source of solar chromospheric jets

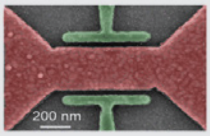
Tony Arber — **CFSA**

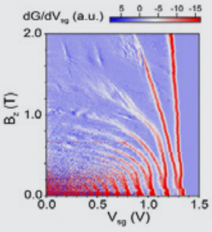
The origin of solar spicules and how the chromosphere is heated are often treated as separate problems. This work demonstrates that MHD waves driven from the photosphere can couple to shocks which both lift cold material forming spicules and simultaneously provide the heating required to balance radiative losses.

ApJ, 829, 80 (2016)

Ballistic One-Dimensional Holes with Strong gFactor Anisotropy in Germanium

Maksym Myronov CMP





Quantum spintronics is an active research field aiming at the development of semiconductor quantum devices with spin-based functionality. This field is witnessing an increasing interest in exploiting the spin degree of freedom of hole spin states, which can present a strong spin–orbit (SO) coupling, enabling electric-field driven spin manipulation and a reduced hyperfine interaction, favouring spin coherence. An international research team led by Maksym Myronov has demonstrated experimental evidence of ballistic hole transport in 1D quantum wires gate-defined in a strained Germanium quantum well (QW). These findings mark an important step toward the realization of novel devices for applications in quantum spintronics.

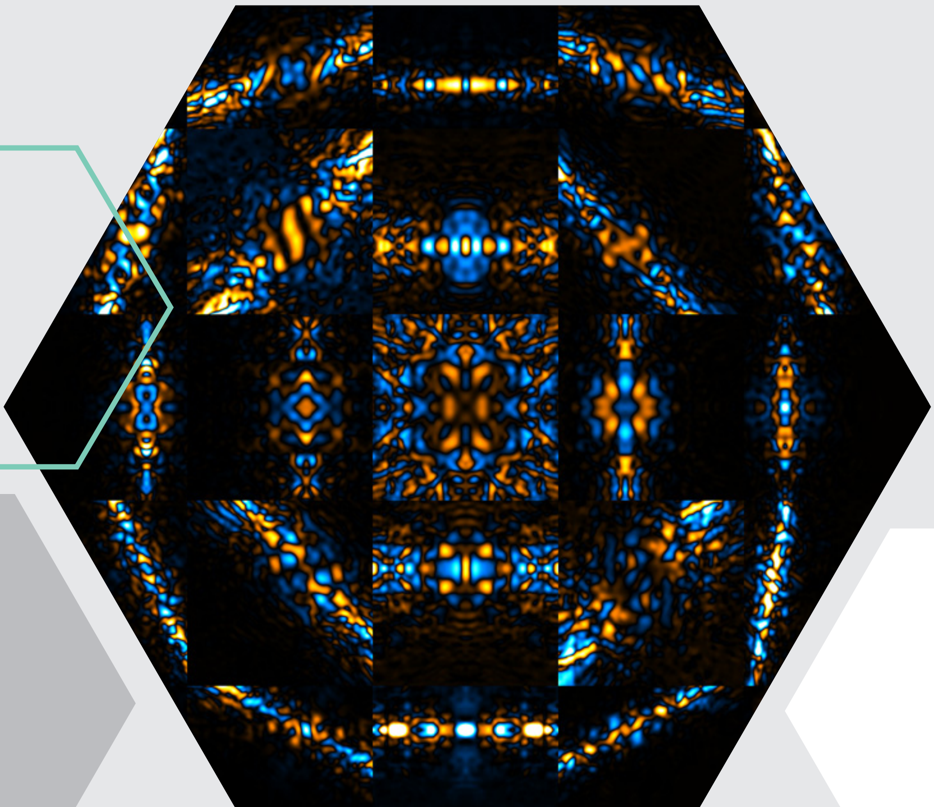
Nano Lett. 2018, 18, 4861−4865

Determining crystal structure to high precision with electron diffraction

Richard Beanland and Rudo Roemer CMP & Theory

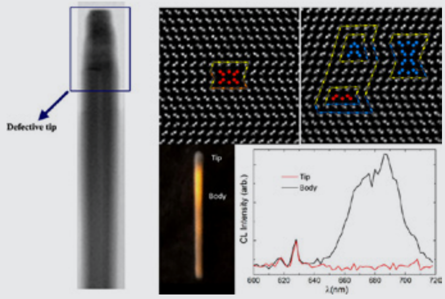
Electron diffraction has not, until now determined atomic positions in a crystal to the same accuracy (10^-13 m) as X-rays. Beanland & Roemer describe a new method which does this and more. They use computer-controlled data acquisition and processing to produce digital large angle convergent beam electron diffraction (D-LACBED) patterns. They demonstrate refinements of atomic coordinates and isotropic Debye-Waller factors (DWFs) for well-known materials using simulations produced with a neutral, spherical independent atom model. They find that atomic coordinate refinements in Al2O3 have sub-pm precision and accuracy. Isotropic DWFs are accurate for Cu, a simple fcc metal, but do not agree with X-ray measurements of GaAs or Al2O3. This lack of agreement is probably caused by bonding and change transfer between atoms. While it has long been appreciated that CBED is sensitive to bonding, examination of D-LACBED data shows that some regions exhibit large changes in intensity from small changes in the periodic crystal potential. Models of bonding will be essential to fully interpret D-LACBED data.

Ultramicroscopy 198, 1-9 (2019)



Stable Defects in Semiconductor Nanowires

Ana M Sanchez and Richard Beanland CMP

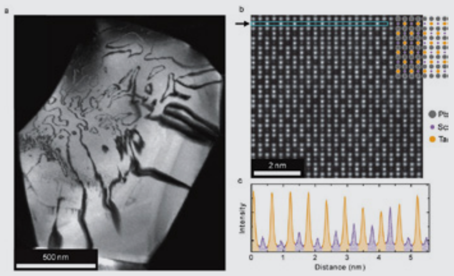


Semiconductor nanowires are commonly described as being defect-free due to their ability to expel mobile defects with long-range strain fields. Sanchez & Beanland analyse the defects present in semiconductor nanowires in regions of imperfect crystal growth, i.e. at the nanowire tip formed during consumption of the droplet in self-catalysed vapour-liquid-solid growth and subsequent vapour-solid shell growth. They use a form of the Burgers circuit method that can be applied to multiply-twinned material without difficulty. Their observations show that nanowire microstructure is very different from bulk material, with line defects either a) trapped by locks or other defects, b) arranged as dipoles or groups with zero total Burgers vector or c) having zero Burgers vector.

Nano Lett. 2018, 18, 5, 3081-3087

Quantitative High-Dynamic-Range Electron Diffraction of Polar Nanodomains in Pb2ScTaO6

Richard Beanland and Ana M Sanchez CMP

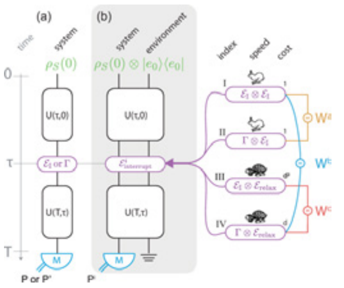


Highly B-site ordered Pb2ScTaO6 crystals are studied as a function of temperature via dielectric spectroscopy and in situ high-dynamic-range electron diffraction. The degree of ordering is examined on the local and macroscopic scale and is determined to be 76%. Novel analysis of the electron diffraction patterns provides structural information with two types of antiferroelectric displacements determined to be present in the polar structure. It is then found that a low-temperature transition occurs on cooling at ≈210 K that is not present on heating. This phenomenon is discussed in terms of the freezing of dynamic polar nanodomains where a high density of domain walls creates a metastable state.

Adv. Matter. 2018, 1806498

Subtleties of witnessing quantum coherence in non-isolated systems

Animesh Datta Theory



The work features experiments that help solve the debate on whether biological processes exploit quantum mechanics to their advantage, and whether evolution could provide us with a template for quantum technologies such as computers, sensors and energy sources. Microscopic particles in a quantum state can display a feature known as quantum coherence where particles can exist in many locations or configurations simultaneously. This effect underpins technologies such as quantum computers, quantum sensors and quantum communication systems, which use ordered systems isolated from the rest of the world. However, whether quantum coherence exists in the noisier and messier real world is more difficult to identify. The paper proposes a test which involves a procedure to destroy quantum coherence, and then to observe the change in later measurements.

Phys Rev A 98. 052328 (2018)

New method to potentially observe double beauty hadrons

Tim Gershon and Anton Poluektov EPP

Particle physics experiments have observed many different types of hadrons, in which quarks are bound together by the strong interaction. Last year, the first ever doubly heavy baryon -- the Xicc++ which contains two charm quarks -- was observed by LHCb. This has inspired renewed theoretical interest in other doubly heavy states, such as those containing two beauty quarks, but the prospects for discovering such particles did not look promising. In a new preprint, Tim Gershon and Anton Poluektov at Warwick have now proposed a new method which exploits a distinctive feature of double beauty hadron decays and may allow them to be discovered. The key point is that such decays may produce a particle called a Bc meson (containing a beauty and an anticharm quark) that does not originate directly from the proton-proton collisions at the LHC, and that nothing else can cause this signature.

JHEP 01 (2019) 019

Self-organised fractional quantisation in a hole quantum wire

Maksym Myronov CMP

Hole transport in quantum wires formed by electrostatic confinement in strained germanium two-dimensional layers is investigated. The ballistic conductance characteristics show the regular staircase of quantum levels with constant plateaus at integer multiples of e^2/h, where e is the fundamental unit of charge and h is Planck's constant. However, as the carrier concentration is reduced, the quantised levels show a behaviour that is indicative of the formation of a zig-zag structure and new quantised plateaux appear at low temperatures.

Y Gul et al 2018 J. Phys.: Condens. Matter 30, 09LT01 (2018)

Touching proteins with virtual bare hands: how to visualize protein-drug complexes and their dynamics in virtual reality

Rudo Roemer Theory

The ability to precisely visualize the atomic geometry of the interactions between a drug and its protein target in structural models is critical in predicting the correct modifications in previously identified inhibitors to create more effective next generation drugs. Roemer and colleagues presents a freely available software pipeline for visualising protein structures through virtual reality (VR) on regular customer hardware, such as the HTC Vive and the Oculus Rift.

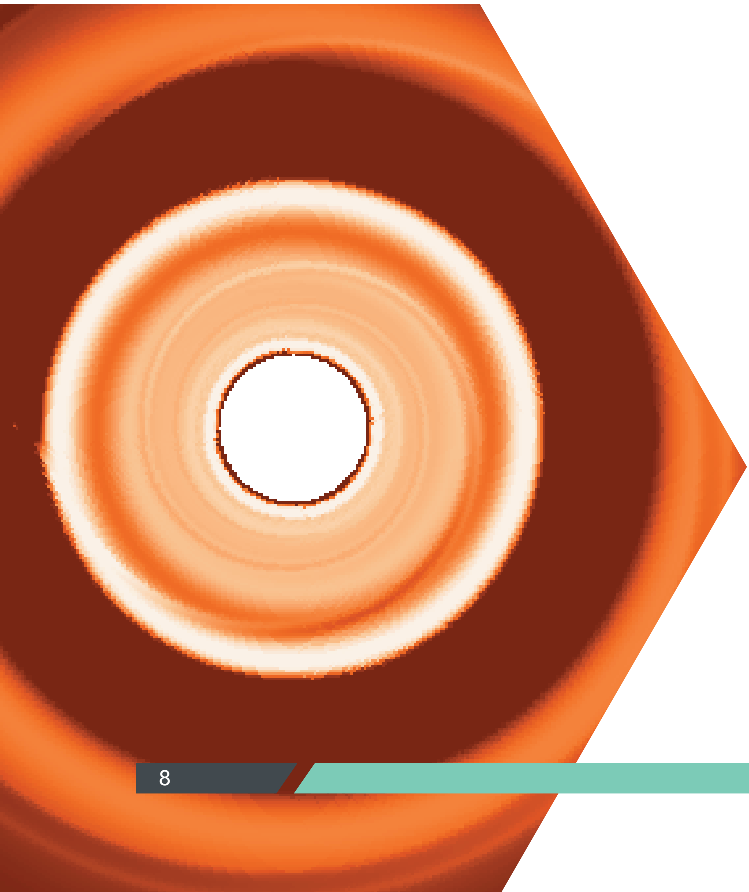
Journal of Computer-Aided Molecular Design 32, 703-709 (2018)

Double dust ring test could spot migrating planets

Farzana Meru A&A

New research by a team led by Farzana Meru has a way of finally telling whether newly forming planets are migrating within the disc of dust and gas that typically surrounds stars or whether they are simply staying put in the same orbit around the star. Planet migration is a process that astronomers have known the theory about for 40 years but only now have we been able to find a way of observationally testing if it really occurs.

