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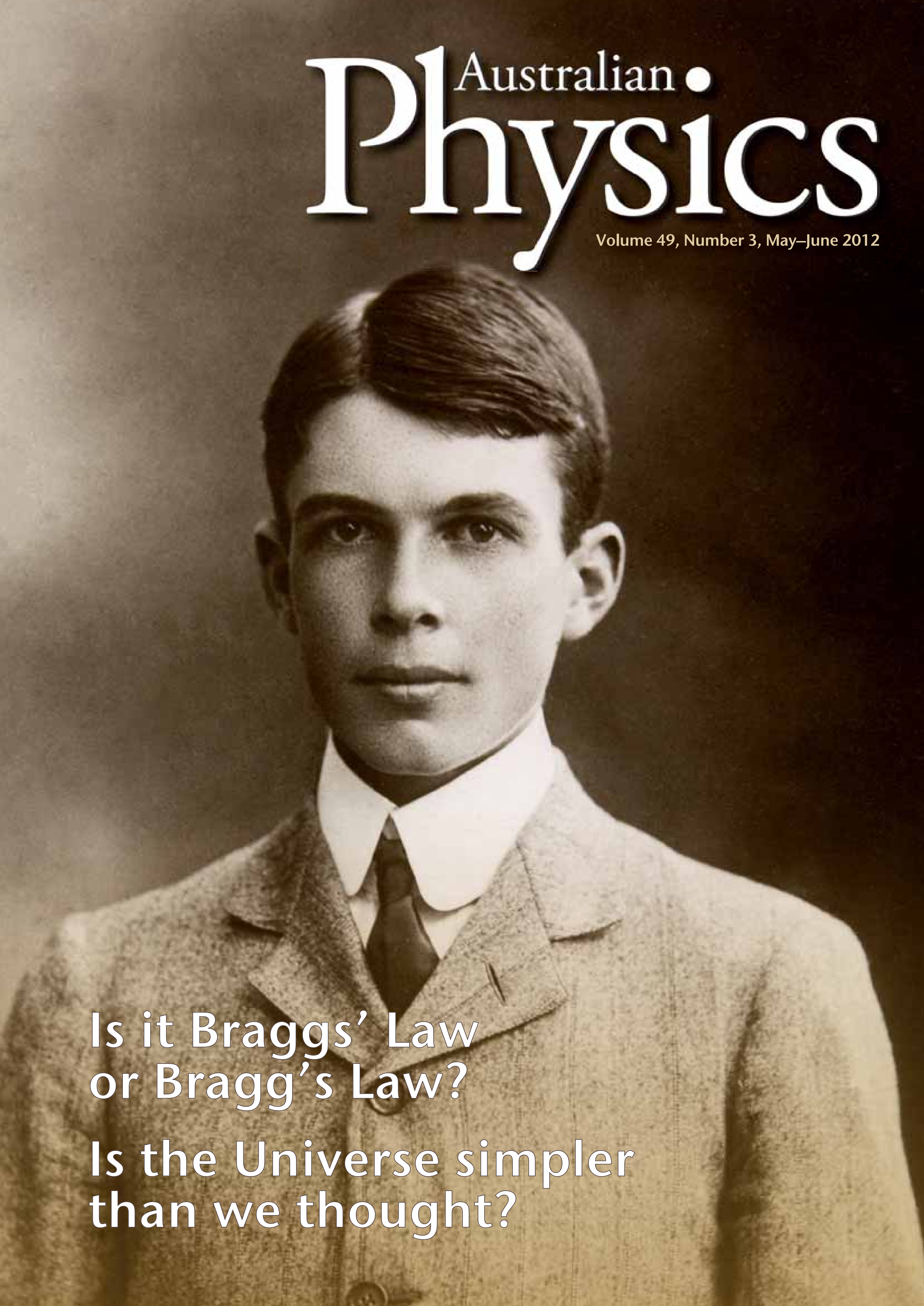

Is it Braggs' Law or Bragg's Law?

Is the Universe simpler than we thought?

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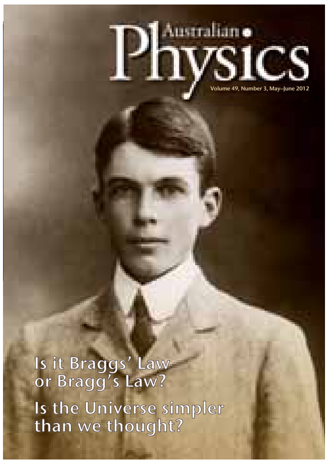

Cover

Lawrence Bragg, aged 16, during his first year at the University of Adelaide in 1906 – see the article by John Jenkin on page 75 [courtesy: Royal Institution, London].