Mon. Not. R. Astron. Soc. 482, 3678 (2018)

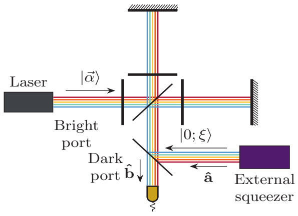


Fundamental quantum limits of optomechanical sensors

Animesh Datta Theory

Dominic Branford and Animesh Datta, working in collaboration with Haixing Miao (Birmingham), have published a paper on the fundamental quantum limits of opto-mechanical sensors (DOI: 10.1103/PhysRevLett.121.110505). Being able to measure very weak forces is central to many applications, such as the direct detection of gravitational waves and monitoring subterranean movement of magma in volancially-active areas. The strength of a force can be inferred via its effect of displacing a mass: the displacement can be sensed by illuminating it with a laser and observing the reflected light, a case of optomechanical sensing.
The authors study the best precision attainable by optomechanical sensors when multi-coloured light is used.

Phys. Rev. Lett. 121, 110505 (2018)



Laser-writing quantum bits into diamond

Gavin Morley, Ben Green and Mark Newton CMP

Nitrogen vacancy colour centres in diamond are excellent quantum bits, but previous attempts at making arrays of them have damaged the diamond too much. Our collaborators in Oxford now make arrays by laser-writing directly into diamond. Our experiments in Warwick show that the colour centres store quantum information for as long as any nitrogen vacancy centres, thanks to the reduced damage that comes from laser writing.

NaturePhoton.11.77(2017), arXiv:1807.03643(2018), arXiv:1807.04028(2018)

IoP eBook on "Tetraquarks and Pentaquarks" published

Tim Gershon — **EPP**

Greig Cowan and Tim Gershon describe recent discoveries of new types of matter called tetraquarks and pentaquarks, and discuss the outlook for understanding these particles. Since 2003 there has been an explosion in the observation of new hadronic states that cannot be classified by the well-tested quark model of mesons (quark-antiquark) and baryons (three quarks or antiquarks). The properties of these states indicate that they are combinations of four, five, or more, quarks and antiquarks, making them manifestly exotic. A recent high-profile example was the discovery of two pentaquark candidates by the LHCb collaboration at the CERN Large Hadron Collider (LHC). No scientific consensus has yet emerged to explain the exotic hadron spectrum, demanding a new set of experimental observations that will feed the development of theoretical models to describe the dynamics of multiquark states. In this Discovery book we will take you on a tour of quantum chromodynamics, explain about the latest research into the physics of exotic hadrons and describe the exciting opportunities that are offered by the next generation of particle physics experiments.

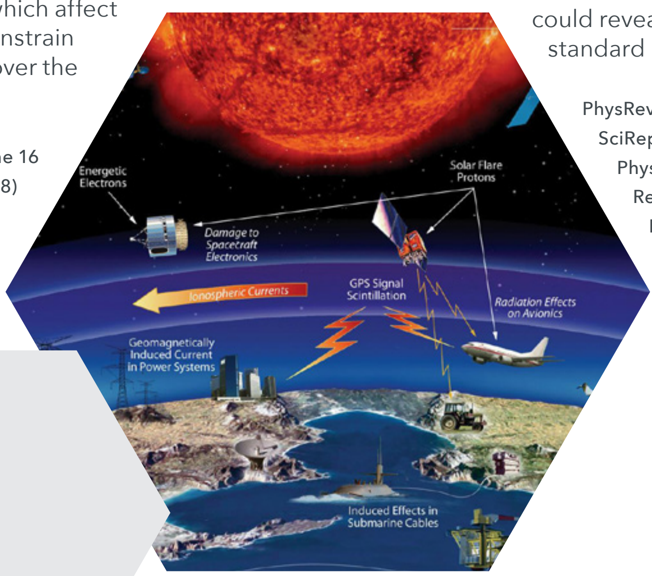
Tetraquarks.&.Pentaquarks, IOP Publishing, (2018)

Predictable aspects of the variable likelihood of extreme space weather events

Sandra Chapman — **CFSA**

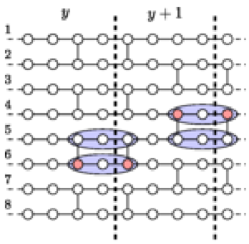
Earth's near-space plasma environment is highly dynamic, with its own space weather. Space weather impacts include power loss, aviation disruption, communication loss, and disturbance to satellite systems. Solar activity drives Earth's space weather. Each solar cycle has a different intensity but we found cycle invariant properties constraining the chance of space storms which affect systems at Earth. This may constrain the space climate expected over the next solar cycle.

Space Weather Volume 16 Issue 8, 937-1169 (2018)



How quantum do you need to be to check a quantum computer?

Animesh Datta — **Theory**



Quantum computers are capable of solving certain problems whose scale lies outside that of classical computers. For some of these problems not even the solution can be efficiently checked with a classical computer. While schemes can verify an arbitrary quantum computation with a limited set of quantum operations, the minimum quantum resources to perform such a verification is an open question. Samuele Ferracin, Theodoros Kapourniotis, and Animesh Datta from the quantum information group have published a paper on verification demonstrating an improvement on the existing requirements for schemes to verify quantum computations. In this work the authors demonstrate a verification scheme which works with a further reduced number of such quantum operations.

PhysRevA.98.022323(2018)

Can we test Schrödinger's ideas about quantum cats?

Gavin Morley — **CM**

The "Schrödinger's cat" thought experiment highlights the fact that we never see everyday objects in quantum superpositions, even though this is routine for atoms. But how large an object can be put into a quantum superposition? Gavin Morley and colleagues are proposing experiments to test this, and have begun building them. They use levitated nanodiamonds, which can be seen in the photo as a green dot. Putting one of these diamonds into a spatial superposition, or indeed finding that Nature forbids this, could reveal new physics beyond the standard model.

PhysRevLett.117.143003(2016),
SciRep.6.21633(2016),
PhysRevA.93.043852(2016),
RevSciInstrum.89.023109(2018),
NewJPhys.20.043016(2018),
arXiv:1807.10830(2018),
arXiv:1810.07045(2018),
ACSOmega3.16099(2018)

UK's first 1GHz solid-state NMR spectrometer

Steven Brown — **CMP**

Part of a new £20 million investment by EPSRC in Nuclear Magnetic Resonance (NMR) equipment across UK institutions, the £8M, 1GHz NMR instrument at Warwick will provide new structural and dynamic information in chemistry, materials science and biology. It will add to our already significant NMR capabilities that include the 850MHz high-field solid-state NMR National Research Facility, which has been serving a broad academic and industrial user-base since 2010.

Allotropes of Phosphorus with Remarkable Stability and Intrinsic Piezoelectricity

Rudo Roemer — **Theory**

Roemer and colleagues construct a class of two-dimensional (2D) phosphorus allotropes by assembling a previously proposed ultrathin metastable phosphorus nanotube into planar structures in different stacking orientations. Three of them are dynamically stable semiconductors with strain-tuneable band gaps and intrinsic piezoelectricity. This may have potential applications in nanosized sensors, piezotronics, and energy harvesting in portable electronic nanodevices.

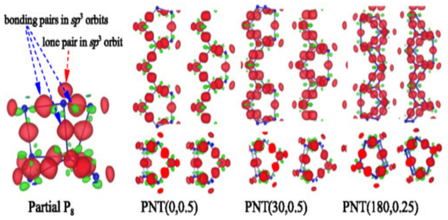
PhysRevApplied.9.044032(2018)

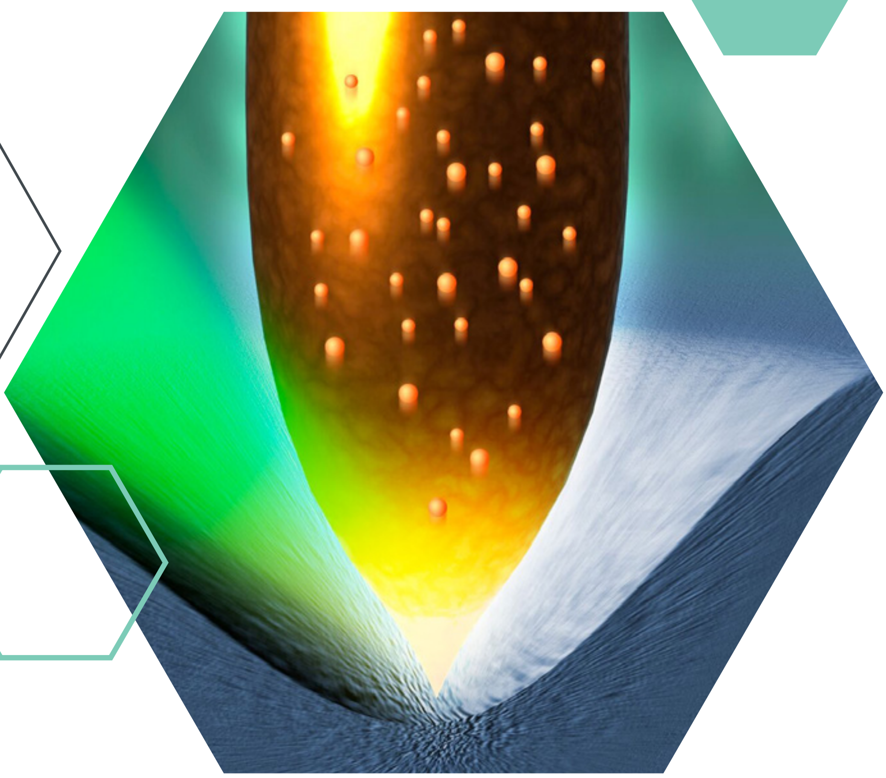
New research could literally squeeze more power out of solar cells

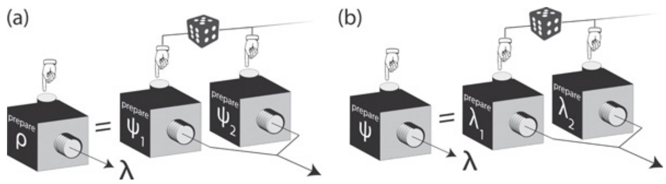
Marin Alexe — **CMP**

A team led by Marin Alexe has published new research in the journal Science that could literally squeeze more power out of solar cells by physically deforming each of the crystals in the semiconductors used by photovoltaic cells. The paper entitled the "Flexo-Photovoltaic Effect" was written by Marin Alexe, Ming-Min Yang, and Dong Jik Kim. The Warwick researchers looked at the physical constraints on the current design of most commercial solar cells which place an absolute limit on their efficiency. Most commercial solar cells are formed of two layers creating at their boundary a junction between two kinds of semiconductors, p-type with positive charge carriers (holes which can be filled by electrons) and n-type with negative charge carriers (electrons). When light is absorbed, the junction of the two semiconductors sustains an internal field splitting the photo-excited carriers in opposite directions, generating a current and voltage across the junction. Without such junctions the energy cannot be harvested and the photo-exited carriers will simply quickly recombine eliminating any electrical charge. The Warwick team wondered if it was possible to take the semiconductors that are effective in commercial solar cells and manipulate or push them in some way so that they too could be forced into a non-centrosymmetric structure and possibly therefore also benefit from the bulk photovoltaic effect.