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EDITORIAL

Centenary of Crystallography

Late last year we celebrated the announcement of the Nobel Prize for Physics to Professor Brian Schmidt of the Australian National University, only the second time that Australia has been awarded the prize. The previous occasion was 96 years earlier when the father–son team of William and Lawrence Bragg were awarded the Nobel Prize in 1915 for their foundation of the field of crystallography in 1912.

In our cover story, John Jenkin recounts the remarkable collaboration between William and Lawrence that led to the publication of the Bragg Law in 1912, the seminal paper in the development of crystallography. John spent most of his career in physics at LaTrobe University and then made the transition into the history and philosophy of science. He is the leading authority on the history of the Bragg family and in 2008 Oxford University Press published his masterly study on the father–son collaboration. John presents the case that the contribution by Lawrence – relative to his father – to the discovery of the Bragg Law has been seriously underestimated.

The centenary of the publication of the Bragg Law will be celebrated this year with a number of events, including a conference to be held in December at the University of Adelaide, where William was Professor of Mathematics & Experimental Physics and where Lawrence completed his undergraduate degree (see inside back cover for details).

Our second feature article we hope will cause some controversy. Former graduate of the University of Melbourne, and now at the University of Arizona, Fulvio Melia proposes a re-examination of the Cosmological Principle and the Weyl postulate. He argues that a new interpretation leads to a simpler and more elegant Universe, one that avoids some of the difficulties facing the current standard model of Cosmology. If Melia's ideas are correct, the concept of inflation would no longer be necessary to describe the very early Universe, a concept which has been one of the central pillars of cosmology over the past 30 years. If you have any comments on this article, we would welcome a 'Letter to the Editor' setting out your ideas.

As this issue goes to press, we are anxiously waiting on the announcement of the site selected for the giant radio telescope known as the Square Kilometre Array. Will it be Australia–New Zealand or Southern Africa or both? The announcement was originally scheduled to be made in February, but the fact that is has been postponed suggests that it is a very close race between the rival bids. We passionately hope that the decision goes our way.

Peter Robertson

Is the cost of scientific publishing sustainable?

It is always nice to start my column with recent good news. Firstly, congratulations to Tanya Monro, who has been awarded the Pawsey medal, and to Brian Schmidt, who has been elected to the Royal Society.

Secondly, at the end of March a funding deal for the Australian Synchrotron was announced. This was a welcome response to strong lobbying by many different groups including the AIP. The funding guarantees four years of operation and comprises $69M from the Federal government and $26M from the Victorian government. A further $5M has been committed by the New Zealand government. The beam lines are funded through these funds and by consortia from each of the Australian mainland states, ANSTO, CSIRO and the Association of Australian Medical Research Institutes (a collaboration of 36 medical institutions). At the end of April the ARC added to the future security of the facility by creating a Special Research Initiative in Synchrotron Science to support researcher access to the Australian Synchrotron. The ARC committed $25 million with the NHMRC co-contributing a further $5 million. Sadly no additional beamlines have been funded meaning that the synchrotron is still dreadfully underutilised and a long way from reaching its full potential. Having secured its future let us hope that new beamlines are not too far away.

For a long time now it has been apparent that university libraries are struggling to provide the journals that the university staff and postgraduate researchers need. Every year for the last few decades lists of journal subscriptions are circulated with requests to cull the lists so that the limited subscription finances can be managed. On top of this many of the most expensive journals also have page charges. The question naturally arises about whether the trend in subscription increases is sustainable and many a department tea table has seen this discussion repeated a number of times. The problem of maximising profits related to scholarly publication is not restricted to the publishers. The growth of the citation indexing agencies and in particular the Institute for Scientific Information, now part of the Thomson Reuters group, is a second aspect that is draining the purse strings of institutions, whilst at the same time biasing the publishing practices of researchers toward higher impact journals that are increasing their subscription prices faster than lower ranking journals.

I was therefore not surprised to read a report on the situation at Harvard University. The Harvard Faculty Advisory Council has written to all faculty staff regarding the '... untenable situation facing the Harvard library'. In this memo the blame is targeted at a couple of (unnamed) publishers who have increased their costs dramatically. The process of bundling to gain premium income also comes under fire. The memo requests staff to consider publishing only in open access journals or ones with reasonable and sustainable costs. It argues that doing so will move the prestige publishing over to open access. It also asks staff to consider options such as: editorial board members of the expensive journals trying to change publisher policies from within or resign; enter into unbundled contracts concentrating on high use journals; encourage professional bodies to raise these issues, to take control of publishing in their fields or shift the management of their e-journals to library-friendly organisations; and move to sustainably charged pay per use systems.