Science 360, 904 (2018)







Towards optimal experimental tests on the reality of the quantum state

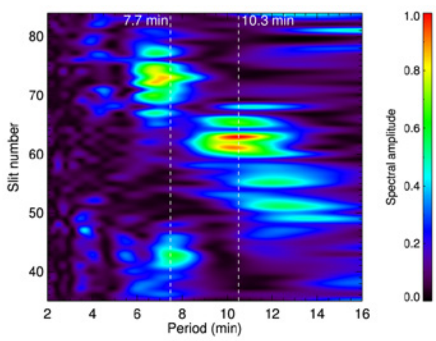
George Knee | **Theory**

The New Journal of Physics has selected George Knee's paper "Towards optimal experimental tests on the reality of the quantum state" (DOI:10.1088/1367-2630/aa54ab) as one of their Highlights of 2017, recognising high-quality publications which have been well-received by the community. The paper, which looks to find tests demonstrating the reality of the quantum state with ever stronger certainty, is one of just six quantum physics papers published in NJP last year to receive such recognition in the NJP's Highlights of 2017

New.Journal.of.Physics,19(2017)

First detection of the second harmonic of decay-less kink oscillations in the solar corona

Val Nakariakov | **CFSA**



Plasma non-uniformities in the outer part of the Sun's atmosphere (the corona), such as coronal loops, are known to support a variety of magnetohydrodynamic (MHD) waves. A commonly detected oscillation mode is transverse displacements of the loop, called kink oscillations. Low-amplitude kink oscillations are known to persist for many periods, despite theoretically being subjected to damping. These ubiquitous, so-called "decay-less" oscillations remain enigmatic. In this work, researchers used the innovative movie processing technique of "motion magnification" to study decay-less kink oscillation in a well contrasted loop. .

Astrophys. J. 854, L5 (2018)

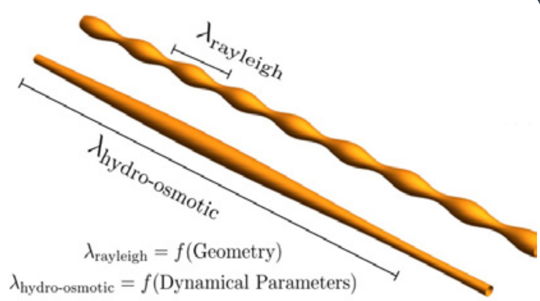
Hydro-osmotic effects in cells

Matthew Turner and George Rowlands | **Theory**

Turner and colleagues are motivated by an organelle called the Contractile Vacuole Complex. This is an organelle that is based on membrane tubes that acts as a pump to regulate cell volume in certain small organisms. The researchers build a theoretical model of a membrane tube with trans-membrane ion pumps and water channels. The ion pumps actively consume energy to transport ions against their concentration gradients, this leads to a swelling of the tube by osmosis.

As the tube swells beyond a critical radius, the geometry becomes unstable to fluctuations and an instability develops. The instability is somewhat similar in nature to a Rayleigh instability on a membrane tube, driven by a sudden increase in surface tension. However, unlike the Rayleigh instability, where the size of fastest growing mode is of the order of the tube radius, the wavelength of these hydro-osmotic instabilities is much longer and depends (weakly) on dynamical parameters - the product of the ion pumping rate to a timescale for viscous dissipation of fluid inside the tube. The wavelength that is selected, rather robustly, is in good agreement with the size of structures found in the contractile vacuole complex of Paramecium. Thus, they propose a new class of osmotic instabilities, with general applicability within Biology, in which the process is continuously driven, rather than suddenly imposed.

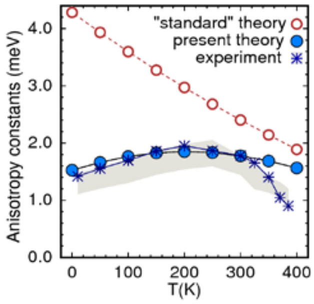
Phys. Rev. Lett. 120, 138102 (2018)



2018

Calculating the Magnetic Anisotropy of Rare-Earth-Transition-Metal Ferrimagnets

Geetha Balakrishnan / Rachel Edwards / Julie Staunton / Martin Lees — CMP



Permanent magnets, like those found inside hybrid car motors, often have to operate in challenging conditions. Having a large "magnetic anisotropy" - which means magnetic materials prefer to have their magnetic moments pointing along certain directions - can help the magnet to keep working effectively even when subjected to high temperatures or strong magnetic fields. One way of engineering this anisotropy is to change the shape of the magnet, e.g. shaping it into a horseshoe, but a much more effective way is to change its chemical composition. Specifically, combining rare-earth (RE) elements (particularly Sm, Nd and Dy) with transition metals (TM; Fe and Co) can generate a huge magnetocrystalline anisotropy (MCA) whose origin is a complicated interplay of special relativity and quantum mechanics. In this work the researchers show how a standard approach of calculating the MCA is not sufficient when trying to understand ferrimagnets, i.e. magnetic materials which contain a number of different magnetic elements, such as the RE-TM magnets. Instead, they have developed a new theory in which they directly simulate the experiments used to measure the MCA. Warwick researchers demonstrate the new theory by comparing its results to experimental measurements made on a single crystal of $GdCo_5$ grown at Warwick.

Phys. Rev. Lett. 120, 097202 (2018)

Photoelectric solar power revisited

Gavin Bell and Yorck Ramachers — CMP/EPP

A new solar power device similar to a thin double-glazed window has been developed by Gavin Bell (Nano Physics) and Yorck Ramachers (Particle Physics). The device uses inert gas instead of vacuum to transport electrical energy and is based on the photoelectric effect rather than conventional photovoltaic materials. The key unknown is the photocathode material which must have highly optimised properties for the device to be efficient enough to compete with conventional photovoltaics. Possibilities include diamond thin films and special perovskite oxide materials.

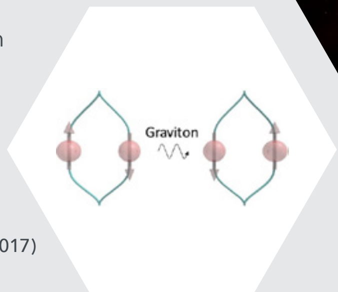
Joule 1(4),639-642, (2018)

2017

Is Gravity a Quantum Force?

Gavin Morley — CMP

Understanding gravity in the framework of quantum mechanics is one of the great challenges in modern physics. A key question is whether gravity permits quantum superpositions but there are no practical ideas yet to test this in a laboratory experiment. In a recent paper, Gavin Morley and colleagues introduce an idea for such a test based on the principle that two objects cannot be entangled without a quantum mediator.



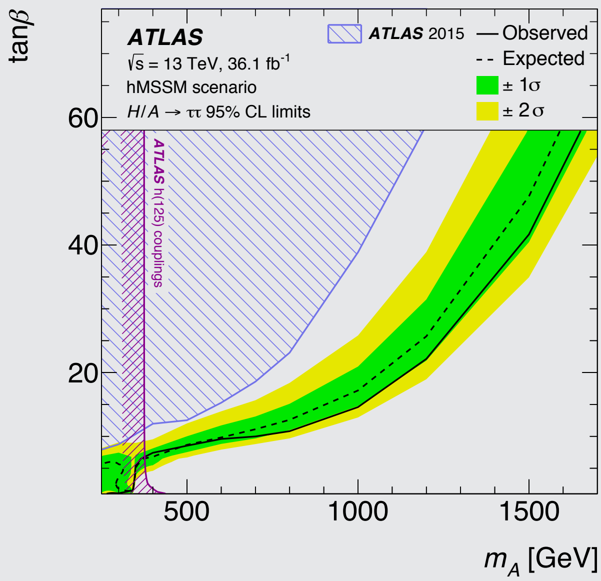
Phys. Rev. Lett. 119, 240401 (2017)

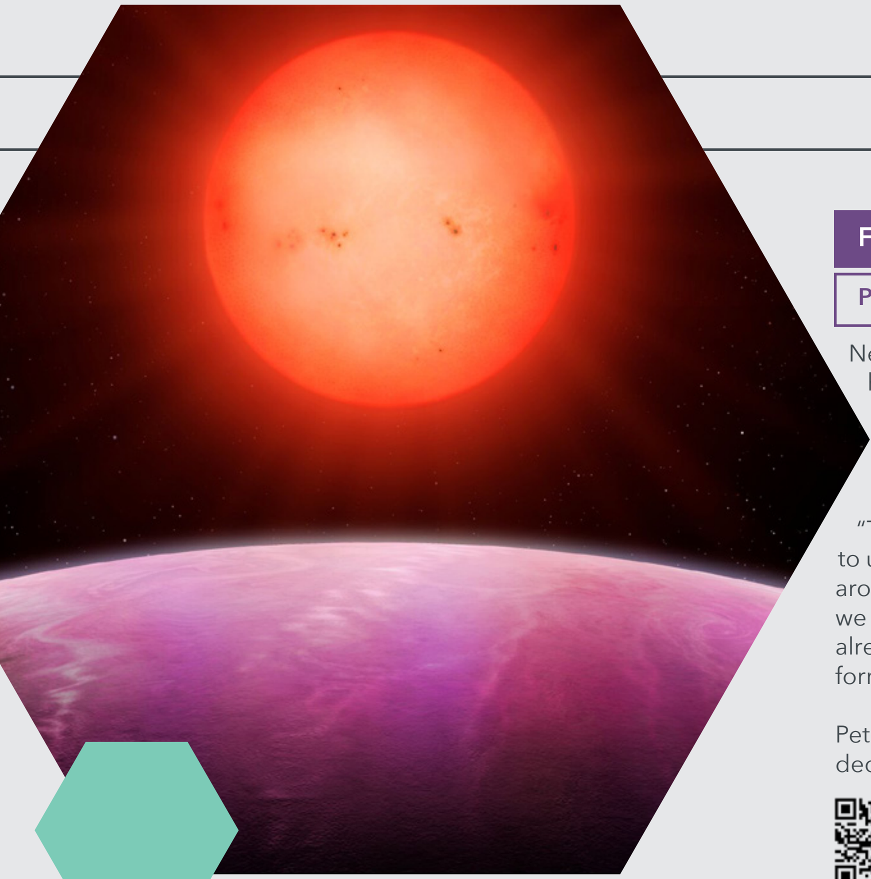
ATLAS hunting second Higgs boson

ATLAS — EPP

After the discovery of the Higgs boson in 2012 a key question is whether it is the only one. The minimal supersymmetric standard model (MSSM) includes five physical Higgs bosons, three of them neutral. ATLAS has just published a search for a second neutral one decaying to tau pairs, covering a wide mass range above that of the discovered one using data collected in the years 2015 and 2016. This is the most sensitive search for such an MSSM Higgs yet.

J. High Energy Phys. 2018, (2018)





First planet found by NGTS - it's a monster!

Peter Wheatley — **A&A**

New research, led by Dan Bayliss and Peter Wheatley, has identified an unusual planet NGTS-1b - the largest planet compared to the size of its companion star ever discovered in the universe.

Dan Bayliss, lead author of the research, commented: "The discovery of NGTS-1b was a complete surprise to us - such massive planets were not thought to exist around such small stars. This is the first exoplanet that we have found with our new NGTS facility and we are already challenging the received wisdom of how planets form."

Peter Wheatley added, "Having worked for almost a decade to develop NGTS, it is thrilling to see it picking out new and unexpected types of planets."