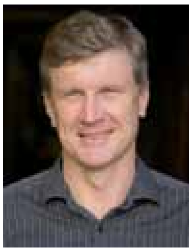
If Harvard University, one of the wealthiest tertiary institutions in the world, is in such difficulty then perhaps it is time for stronger action. Two ideas come to mind. University consortia on a national or even an international scale could use their buying power to say no to the unreasonably expensive publishers. They agree to only subscribe to reasonably priced publications without bundling, except where bundling offers a genuine reduction in costs for wanted journals. Australian universities alone could not hope to have a significant impact but US and European collectives could and we should join them. Secondly, funding agencies at national levels could set publishing policy parameters in place that drive change toward open access. Either or both of these approaches are needed because the situation globally is starting to impact on the viability of research itself. Without realistic access to published work, future research will be severely restricted or even threatened.

Marc Duldig

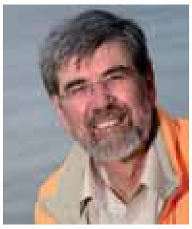
New Academy Fellows

Physics & Astronomy has done exceptionally well in the recent announcement of new Fellows elected in 2012 to the Australian Academy of Science, accounting for five of the 21 new fellows from across all branches of science. Academy President Suzanne Cory said: "I warmly congratulate all of our new Fellows for their outstanding contributions to Australia and the world." Among the new fellows is Professor Tim Flannery (Macquarie University), cited for advancing public awareness and understanding of science.

The five new Fellows in Physics & Astronomy are:



- **Professor Joss Bland–Hawthorn** (Institute of Photonics and Optical Science, University of Sydney) for pioneering the science of astrophotonics and making significant contributions to experimental physics and astrophysics



- **Dr John Church** (CSIRO Marine and Atmospheric Research) for investigating oceanic climate change indicators and providing pre-eminent expertise on the rate of sea level rise in the 20th Century

- **Professor Tanya Monro** (Institute for Photonics and Advanced Sensing, University of Adelaide) for developing nanophotonics for non-linear optics and sensing, resulting in novel solutions to diverse measurement problems [see *AP* **49**, 10 (2012)]

- **Professor John Norris** (Research School of Astronomy and Astrophysics, ANU) for making discoveries that changed several concepts in astronomy, including the formation of galaxies

- **Professor Michael Tobar** (School of Physics, University of WA) for pioneering the development of devices for precision frequency generation and measurement, including in space.

The new fellows presented summaries of their work at the Academy's annual three-day celebration, held on 2–4 May at the Shine Dome in Canberra.

'Bumpy' nanoparticles improve solar cells

In a boon for the local solar industry, a team from Swinburne University of Technology and Suntech Power Holdings in Melbourne has developed the world's most efficient broadband nanoplasmonic solar cells. In a paper published in *Nano Letters*, the researchers describe how they have manufactured thin film solar cells with an absolute efficiency of 8.1%.

The research was conducted under the auspices of the Victoria–Suntech Advanced Solar Facility (VSASF) at Swinburne, a $12 million program jointly funded by the Victorian Government, Swinburne and Suntech. The group aims to dramatically increase the efficiency of thin film solar technology.

Nanoplasmonic solar cell developed by Swinburne and Suntech Power

According to Professor Min Gu, Director of the VSASF, thin film cells have attracted enormous research interest as a cheap alternative to bulk crystalline silicon cells. However, the significantly reduced thickness of their silicon layer makes it more difficult for them to absorb sunlight. "Light trapping technology is of paramount importance to increase the performance of thin film solar cells and make them competitive with silicon cells," Gu said. "One of the main potential applications of the technology will be to cover conventional glass, enabling buildings and skyscrapers to be powered entirely by sunlight."

The VSASF group has been improving thin film cell efficiency by embedding gold and silver nanoparticles into the cells. This increases the wavelength range of the absorbed light, improving the conversion of photons

Chondrules and the early Solar System

Dr Raquel Salmeron [credit: Tim Wetherell, ANU]

New research at the Australian National University has answered a decades old conundrum on how 'chondrules' – tiny particles found within meteorites – could have formed in extreme heat, especially when the meteorite structure surrounding them remained cold. Chondrules are spherical particles of molten material, but their origins have long been a mystery. No more than about 1 mm in diameter, they melted at temperatures of more than 1000°C, while the cooler materials surrounding them only experienced temperatures of a few hundred degrees.

Dr Raquel Salmeron from the ANU Research School of Astronomy and Astrophysics, and Dr Trevor Ireland from the Research School of Earth Sciences, have proposed a new theory on chondrule formation in the early Solar System. "Most of the Solar System is cold, so it's been unclear for decades what caused the chondrules to experience such extreme heat. We believe that chondrules formed in jets of material ejected from flattened disks, called 'protostellar disks', which encircle young stars," Salmeron said.

"These disks are somewhat like the rings around Saturn. The modern planets are the remnants of material of these disks clumping together. In observations of the formation of new stars, we can see jets of material accelerating out of protostellar disks. We show that as these jets shoot out, from about the Earth–Sun distance away, the materials brought with them are heated to the point of melting. The heavier items in them then drop back into the disks, where they cool and re-form."

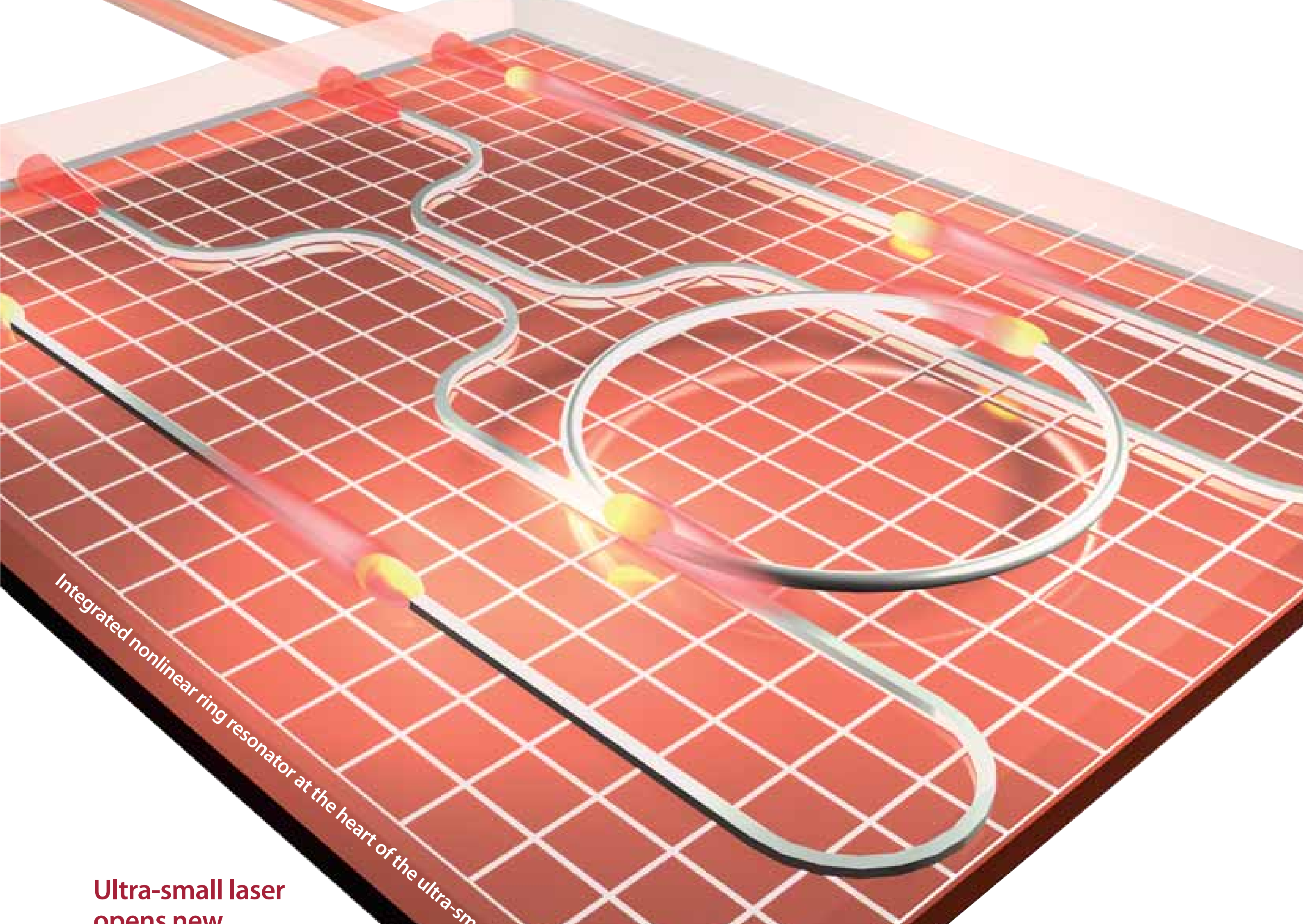
Salmeron said that this theory challenged old assumptions about the formation of chondrules. "For decades it has been assumed that jets could only form chondrules through the heating of materials in the vicinity of the Sun, followed by their transportation into the protostellar disk. We believe that our new theory explains how chondrules – among the earliest materials in the Solar System – reached the temperatures required for melting, even though the early solar nebula was cold. It also explains the fairly uniform size of chondrules and provides a means for them to mix and combine with unheated material."

into electrons. In their most efficient cells yet, the researchers went one step further, using what are known as nucleated or 'bumpy' nanoparticles.