Mon. Not. R. Astron. Soc. 475, 4467 (2018)

Gold origin confirmed with first ever neutron star gravitational wave sighting

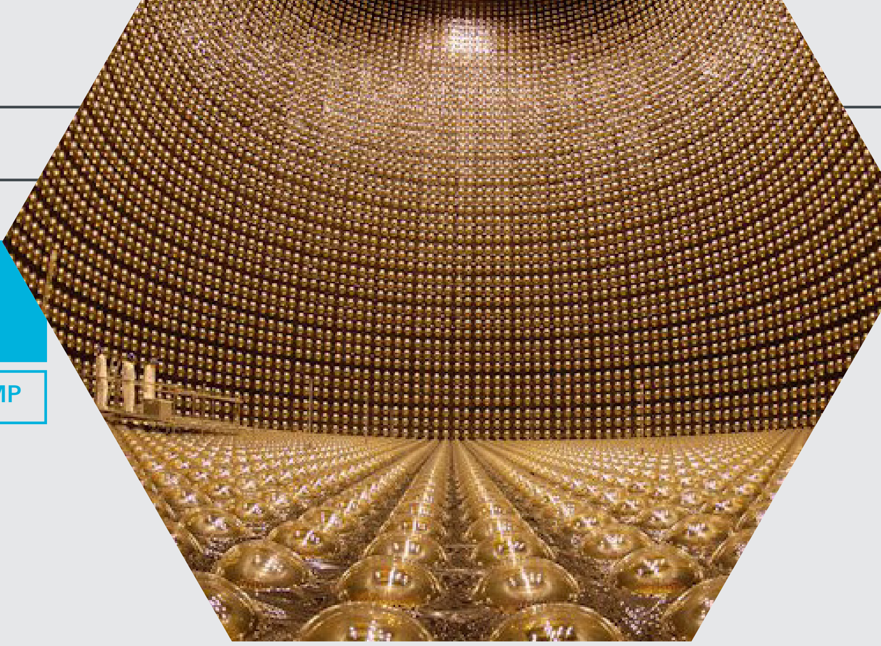
Andrew Levan and Danny Steeghs — **A&A**

Gold's origin in the Universe has finally been confirmed, after a gravitational wave source was seen and heard for the first time ever by an international collaboration of researchers, with astronomers at the University of Warwick playing a leading role. Andrew Levan, Joe Lyman, Sam Oates and Danny Steeghs, led observations which captured the light of two colliding neutron stars, shortly after being detected through gravitational waves – perhaps the most eagerly anticipated phenomenon in modern astronomy. Huge amounts of gold, platinum, uranium and other heavy elements were created in the collision of these compact stellar remnants, and were pumped out into the universe – unlocking the mystery of how gold on wedding rings and jewellery is originally formed. The collision produced as much gold as the mass of the Earth.

Astrophys. J. Lett. 848, L27 (2017)

Nature Astronomy 2, pages751–754 (2018)

2017



Mid-infrared light emission > 3 micrometer wavelength from tensile strained GeSn microdisks

Maksym Myronov and Don Paul CMP

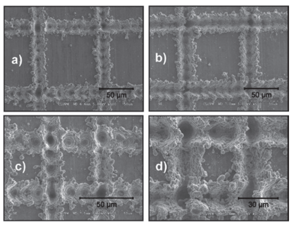
GeSn alloys with Sn content of 8.4 % and 10.7 % are grown pseudomorphically on Ge buffers on Si (001) substrates. The alloys as-grown are compressively strained, and therefore indirect bandgap. Undercut GeSn on Ge microdisk structures are fabricated and strained by silicon nitride stressor layers, leading to tensile strain in the alloys and direct bandgap photoluminescence in the 3– 5 um gas sensing window. The use of pseudomorphic layers and external stress mitigates the need for plastic deformation to obtain direct bandgap alloys. It is demonstrated, that the optically pumped light emission overlaps with the methane absorption lines, suggesting that GeSn alloys are well suited for mid-infrared integrated gas sensors on Si chips.

Optics.Express 25, 25374-25385 (2017)

Influence of ambient conditions on the evolution of wettability properties of aluminium alloys

Warwick XPS Facility CMP

Micro cell structures of different sizes were patterned using a nanosecond near-infrared laser source on Al2024 aluminium alloy plates with 2 mm thickness. The influence of laser parameters on the shape and size of the produced patterns were studied together with the evolution of wettability properties over time for different storage conditions. Samples were found to be superhydrophobic from a single step laser patterning, requiring no further treatment. Exposure to ambient air was shown to be a key factor in the property changes of the samples over time. The produced surface patterns with different laser parameter settings were correlated with the contact angle measurements, revealing a great influence of the amount of recast material on the hydrophobic properties. X-Ray photoelectron spectroscopy was used to study the impact of surface chemistry changes on hydrophobicity, analysis of elemental composition proved that chemisorbed organic molecules present in the ambient air were responsible for the hydrophilic to superhydrophobic transition.



RSC Adv. 7, 39617 (2017)

Neutrinos help to understand the dominance of matter over antimatter in the Universe

T2K consortium EPP

New results from the T2K experiment, in which Warwick is a key collaborator, have strengthened previous hints of a difference in the behaviour of neutrinos and antineutrinos. Neutrinos and antineutrinos come in three types (or flavours) and are capable of changing flavour as they travel from source to detector in a process known as ‘flavour oscillations’. The recent analysis indicates that neutrinos and antineutrinos flavour oscillate with different probabilities. These results will help us shed light on the question of why the universe is dominated by matter, with very little observed antimatter.

Phys. Rev. Lett. 121, 171802 (2018)

Rare-earth/transition-metal magnetic interactions in pristine and (Ni,Fe)-doped YCo5 & GdCo5

Geetha Balakrishnan / Rachel Edwards / Julie Staunton / Martin Lees CMP

It is important to understand the fundamental physics of rare-earth transition-metal magnets, which are used in much of today’s technology, so that new materials can be identified which will reduce our dependence on the economically-volatile and environmentally-damaging rare earths. A recurring challenge is how to make the connection between what is measured in the lab, and what is happening in the material itself at the atomic level, i.e. the behaviour of individual electrons and nuclei. In this collaborative work between theorists and experimentalists based at Warwick and STFC Daresbury, “first-principles” computational modelling is used to explain experimental measurements on the magnetic materials YCo_5 and $GdCo_5$.

Phys. Rev. Materials 1, 024411 (2017)

Mission to discover habitable Earths given green light

Don Pollacco | **A&A**

A mission to discover and characterise Earth-sized planets and super-Earths orbiting Sun-like stars in the habitable zone of the solar system – scientifically led by the University of Warwick - has been given the go-ahead today by the European Space Agency (ESA). Planetary Transits and Oscillations of stars (PLATO) will be launched into the 'L2' virtual point in space - 1.5 million km beyond Earth, as seen from the Sun – and will monitor thousands of bright stars over a large area of the sky. The satellite will search for tiny, regular dips in brightness as their planets cross in front of the stars, temporarily blocking out a small fraction of the starlight.

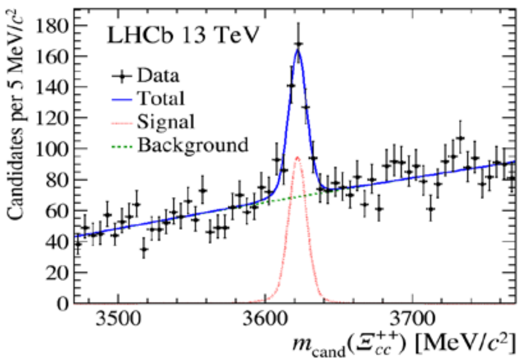
The PLATO mission will address fundamental questions such as 'how common are earth-like planets?' and 'is our solar system unusual or even unique?', and could eventually even lead to the detection of extra-terrestrial life.

Doubly charming discovery by LHCb

Tim Gershon | **EPP**

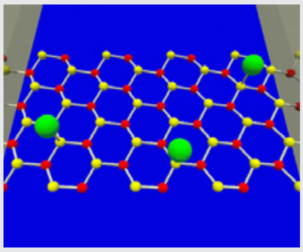
The LHCb collaboration has announced the discovery of a new particle, the Ξ_{cc}^{++} state. Just like the protons that circulate in the Large Hadron Collider, the new particle is a baryon, composed of three quarks bound together by the strong force. However, unlike the proton which is made from three light quarks (two up quarks and a down quark), the Ξ_{cc}^{++} contains one up quark and two charm quarks. This discovery opens the door for novel investigations of the strong force that binds hadrons together.

Phys. Rev. Lett. 119, 112001 (2017)



Spin-polarized electric current in silicene nanoribbons induced by atomic adsorption

Rudo Roemer | **Theory**



The field of spintronics is rapidly developing from its roots in magnetic metal multilayers. In recent years, two-dimensional (2D) materials came to the forefront and advances in this field are expected to occur based on hybrid systems. A plethora of novel 2D materials offers fascinating fundamental properties for spin transport and controlled spin-light interaction. In this context, silicene is a particularly promising candidate for the design of spintronic devices. The paper, shows how disorder, normally associated with reduced charge transport characteristics, can be used in silicence to enhance spin transport.

Phys. Rev. B 96, 045403 (2017),

Telescope for detecting optical signals from gravitational waves (GOTO) launched

Danny Steeghs | **A&A**

A state-of-the-art telescope for detecting optical signatures of gravitational waves - built and operated by an international research collaboration, led by the Astronomy and Astrophysics group - has been officially launched.

New ultrasonic ZIP probe tests Zinc galvanizing kettles while bathed in 450°C molten metal

Steve Dixon CMP

Zinco UK Limited and Sonemat Limited, a Warwick spin-out company, have signed an agreement to use ultrasonic probe technology developed from research which was first conducted at the University of Warwick. The new probe technology can conduct safety critical testing inside-galvanizing kettles equipment while still holding molten zinc at 450°C.

It rains on the Sun! The dynamics of cool condensation in the solar corona.

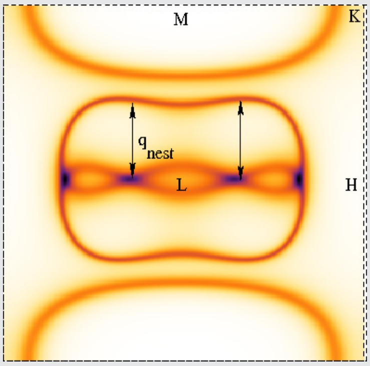
Petra Kohutova and Erwin Verwichte CFSA

Coronal rain are cool dense condensations, with temperatures of 80000K and less, that form in the million degrees hot corona of the Sun. They are the manifestation of catastrophic cooling linked to a magnetohydrodynamic (MHD) thermal instability.
In a series of studies Petra Kohutova (RoCS) & Erwin Verwichte (CFSA) investigated the dynamics of coronal rain through solar observations and numerical simulations. They analysed observations from space-born solar instruments on board IRIS, Hinode and SDO and identified transverse oscillatory motions in the rain. By comparing these with our theoretical model, the researchers were able to deduce for the first time the fraction of the coronal loop mass condensing to form rain. This provides insight into the physical nature of the thermal instability, heating and mass cycle in the solar corona.

Astron. Astrophys. 601, L2 (2017)

The electrons that make heavy rare earth metal magnets critical

Julie Staunton Theory



Heavy rare earth magnets like terbium and dysprosium comprise atom-sized magnetic dipoles sitting in a surrounding electronic 'glue'. This glue is common to all the heavy rare earth elements and makes them chemically very similar. In their paper Eduardo Mendive-Tapia and Julie Staunton find that it both enables the dipoles to interact with each other and that it also responds to the extent and nature of how the dipoles arrange themselves.
This feedback sets the main features of the complex magnetic structures that heavy rare metal elements form at various temperatures and under applied magnetic fields. Moreover it explains transitions at critical temperature and field values between, for example, long-ranged, helical magnetic configurations, fan patterns and uniform, all-lined up dipole arrangements.
The magnetic properties of materials containing heavy rare earth elements make them indispensable components in materials for many high-tech applications.