Dr Baohua Jia at Swinburne believes that this new technology will have an important impact on the solar industry: "The broadband plasmonic effect is an exciting discovery by the team. What we have found is that nanoparticles that have an uneven surface scatter light even further into a broadband wavelength range. This leads to greater absorption, and therefore improves the cell's overall efficiency," Jia said.

Professor Gu applauded the quick timeframe in which the research group has been able to achieve 8.1% total efficiency, however he believes there is still considerable scope to improve the cells and transform the way the world sources energy. "We are on a rapid upwards trajectory with our research and development. We are well on track to reach the VSASF's target to develop solar cells that are twice as efficient and are half the cost of those currently available," he said.

Gu points out that another advantage of the group's approach is that nanoparticle integration is inexpensive and easy to upscale and therefore can easily be transferred to the production line. "We have been using Suntech solar cells from the outset, so it should be very straightforward to integrate the technology into mass manufacturing. We expect these cells to be commercially available by 2017."



Integrated nonlinear ring resonator at the heart of the ultra-small laser [credit: Marco Peccianti]

Ultra-small laser opens new possibilities

A team of scientists from Canada, Italy and the US, and including Dr David Moss from the University of Sydney, has created a new form of ultra-small laser. Featured on the front cover of *Nature Communications* in April, the laser is the first to be mode-locked using a micro-cavity resonator, making it highly precise, ultra-fast and ultra-small. Moss is based in the ARC Centre of Excellence for Ultrahigh Bandwidth Devices for Optical Systems (CUDOS) and the Institute of Photonics and Optical Science.

"It's the first time we've been able to use a micro-cavity resonator to lock the modes of a laser, which is how ultra-short pulsed lasers are created. Lasers that have their modes locked generate the shortest optical pulses of light" said Moss. "The micro-cavity is a glass based integrated ring resonator where the laser light modes are generated and locked extremely efficiently, because we've engineered the resonator to have ideal qualities, particularly nonlinear optical properties."

Making lasers that can pulse at very high and flexible repetition rates – much higher than those achieved with electronics – is a field that has been widely pursued. Various solutions to creating these lasers have been proposed, but they have not been successful in creating a stable laser of this sort. "Our new laser achieves extremely stable operation at unprecedented high repetition rates of 200 GHz, while maintaining very narrow linewidths, which leads to an extremely high quality pulsed emission," said Moss.

The new laser will have applications in existing technologies and will also open up entirely new areas such as precision optical clocks for applications in metrology, ultra-high speed telecommunications and microchip-computing. "In order to make our laser work, we use a new mode-locking method known as filter-driven four-wave mixing. What's really different is that the resonator is not simply used as a filter, but acts as the nonlinear element as well," explained Moss.

"Traditional four-wave-mixing schemes make the nonlinear interaction occur in the fibre, then filter the light separately using a linear Fabry–Pérot filter. However, in our new system we have the resonator playing these two roles, making our laser intrinsically more efficient and with a radically shorter cavity length. The new laser is a versatile, stable, efficient and ultra-small laser, which offers many exciting applications in a huge range of areas," said Moss.

AIP Medals and Awards for 2012

Call for Nominations

Harrie Massey Medal to recognise contributions to physics made either by an Australian physicist or by work carried out in Australia.

General Conditions: The prize is awarded biennially for contributions to physics or its applications made by an Australian physicist working anywhere in the world, or by a non-Australian resident in, and for work carried out in, Australia. The recipient must be a member of the Australian Institute of Physics or the Institute of Physics.

Alan Walsh Medal recognises significant contributions by a practising physicist to industry in Australia.

General Conditions: The prize is awarded biennially for physics research and/or development that has led to patents, processes or inventions which, in the opinion of the judging panel, have led to significant industrial and/or commercial outcomes, such as devices that are being manufactured or have influenced a major industrial process.

Walter Boas Medal to promote excellence in research in Physics in Australia and to perpetuate the name of Walter Boas.

General Conditions: The prize is awarded annually to a member of the AIP by the Victorian Branch for physics research carried out in the five years prior to the date of the award, as demonstrated by both published papers and unpublished papers prepared for publication.

Education Medal to emphasise the importance of all aspects of physics education in Australia.

General Conditions: The prize is awarded biennially to a member of the AIP who is judged to have made a significant contribution to university physics education in Australia. In determining the recipient of the award, the quality of the work, the significance to physics education, and the creativity displayed will be taken into account.