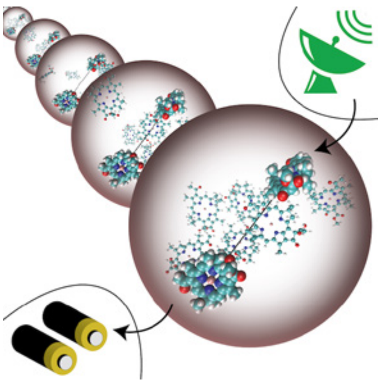
Phys. Rev. Lett. 118, 197202, (2017)

Structure-Dynamics Relation in Physically-Plausible Multi-Chromophore Systems

George Knee and Animesh Datta Theory

This work explores the relationship between structure and energy transport on the nanoscale. The work looks at 50,000 different ways of arranging 6 bacteriochlorophyll molecules between a fixed input and output molecule. One such arrangement is the naturally occurring one found in the famous Fenna-Matthews-Olsen (FMO) light-harvesting complex – a prototypical component of photosynthesis. By looking at many alternative structures, one can gain some insight into this puzzle, and also try to identify which structural features of a general structure are important for optimising energy transport. Such insight would likely be very useful in designing artificial energy transport structures such as those found in solar cells.

J. Phys. Chem. Lett. 8, 2328, (2017)

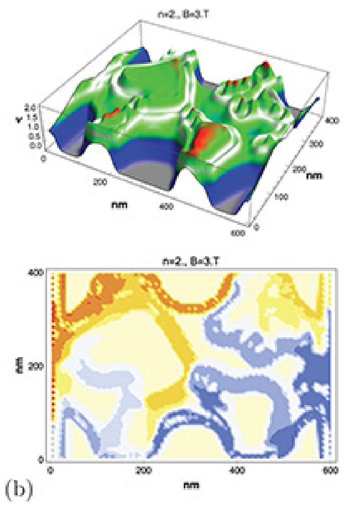


Extreme Nanowires and Single Atom Coils of Metallic Tellurium Formed Within Ultra-Narrow Carbon Nanotubes

Jeremy Sloan and David Quigley — **CMP & Theory**

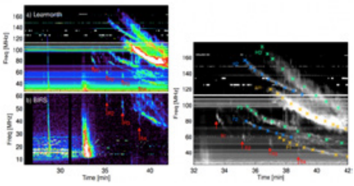
New research by J. Sloan, D. Quigley and PhD student Sam Marks in Warwick, colleagues P. Mederios and A. J. Morris in Cambridge and Q. Ramasse at STFC SuperSTEM confirm the formation of metallic 'Extreme Nanowires' (ENs) of single atom width tellurium atomic chains in ultra-narrow Single Walled Carbon Nanotubes. Sloan & Quigley combined state-of-the-art imaging techniques and 1D-adapted ab initio structure prediction to treat both confinement and periodicity effects. The studied Te ENs adopt a variety of structures, exhibiting a true 1D realization of a Peierls structural distortion and transition from metallic to insulating behaviour as a function of encapsulating diameter as well as the formation of discrete atomic coils of metallic tellurium.

ACS Nano 11, 6178-6185 (2017



Observation of quasi-periodic solar radio bursts associated with propagating fast-mode waves

Val Nakariakov — **CFSA**



Energy releases, such as solar flares, trigger waves and oscillations in the upper part of the solar atmosphere, the corona. The study of these waves and oscillations allows comparisons to magnetohydrodynamic theory and modelling to be made, and seismological inversions based on this comparison. Simultaneous EUV imaging with satellites and radio observations with ground-based telescopes make it possible to study how these waves and oscillations can produce or modify radio emission from the coronal plasma.

A&A 594, A96, 8 (2016)

Earth-size plasma facula oscillating at the surface of the Sun

Val Nakariakov — **CFSA**

Solar magnetic element of the Earth's size oscillates with a few hours period and increasing amplitude, manifesting the vortex shedding effect in the magnetic flux emergence from the solar interior. Analyses of periodic variations in small-scale solar magnetic structures, of the sizes less than 10 arcsec, such as faculae and pores, require cutting edge instrumental sensitivity and resolution. So far, the longest detected periodicities in such structures were limited by a few tens of minutes. Our study shows the presence of a much longer-period oscillation in a photospheric facula. This object is a photospheric crosscut of a magnetic flux tube, generated in the solar interior by dynamo, and emerging in the upper regions of the solar atmosphere.

A&A,598 (2017) L2

Interactions dominate even in the integer quantum Hall effect

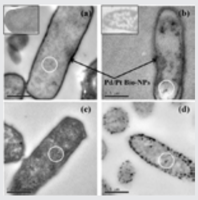
Rudo Roemer — **Theory**

The quantum Hall effect is a test case for a complex quantum system. The presence of many electrons leads to the formation of highly non-trivial dynamics and so-called collective phenomena. Usually, however, it is the fractional quantum Hall effect at extremely strong magnetic fields where many-body effects take centre stage, leading to the formation of quasi-particles. In a new work, Oswald and Roemer show that already in the integer quantum Hall effect at weaker magnetic fields, the interactions play a dominant role.

EPL 117, 57009 (2017)

Upgrading heavy oils using bio-metallic catalysts

Warwick XPS Facility CMP



With the continuous depletion of global oil reserves, unconventional alternative oil resources like heavy oil and bitumen have become increasingly attractive. This study investigates the use of bimetallic bio-nanoparticles (bio-NPs), a potential alternative to commercial catalysts in heavy oil upgrading. The bio-NPs were made by sequential reduction of precious metal (Pd and Pt) ions with hydrogen as the electron donor at 5 wt% and 20 wt% metal loading using bacterial (*Desulfovibrio desulfuricans* and *Bacillus benzeovorans*) cells as support. The potential advantage of using bio-NPs is that the precious metals can be sourced cheaply from waste streams, which could serve as a potential platform for the green synthesis of catalytically active materials using bacteria for in-situ catalytic upgrading of heavy oils.

Applied Catalysis B, pp807-819 (2017)

Colossal terahertz magnetoresistance

James Lloyd Hughes and Martin Lees CMP

New materials that have electronic functionality beyond that of simple semiconductors and metals are a fertile area of research. Complex oxides have been shown to exhibit colossal magnetoresistance effects, where the electrical resistance changes by orders of magnitude under a magnetic field. However, the dynamics of charge transport in these compounds is still poorly understood. Recently, researchers at Warwick have shown for the first time that colossal magnetoresistance can be found at terahertz frequencies. Importantly, they track the local motion of electrons using terahertz spectroscopy, and find that the effect is an intrinsic property of the conductive oxide. They gained insights into the relative length scales of electron motion, and how rapidly electrons scatter. Driving electronics at terahertz frequencies (1012Hz) is important for future devices and wireless communications

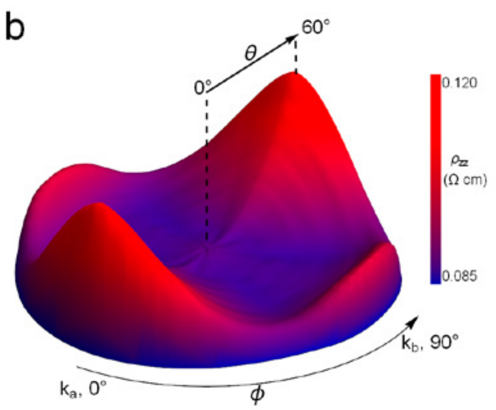
Nano Lett 2017,17,4,2506-2511

Guiding the development of new nanoparticle biosensors

Warwick XPS Facility CMP

Recent work by the group of Matt Gibson in the Department of Chemistry, in collaboration with the interdepartmental and physics-based XPS facility, is expected to lead to nanoparticle biosensors with enhanced specificity, affinity, and stability.

J. Polym. Sci., Part A: Polym. Chem. 2016, 55, 1200-1208

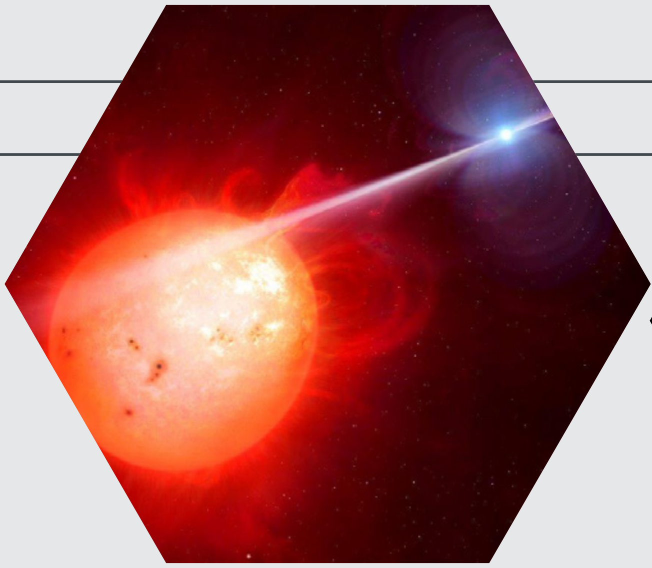


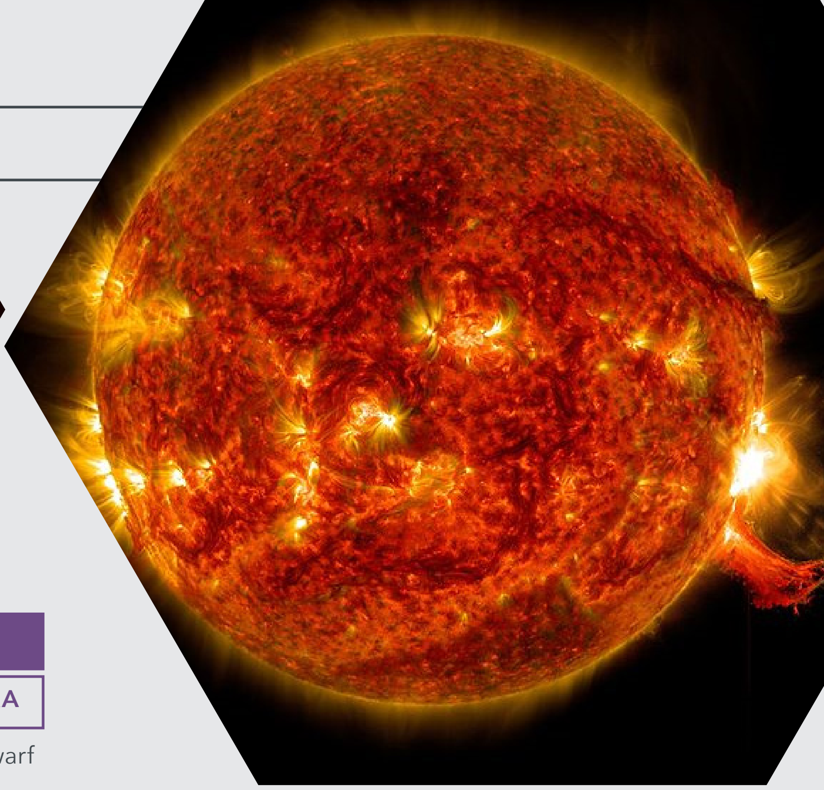
Broken rotational symmetry on the Fermi surface of YBCO

Paul Goddard CMP

Understanding the electronic properties of the cuprate superconductors is key to figuring out the reason for their high transition temperatures. Technically challenging measurements in very high magnetic fields have recently shown that the Fermi surface of an underdoped high-temperature superconductor breaks fourfold rotational symmetry setting limits on the nature of the electronic interactions that compete for dominance in these materials.