Bragg Gold Medal to recognise the work done by a PhD student in Australia that is considered to be of outstanding quality.

General Conditions:: The medal is awarded annually to the student who is judged to have completed the most outstanding PhD thesis in Physics under the auspices of an Australian university, whose degree has been approved but not necessarily conferred in the previous thirteen months. No candidate may be nominated more than once.

Outstanding Service to Physics to recognise an exceptional contribution on the part of an individual.

General Conditions: The AIP Award for Outstanding Service to Physics will recognise an exceptional contribution on the part of an individual who gives great amounts of time and effort to the furtherance of Physics as a discipline. Nominations may be made by a Branch Committee or by three members of the AIP. There will be no more than three awards nationwide in any one year.

Presentation of the Awards

All the above awards will be presented at the biennial Congress by the President of the AIP. The next presentation will be made at the 2012 Congress in Sydney. Each recipient is expected to present a talk at the Congress on her/his work.

Nominations

Nominations for all awards (except the Bragg Gold Medal) should be sent to Olivia Samardzic, Special Project Officer AIP, by 31 July 2012. Details for the Bragg Gold Medal nomination process can be found on the web site listed below.

Further information about these awards can be found at www.aip.org.au/content/medals or obtained by email from the AIP Special Projects Officer at olivia.samardzic@dsto.defence.gov.au or by phone on (08) 7389 5035. Applications and nominations (except for the Bragg Gold Medal) should be sent by email attachment to the above email address or to the Special Projects Officer at Olivia Samardzic, 205 Labs, EWRD, DSTO, PO Box 1500, Edinburgh, SA 5111.

Braggs' Law or Bragg's Law?

The apostrophe matters, even 100 years later!

John Jenkin

On 11 November 1912 (William) Lawrence Bragg announced his discovery of Bragg's Law and his solution of the first crystal structure. Ever since, Lawrence has been denied full credit for this pivotal discovery, and he has been repeatedly denigrated. In celebrating the 2012 centenary of its discovery, we should acknowledge Lawrence as one of the foremost physicists of the twentieth century, and one of Australia's greatest sons [1].

Introduction

Lawrence Bragg is still the youngest person ever to win a Nobel Prize in any discipline – with his father, for Physics, in 1915 – for the 'analysis of crystal structures by means of X-rays'. At its jubilee, Lawrence delivered the first Nobel Guest Lecture at the 1965 Nobel ceremonies in Stockholm. He began as he had done innumerable times before: "It is sometimes said that my father and I started X-ray analysis together, but actually that was not the case"; and he went on to point out that, as a research student at Cambridge, *he alone* had first analysed the Laue photographs using a reflection model, that *he alone* had devised Bragg's Law, and that *he alone* had thereby determined the first crystal structures, of zincblende and the alkali halides.

The journey to Bragg's Law

Late in 1885, persuaded by his Cambridge friend and tennis partner J. J. Thomson, William Henry Bragg applied for the vacant chair of mathematics and experimental physics at the University of Adelaide. At the interviews, a committee composed of Thomson and the previous incumbent, Horace Lamb, selected Bragg. William, aged just 23, had graduated BA with first class honours in mathematics but had never devised a university course nor taught one, and he had done no research!

Young Adelaide professor W. H. Bragg, circa 1888 [courtesy: Mrs E. Wells].

The Bragg family at home, Adelaide, circa 1902, with Lawrence on the left and younger brother Robert ('Bob') [courtesy: Dr S. L. Bragg].

Lawrence Bragg, Cambridge University research student, circa 1913 [courtesy: Dr S. L. Bragg].

On his first day in Adelaide, William was taken to meet the senior scientist in the colony, Charles Todd and his family, but it was their third daughter, Gwendoline, that caught his eye. They fell in love, were married three years later, and three children were subsequently born in Adelaide: (William) Lawrence in 1890, then 'Bob' and later 'Gwendy'.

William's teaching, public lectures and research slowly blossomed, until he became a world authority on alpha-particles from radioactive decay and was elected an FRS. This was followed by an investigation of the nature of radiation, in which he suggested that it was composed of neutral particle pairs (α^+ plus β^-) rather than waves. These showed all the then-known properties of X- and gamma-rays, although he wrote that ultimately a new model would be required that embraced both wave and particle characteristics!

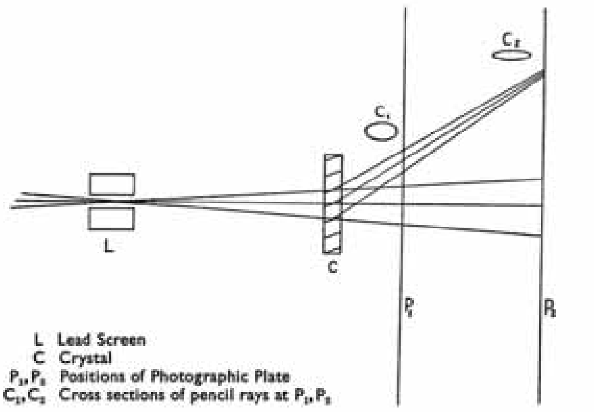
Lawrence and Bob were educated at St Peter's College in Adelaide, where Lawrence was promoted to higher and higher grades ahead of his peers. This unhappy disjunction continued at the university, where he topped most of his classes, many taught by his father. He graduated BA at age eighteen, with first-class honours in mathematics, only weeks before the family sailed for England: William to the physics chair at Leeds; Lawrence to further study at Cambridge.

A year later, encouraged by his father, Lawrence changed to physics and again graduated with a First. He entered the Cavendish Laboratory, but was very disappointed by the research project J. J. allocated to him, and he happily joined the family on the Yorkshire coast for the summer holidays of 1912. Here they read a letter from Germany reporting the Laue experiment that showed that X-rays could be diffracted by a crystal; but it was also clear to them that Laue's analysis of the results was incomplete. It assumed, for example, that the diffraction spots on the photographic film were caused by fluorescent radiation from the simple cubic crystal.

William returned to Leeds to try to salvage his particle model; Lawrence returned to Cambridge to try and find a better explanation. Using insights provided by his undergraduate lectures and advice about possible crystal structures, Lawrence envisaged a *reflection* of the *incident* radiation from atoms in a *face-centred cubic* structure, leading to *elliptical* diffraction spots that *precisely* reproduced the German data. He presented his findings to the Cambridge Philosophical Society, which soon published them.

Lawrence's subsequent career

Using a crystal of known structure, father William now used the technique to study X-rays, until Rutherford in Manchester bullied him out of it in favour of Harry Moseley. William then turned his new spectrometer to



Lawrence's illustration of elliptical diffraction spots from X-ray reflection [courtesy: The British Council].

the study of crystals, and father and son, together and separately, plundered the new field. Lawrence recalled, "we had a wonderful time... discovering a new goldfield where nuggets could be picked up on the ground... until the war stopped our work together."

For more than four years Lawrence played a *major* role in the drive for Allied victory in the First World War, a story still to be adequately told and acknowledged. Here we may simply note that in 1915 the family's Nobel Prize could not be celebrated, because of the war and because brother Bob had been killed at Gallipoli. Father's internationalism never recovered, mother's mourning was deep and long lasting, and Lawrence's equanimity was threatened by the horrors of the Western Front. Appointed post-war to Rutherford's Manchester chair, Lawrence suffered a nervous breakdown, overcome when his research blossomed, he was made an FRS, and he married the bubbly Alice Hopkinson.

Lawrence's research began with an early – and inaccurate – determination of ionic radii and an experimental study of quantitative aspects of X-ray diffraction, and he revised the earlier book with his father, *X Rays and Crystal Structure*. He had a spectrometer made in his father's Leeds workshop, and he and his 'Manchester School' began a long and successful program to determine the structures of silicate minerals.

Lawrence was also extremely busy with teaching and administration; he refurbished the teaching laboratories and planned a new building. He wrote a new book, *The Crystalline State: A General Survey*, and he launched a new study of metals and alloy and alloy phase diagrams. He himself focussed on order–disorder transformations. Exhausted, he spent several months in Munich and there recovered his strength. In a lecture to the Royal Society of Edinburgh, he mentioned the attraction of "an X-ray investigation of structures produced by living matter", and that it might be "the most interesting field of all".

Lawrence and Alice Bragg on their wedding day, 1921 [courtesy: Mrs Staughton and Lady Heath].

In 1937 Lawrence again succeeded Rutherford, this time in the Cavendish chair at Cambridge, where the reception was again cool. Many said a crystallographer wasn't a real physicist at all! But again Lawrence triumphed. As Pippard said later, "when one looks back on Bragg's tenure... [it] came to fruition in advances... that even eclipsed any from Rutherford's Cavendish" [2]. He was no doubt thinking of the Nobel Prizes awarded to Crick, Watson, Kendrew, Perutz and later Ryle and Hewish. Nevertheless, Lawrence's successor, Neville Mott, threw crystallography and biophysics out of the Cavendish; it was re-established in Cambridge as the independent MRC Laboratory of Molecular Biology.

Finally, Lawrence Bragg accepted another poisoned chalice at the Royal Institution of Great Britain, where he reorganised its dysfunctional administration, introduced successful lectures for school children, gave discourses that were televised for the first time, and saw his research blossom yet again. He died on the first of July 1971.