Quantum Materials 2, 8 (2017)





Mysterious white dwarf pulsar discovered

Tom Marsh and Boris Gänsicke — A&A

University of Warwick researchers identify a white dwarf pulsar – a star type which has eluded astronomers for half a century. Tom Marsh and Boris Gänsicke of the University of Warwick's Astrophysics Group, with David Buckley from the South African Astronomical Observatory, have identified the star AR Scorpii (AR Sco) as the first white dwarf version of a pulsar - objects found in the 1960s and associated with very different objects called neutron stars. Star lashes its neighbour with intense radiation beam every two minutes.

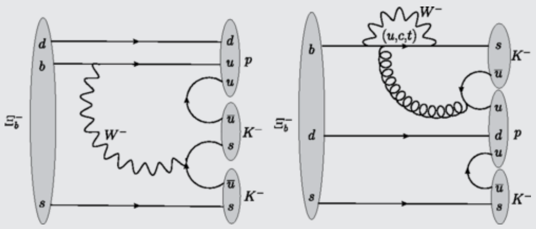
Nat. Astron. 1, 0029 (2017)

An improved Bayesian algorithm for modelling time series with long memory and heavy tails

Nicholas Watkins — CFSA

From finance to solar flares, time series whose statistics show long memory and heavy tails are commonplace. Watkins presents a more accurate way to measure the memory and estimate the risk of extremes. The algorithm uses a Bayesian approach to estimate both parameters simultaneously. This approach is both more general and computationally ""better value"" than past algorithms, which estimate the two parameters separately.

Physics A, Statistical Mechanics & its Applications, 473 (2017)



Observation of rare decays of baryons containing the b quark

Tim Gershon — EPP

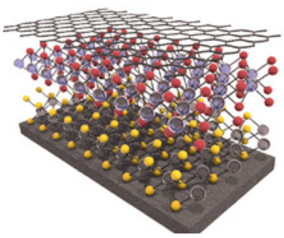
The LHCb collaboration has just published the first observation of a class of rare decays of a baryon containing the b quark. Studies of particles containing the b quark are of great interest as they provide opportunities to investigate asymmetries between matter and antimatter. Current and previous experiments have made detailed investigations into b mesons, but there is much less information available concerning b baryons. Observation of this new class of decay modes shows that it will in future be possible to make detailed studies of matter-antimatter asymmetries also with baryons, which may help to address one of the big mysteries in science today -- why a small amount of matter, that makes up our observable Universe today, survived from the symmetric conditions that existed shortly after the Big Bang.

Phys. Rev. Lett. 118, 071801 (2017)

Layered Material Heterostructures

Nick Hine and Neil Wilson — Theory & CMP

Heterostructures combining multiple 2D materials are key to exploiting the promise of these novel materials in technological devices. New work involving investigators Hine & Wilson from the Department of Physics has investigated the unusual electronic structure effects at the interfaces formed when different transition metal dichalcogenide (TMDC) materials such as $MoSe_2$ and WSe_2 are combined.



Science Advances 3, e1601832

‘Glue’ that makes plant cell walls strong could hold the key to wooden skyscrapers

Ray Dupree CMP

The study, led by a father and son team at the Universities of Warwick and Cambridge, solves a long-standing mystery of how key sugars in cells bind to form strong, indigestible materials. The two most common large molecules – or ‘polymers’ – found on Earth are cellulose and xylan, both of which are found in the cell walls of materials such as wood and straw. They play a key role in determining the strength of materials and how easily they can be digested. For some time, scientists have known that these two polymers must somehow stick together to allow the formation of strong plant walls, but how this occurs has, until now, remained a mystery: xylan is a long, winding polymer with so-called ‘decorations’ of other sugars and molecules attached, so how could this adhere to the thick, rod-like cellulose molecules?

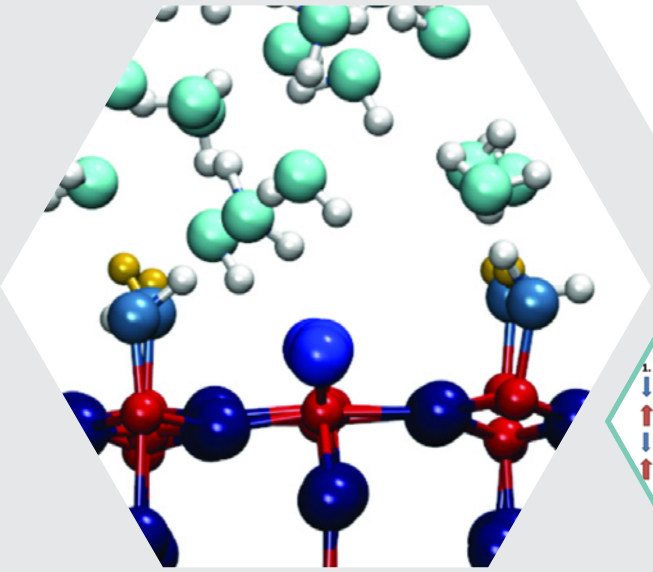
Nature Comms 7, 13902 (2016)

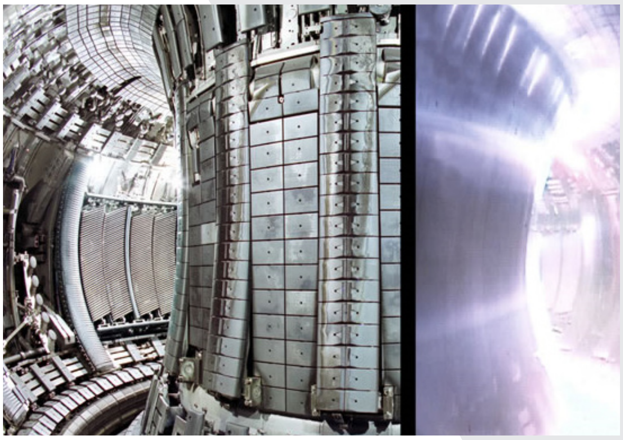
Structure of a model TiO_2 photocatalytic interface

Oier Bikondoa CMP/XMAS

The interaction of water with surfaces and the interfacial structure is of crucial importance for a wide range of technologies (e.g. light harvesting, heterogeneous catalysis and corrosion control). Warwick researchers have determined the structure of a model photocatalytic interface combining scanning microscopies, surface diffraction and density functional theory calculation. The results will allow to explore at the atomic scale the mechanisms involved in TiO_2 photocatalysis.

Nat. Mater. 16, 461 (2017)





The global build-up to intrinsic ELM bursts and comparison with pellet precipitated ELMs seen in JET

Sandra Chapman & Richard Dendy CFSA

Nuclear fusion, the process that powers the sun, offers the promise of a safe, almost unlimited and environmentally friendly source of energy. One of the remaining challenges is the understanding and control of instabilities in magnetically confined plasmas. For example, Edge Localized Modes (ELMs) increase the flux of energy and particles from the hot core of fusion plasmas, adversely affecting performance and increasing localized heat loads on plasma facing materials. This paper presents new insight in understanding ELMs and their dynamical evolution.

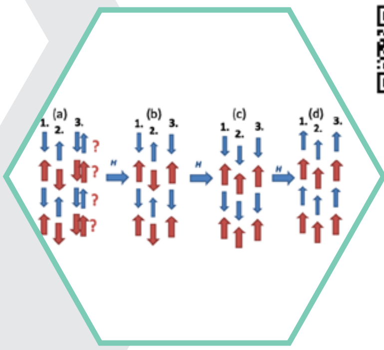
Nucl. Fusion, 58 126003 (2018), DOI:
Phys. Plasmas, 25, 062511 (2018), DOI:

Extraordinarily large coercive field in a frustrated magnet

Paul Goddard CMP

Sr_3NiIrO_6 and Sr_3CoIrO_6 are subjected to ultra-high magnetic fields at cryogenic temperatures. Researchers at Warwick show that as a result of the interplay between correlations, frustration, reduced dimensionality and anisotropy, the materials exhibit record high coercive magnetic fields of up to 55 T.

Phys. Rev. B 94, 224408 (2016)



Solar power could become cheaper and more widespread

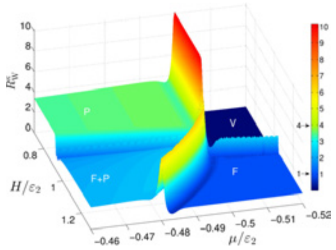
Warwick XPS Facility

A breakthrough in solar cell materials could make the technology cheaper and more commercially viable, thanks to research at the University of Warwick recently published in Nature Energy. Ross Hatton and colleagues in the Departments of Physics and Chemistry show that perovskites using tin in place of lead are much more stable than previously thought, and so could prove to be a viable alternative to lead perovskites for solar cells.

Nat. Energy 1, 16178 (2016)

Dimensionless ratios: Characteristics of quantum liquids and their phase transitions

Rudo Roemer — Theory



Dimensionless ratios of physical properties can characterize low-temperature phases in a wide variety of materials. As such, the Wilson ratio (WR), the Kadowaki-Woods ratio, and the Wiedemann-Franz law capture essential features of Fermi liquids in metals, heavy fermions, etc. Here Roemer and colleagues prove that the phases of many-body interacting multicomponent quantum liquids in one dimension can be described by WRs based on the compressibility, susceptibility, and specific heat associated with each component. These WRs arise due to additivity rules within subsystems reminiscent of the rules for multiresistor networks in series and parallel—a novel and useful characteristic of multicomponent Tomonaga-Luttinger liquids independent of microscopic details of the systems.

Phys. Rev. B 94, 195129 (2016)

The mystery of the missing tetraquark

Tim Gershon — LHCB

The LHCb collaboration has searched for signals of a new particle, recently claimed by the D0 collaboration. Finding no signal, limits are set which are apparently at odds with the D0 claim.

Phys. Rev. Lett. 117, 152003 (2016)

Quantum imaging with Gaussian light

Animesh Datta — Theory

Today, a picture taken by a camera on a typical smartphone can consist of more than 10 million pixels. This is the reality of modern-day cameras and imaging. The ability of record millions of pixels simultaneously will therefore be expected to be a necessary part of any future imaging technology as a matter of course. And that includes quantum enhanced strategies. Measuring (or estimating) multiple parameters simultaneously, however, is one of the fundamental limitations of quantum mechanics. It is what sets quantum mechanics apart from classical physics. What then is the future of quantum enhanced imaging?

Phys. Rev. A 94, 1 (2016)

Planet Nine could spell doom for solar system

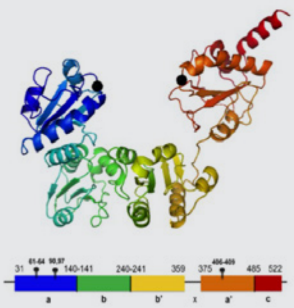
Dimitri Veras — A&A

The solar system could be thrown into disaster when the sun dies if the mysterious 'Planet Nine' exists, according to research from the University of Warwick. Dimitri Veras in the Department of Physics has discovered that the presence of Planet Nine – the hypothetical planet which may exist in the outer Solar System - could cause the elimination of at least one of the giant planets after the sun dies, hurling them out into interstellar space through a sort of 'pinball' effect.

Mon. Not. R. Astron. Soc. 463, 2958 (2016)

The dynamics and flexibility of protein disulphide-isomerase

Rudo Roemer — Theory



Roemer and colleagues from the School of Life Sciences have studied the mobility of the multi-domain folding catalyst, protein disulphide-isomerase (PDI), by a coarse-graining approach based on flexibility. His researchers analyse our simulations of yeast PDI (yPDI) using measures of backbone movement, relative positions and orientations of domains, and distances between functional sites. They find that there is interdomain flexibility at every interdomain junction but these show very different characteristics. The extent of interdomain flexibility is such that yPDI's two active sites can approach much more closely than is found in crystal structures – and indeed hinge motion to bring these sites into proximity is the lowest energy normal mode of motion of the protein. The flexibility predicted for yPDI (based on one structure) includes the other known conformation of yPDI and is consistent with (i) the mobility observed experimentally for mammalian PDI and (ii) molecular dynamics. They also observe intradomain flexibility and clear differences between the domains in their propensity for internal motion. Our results suggest that PDI flexibility enables it to interact with many different partner molecules of widely different sizes and shapes and highlights considerable similarities of yPDI and mammalian PDI.

Proteins Struct. Funct. Bioinforma. 84, 1776 (2016)

Temperature-Dependent Photoluminescence Characteristics of GeSn Epitaxial Layers

Maksym Myronov — **CMP**

Germanium Tin (GeSn) epitaxial heterostructures are emerging as prominent candidates for the monolithic integration of light sources on Si substrates. Myronov and colleagues propose a suitable explanation for their temperature-dependent photoluminescence (PL) that is based upon the so far disregarded optical activity of dislocations. By working at the onset of plastic relaxation, which occurs whenever the epilayer releases the strain accumulated during growth on the lattice-mismatched substrate, the research demonstrates that dislocation nucleation can be explicitly seen in the PL data. Notably, findings point out that a monotonic thermal PL quenching can be observed in coherent films, in spite of the indirect nature of the GeSn band-gap. The Warwick investigation, therefore, contributes to a deeper understanding of the recombination dynamics in this intriguing group IV alloy and offers insights into crucial phenomena shaping the light emission efficiency.

ACS Photonics 3 (11), 2004-2009 (2016), DOI:

Star's intense radiation beams whip neighbouring red dwarf

Tom Marsh and Boris Gänsicke — **A&A**

New research from the University of Warwick finds a new type of exotic binary star, in which a rapidly-spinning burnt-out stellar remnant called a white dwarf sweeps powerful beams of particles and radiation over its nearby companion star, causing it to pulse across almost the entire electromagnetic spectrum from the ultraviolet to radio.

Nature 537, 374-377 (2016)

Solar cycle variation of energy in the solar wind

Sandra Chapman — **CFSA**

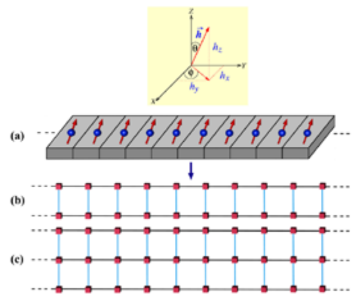
We need to know how frequent, long-lasting, and intense large-scale disruptive space weather events are likely to be and how this changes as space weather changes with the solar cycle. Since these are by definition rare events, it is challenging to obtain this information directly from observations. We have sufficiently high time resolution observations from satellites over the last two solar cycles. Warwick researchers analysed this data and found that whilst event intensity and duration both vary with solar cycle changes in activity, there is a relationship between them that does not change. Event intensity predicts event duration and vice versa. This provides a constraint on the potential impact of space weather events and is a check on models. It may even be useful in real-time characterization of space weather events.

J. Geophys. Res. Sp. Phys. 123, 7196 (2018)

Spin filter for arbitrary spins by substrate engineering

Rudo Roemer — **Theory**

Roemer and colleagues design spin filters for particles with potentially arbitrary spin S (=1/2, 1, 3/2, ...) using a one-dimensional periodic chain of magnetic atoms as a quantum device. Describing the system within a tight-binding formalism the researchers present an analytical method to unravel the analogy between a one-dimensional magnetic chain and a multi-strand ladder network. Our scheme is applicable to ultracold quantum gases and might inspire future experiments in this direction.



J. Phys. Condens. Matter 28, 335301 (2016)

Growth of Large Crystalline Grains of Vanadyl-Phthalocyanine without Epitaxy on Graphene

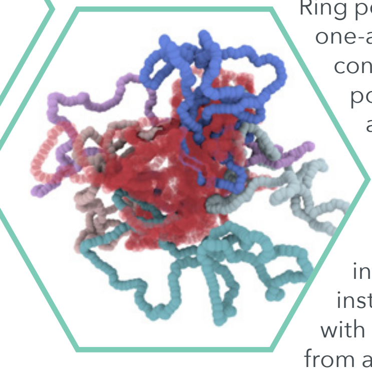
Neil Wilson — **CMP**

Graphene's flat, homogeneous surface can encourage the growth of large organic semiconducting crystals without relying on epitaxy: a promising development for its application as an electrode material.

Adv. Funct. Mater. 26, 1188 (2016)

Threading between ring polymers – towards a topological glass.

Matthew Turner — Theory



Ring polymers interpenetrate and "pin" one-another's motion. To what extent do concentrated solutions, or melts, of ring polymers thread through one another at equilibrium? An analogous system is a well-shaken bucket full of very long rubber bands. If one attempts to withdraw a single rubber band it is very likely that a large tangle of interpenetrating rubber bands will instead emerge. This is to be contrasted with an attempt to withdraw a single strand from a bowl of freshly cooked spaghetti, analogous to a system of linear polymers.

Proc. Natl. Acad. Sci. 113, 5195 (2016)

High order local and nonlocal correlations for 1D strongly interacting Bose gas

Rudo Roemer — Theory

The correlation function is an important quantity in the physics of interacting quantum systems such as, e.g. ultracold quantum gases, because it provides information about the quantum many-body wave function beyond a simple density profile. Warwick researchers explicitly calculate the local correlation functions in terms of interaction strength and symmetry phase at zero, low, and intermediate temperatures. They also express the leading order of the short distance non-local correlation functions of the strongly repulsive Bose gas in terms of the wave function of M bosons at zero collision energy and zero total momentum. These general formulas of the higher-order local and non-local correlation functions of the 1D Bose gas provide new insights into the many-body physics.

New J. Phys. 18, 055014 (2016)

Umbilic Lines in Orientational Order

Gareth Alexander — Theory

Ordered materials such as Bose condensates, and liquid crystals display complex three-dimensional structures. Research by Thomas Machon and Gareth Alexander provides new insights into their behaviour.

Phys. Rev. X 6, 1 (2016)

The damping profile of standing kink modes in coronal loops

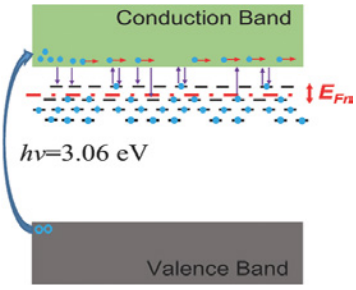
Val Nakariakov — CFSA

Oscillations of solar coronal loops are observed to be strongly damped. This can be explained by mode coupling, which converts the wave energy from bulk transverse motions to localised, unresolved azimuthal motions. Using the highest quality data currently available, Nakariakov and colleagues have found evidence for the Gaussian damping profile predicted by the recently developed theory of damping by mode coupling.

Astron. Astrophys. 605, A65 (2017)

Electronic Origin and Tailoring of Photovoltaic Effect in BiFeO3 Single Crystals

Marin Alexe — CMP



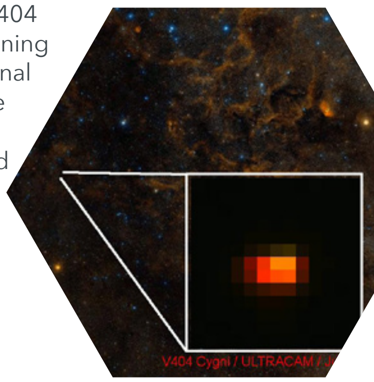
Well, high school physics (courtesy Herrn (Mr.) Albert Einstein) tells us that when a material is subjected to illumination, an electron in released from the valence to the conduction band under the condition that the energy of the incoming photon is higher than the band gap of the material. This effect is known as the photoelectric effect. If, by any means, this electron is forced to remain in conduction band, then a persistent current can be drawn from the material. This is pretty much the underlying mechanism of solar cells, where such electrons are inhibited from recombining by creating an artificial potential junction.

Adv. Electron. Mater. 1, 1500139 (2015)

Astronomers see black hole raging red

A&A

In June 2015, a black hole called V404 Cygni underwent dramatic brightening for about two weeks. An international team of astronomers, including the University of Warwick, report that the black hole emitted dazzling red flashes lasting just fractions of a second, as it blasted out material that it could not swallow.



2016

LIGO discovers gravitational waves

Andrew Levan — **A&A**

The LIGO team at Warwick are to be congratulated on their compelling detection of a gravitational wave signal produced by a pair of coalescing black holes. This represents a remarkable achievement, presenting not only the first detection of a gravitational wave, but also the first detection of a pair of merging black holes.

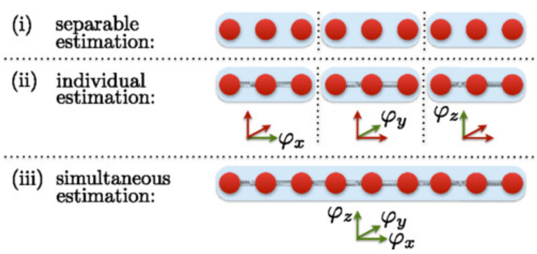
Danny Steeghs comments, "A century after Einstein's theory of General Relativity was presented, a long anticipated window on the Universe has now opened. These events also leave visible signatures that we will be chasing up with our new telescope, the Gravitational wave Optical Transient Observer (GOTO)."

Better off together: Improved quantum estimation of multiple parameters

Animesh Datta — **Theory**

Numerous scenarios in science and technology require the estimation of vectors such as electric, magnetic, gravitational or other force fields with extreme precision, the fundamental limits to which are set by quantum mechanics. In their latest paper, Tillmann Baumgratz and Animesh Datta show that quantum mechanics allows a more precise estimation of multiple parameters simultaneously rather than individually. The result provides a fundamentally better way estimating vector fields for a fixed amount of resources, and could be used in applications ranging from the study of quantum phase transitions to neuroimaging.

Phys. Rev. Lett. 116, 1 (2016)



2015

Experimental Demonstration of Room-Temperature Spin Transport in n-Type Germanium Epilayers

Maksym Myronov — **CMP**

We report an experimental demonstration of room-temperature spin transport in n-type Ge epilayers grown on a Si(001) substrate. By utilizing spin pumping under ferromagnetic resonance, which inherently endows a spin battery function for semiconductors connected with a ferromagnet, a pure spin current is generated in the n-Ge at room temperature. The pure spin current is detected by using the inverse spin-Hall effect of either a Pt or Pd electrode on n-Ge. From a theoretical model that includes a geometrical contribution, the spin diffusion length in n-Ge at room temperature is estimated to be 660 nm. Moreover, the spin relaxation time decreases with increasing temperature, in agreement with a recently proposed theory of donor-driven spin relaxation in multivalley semiconductors.

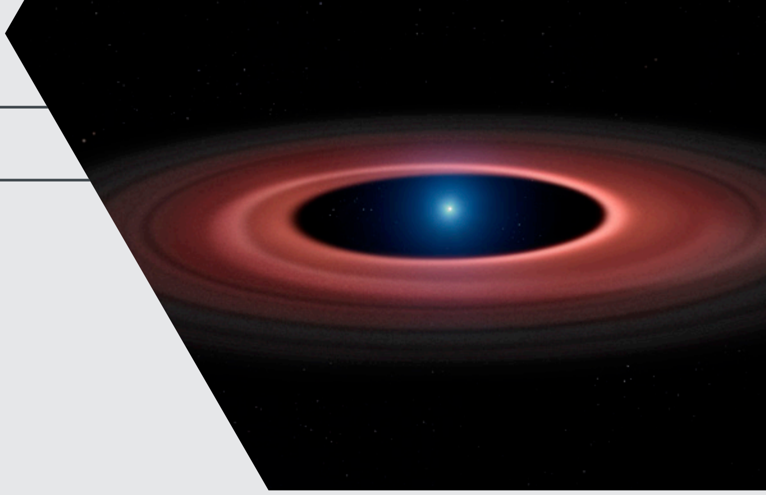
Phys. Rev. Lett. 114, 196602 (2015)

Spinless composite fermions in an ultrahigh-quality strained Ge quantum well

Maksym Myronov — **CMP**

We report on an observation of a fractional quantum Hall effect in an ultrahigh-quality two-dimensional hole gas hosted in a strained Ge quantum well. The Hall resistance reveals precisely quantized plateaus and vanishing longitudinal resistance at filling factors Î½ = 2/3,4/3, and 5/3. From the temperature dependence we obtain the composite fermion mass of $0.4m_e$, where m_e is the mass of a free electron. Owing to large Zeeman energy, all observed states are spin polarized and can be described in terms of spinless composite fermions.

Phys. Rev. B 91, 241303(R) (2015)



Most Earth-like planet uninhabitable due to radiation, new research suggests

Dave Armstrong A&A

The most Earth-like planet could have been made uninhabitable by vast quantities of radiation, new research led by Dave Armstrong of the Astronomy Group has found. The atmosphere of the planet, Kepler-438b, is thought to have been "stripped away" due to "superflaring" of its star, the Red Dwarf Kepler-438.

5400mph winds discovered hurtling around planet outside solar system

Peter Wheatley A&A

A team of researchers from the Astrophysics Group led by Tom Louden discovered winds of over 2km per second flowing around a planet outside of the Earth's solar system.

"This is the first ever weather map from outside of our solar system. Whilst we have previously known of wind on exoplanets, we have never before been able to directly measure and map a weather system."

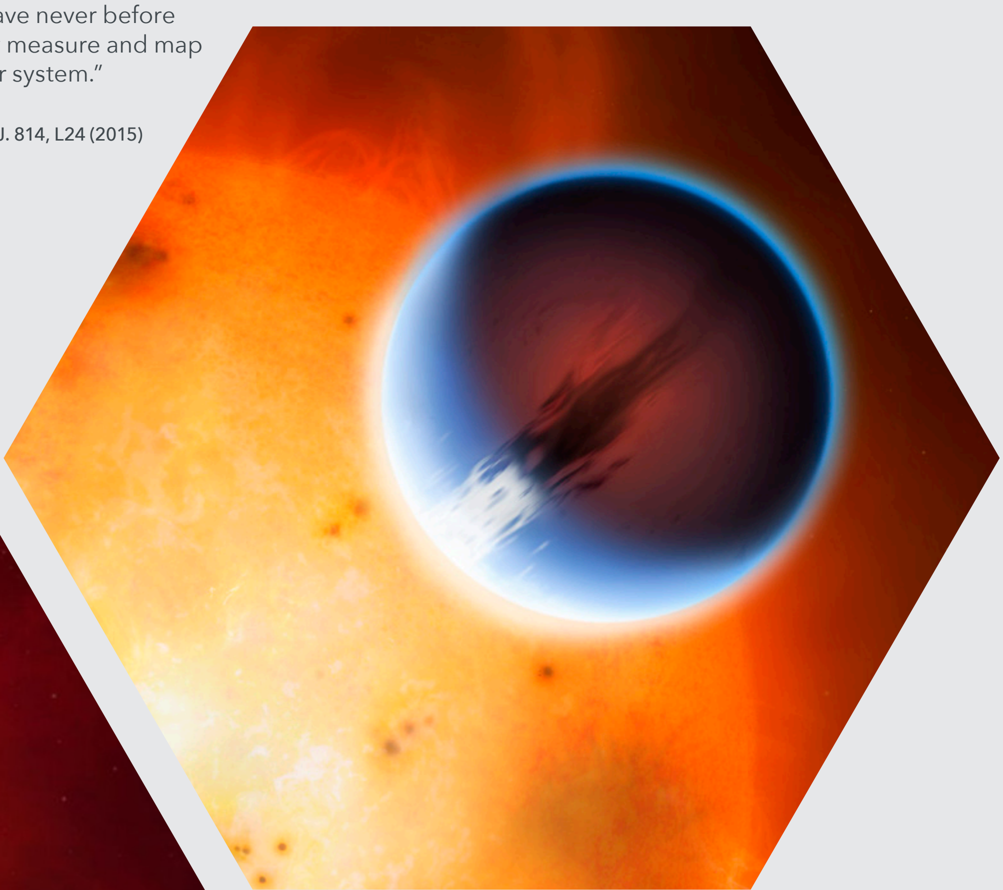
Astrophys. J. 814, L24 (2015)

Asteroid ripped apart to form star's glowing ring system

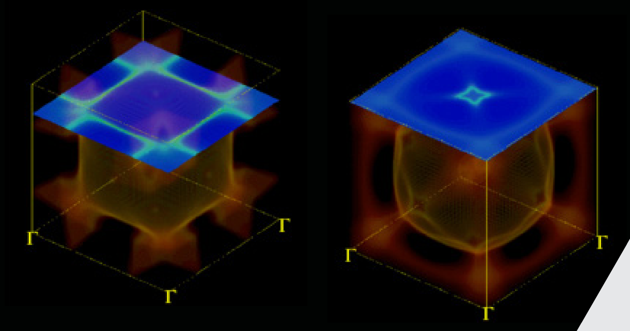
Christopher Manser A&A

The sight of an asteroid being ripped apart by a dead star and forming a glowing debris ring has been captured in an image for the first time.
Led by Christopher Manser of the University of Warwick's Astrophysics Group, the researchers investigated the remnants of planetary systems around white dwarf stars.

Mon. Not. R. Astron. Soc. 455, 4467 (2016)



2015



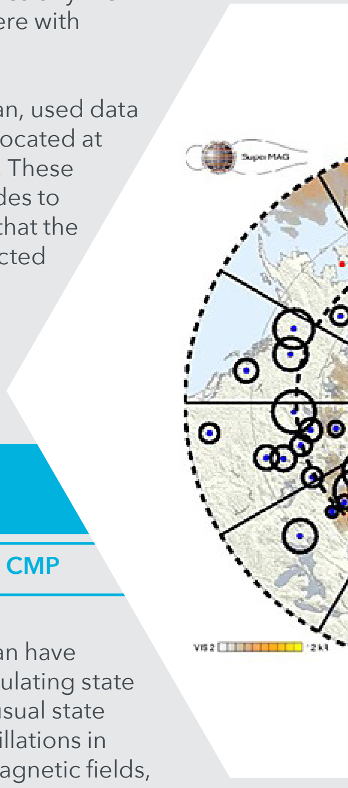
Researchers find that magnetometers have a social network where they talk about the weather

Sandra Chapman CFSA

New research led by physicists at the University of Warwick has used tools designed to study social networks to gain significant new insights into the Northern Lights, and space weather – particularly the interaction of events in the sun's atmosphere with Earth's ionosphere.

The research team, led by Sandra Chapman, used data from over 100 individual magnetometers located at high latitudes in the northern hemisphere. These magnetometers have been used for decades to track space weather but it is only recently that the data from all these devices has been collected in one place in the SuperMAG project.

J. Geophys. Res. A Sp. Phys. 120, 7774 (2015)



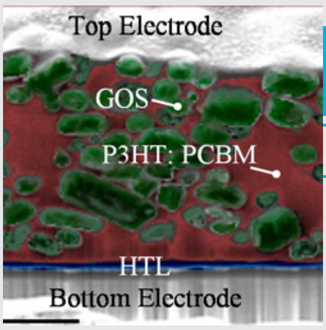
Understanding the magnetism in lanthanide-transition metal magnets

Julie Staunton Theory

Julie Staunton's electronic structure calculations, that reveal the profound complexity of magnetic interactions in technologically relevant intermetallic materials, have been highlighted on the front cover of the latest issue of Physical Review Letters, the world's premier physics letter journal.

The calculations give a quantitatively accurate description of the diverse magnetism of Cs-Cl (B2) ordered phases of Gd with Zn, Cd, and Mg, which are tested against experimental data and show the complex role played by the spin-polarized valence electrons.

Phys. Rev. Lett, 115,207201 (2015)



Paving the way for more efficient X-ray detectors

Oier Bikondoa CMP

A team including Warwick beamline scientist Oier Bikondoa has published a new approach to fabricate more efficient and cheaper X-ray detectors for medical applications. In radiography, the human body is exposed to X-rays and the transmitted intensity is captured by a detector. With more efficient detectors the exposure to X-rays can be reduced.

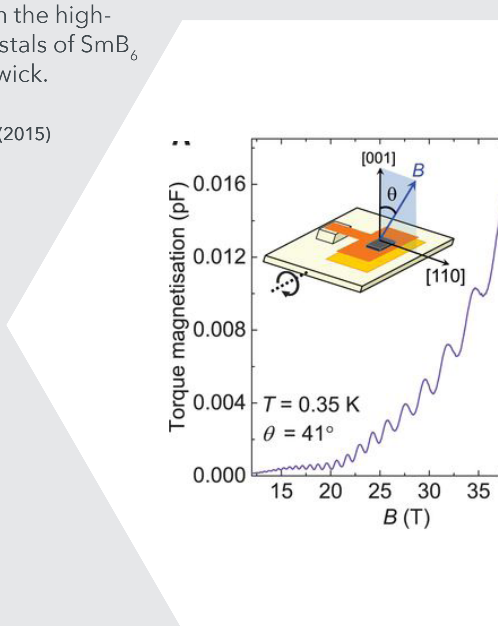
Nat. Photonics 9, 843 (2015)

Unconventional Fermi surface in an insulating state

Geetha Balakrishnan CMP

A team including Warwick authors Geetha Balakrishnan and Monica Ciomaga Hatnean have discovered the existence of an unusual insulating state in the Topological Insulator SmB_6. The unusual state was inferred from observing quantum oscillations in magnetic torque measurements at high magnetic fields, which depended crucially on the high-quality single crystals of SmB_6 prepared at Warwick.

Science (80) 349, 287 (2015)

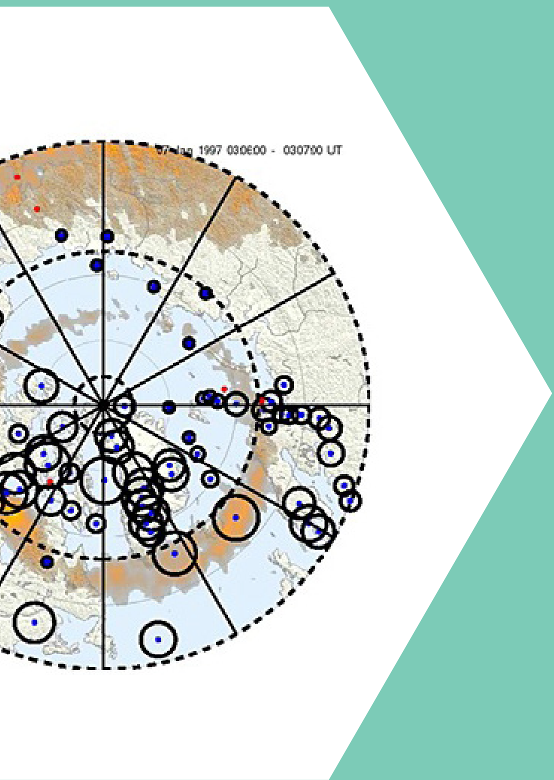


Ongoing Research events in the department:

Research "Nuggets" – latest research highlights

Colloquium – a public event, every second week of term, open to all – featuring exciting physics and quality speakers

Physics Days



Research Seminars in all groups/clusters as follows:

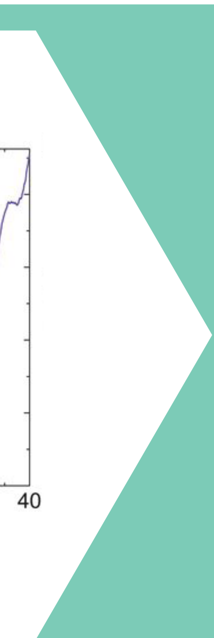
Astronomy and Astrophysics

Theoretical Physics

Centre for Fusion, Space and Astrophysics

Elementary Particle Physics

Condensed Matter Physics



Publications – complete list available on-line, on WRAP – Warwick Research Archive Portal

Read our students' theses on WRAP