Swedish postage stamp in 1975, commemorating the Braggs' Nobel Prize and showing them as in 1915 [courtesy: Swedish Postage Stamps].

Father and son

Lawrence lived in his father's shadow for much of his life. They had similar childhoods and, after Lawrence's initial breakthrough, they both spent the remainder of their lives in X-ray crystallography. William tried unsuccessfully to see that Lawrence received the credit he deserved, but father was an established scientist and son was an unknown research student. William was always asked to speak and travel. At the conclusion of one such lecture in America in 1914, a member of the audience rose to say, "*Quod facit per filium se*: what a man does through his son he does himself", and the audience cheered and laughed uproariously. At home and overlooked, Lawrence did not cheer, and he did not laugh.

I cannot list the endless number of times that scientists, scholars, the media and the general public have confused them; one example will have to suffice. Robert Olby's recent biography of Francis Crick says, "Sir Lawrence Bragg… was, with his father, one of the pioneers of X-ray crystallography and co-author of the well-known equation that bears their name" [3]. *No, William wasn't a co-author; Lawrence did it by himself!*

Poisonous accusations

As a post-doc in England in the 1960s I heard a lot of scuttlebutt about Lawrence Bragg, but I largely ignored it and then I forgot it. But in 2004, when the first major biography of Lawrence Bragg was published by Oxford University Press, the scuttlebutt was put on the public record and now had to be taken seriously [4]. The author, Graeme Hunter, appears to have gathered it from still-disenchanted scientists in England, but he failed to check its authenticity.

I quote the most outrageous accusations: First, the relationship between Lawrence and his father. Hunter and many others have discerned a tension and a coolness, based upon their competitiveness in research and Lawrence's belief that his father had not done enough to ensure his adequate recognition (pp. 142–3).

Second, Hunter says: "Despite Bragg's lifelong wish to be thought of as a physicist, and despite his tenure of numerous senior positions in British and international physics, it must be said that his work had no great influence on the physics of his time – or after" (p. 248).

Third, Hunter reports: "Nor, despite his early training in mathematics, was Bragg a mathematical physicist. Crick said, 'I don't think he was very powerful mathematically; I think some of the physicists rather looked down on him.'" (pp. 248–9).

Fourth, Hunter writes: "The term 'classical physicist', often applied to [Lawrence] Bragg by his contemporaries, was not, of course, meant as a compliment. As a classical physicist in the age of quantum theory, he was a scientific dinosaur in a world dominated by the mammals" (p. 249).

Fifth, Hunter says: "Bragg was quite ignorant of chemistry and biology and had little interest in either discipline." (p. 250).

Sixth and last, Hunter suggests that Lawrence "did not have a flamboyant personality" (p. xiv).

These are all egregiously wrong and I have refuted them in [1]. Here I discuss only the second and fourth accusations regarding Lawrence's standing as a physicist.

Physics changed dramatically in the twentieth century, the emergence of solid-state or condensed-matter physics being perhaps the most notable and certainly the most commercially productive of the changes. The pace and breadth of discovery and innovation was unprecedented. At century's end a range of writers was required to write the history of its development. All agreed, however, that the essential ingredients were the inventions of X-ray crystallography and quantum mechanics, plus the realisation that some properties depend on an idealised crystal pattern and others on surface and interior imperfections. Lawrence's work had no great influence on physics? Balderdash!

Some physics is still classical, and there is no shame in that. Furthermore, Lawrence was *not* ignorant of quantum mechanics. He introduced a course on it at Manchester very early, he wrote the Foreword to the resulting textbook, and he persuaded Mott to give such lectures to his Manchester staff, which he himself attended with great en-

Lawrence Bragg and George Thomson, close and long-term friends, both Nobel Laureates with physics Laureate fathers, 1965 [courtesy: Royal Institution, London].

thusiasm. In 1931 he deliberately spent three months at Sommerfeld's Institute of Theoretical Physics in Munich. And there is more; hardly the actions of a dinosaur!

Conclusion

Lawrence's personality was more complex than his father's, although he did share his father's humility and love of private family life. Arriving in England as a young man, Lawrence tried valiantly to blend into Cambridge and English life, but he did not have an English public-school education and he was socially inexperienced and naïve. He then suffered the vivid horrors of The Great War, and later he also experienced episodes of depression.

He rebuilt the Physics Department at Manchester, he diversified the Cavendish Laboratory in Cambridge, and he rescued the Royal Institution in London, all against severe opposition, and history has judged him very kindly in all three cases. However, to many of the leaders of British science Lawrence remained an outsider, a 'colonial', who was honoured too young, who was not a 'real' physicist (or chemist or biologist), who did not adequately respect English forms, and who lacked his father's equanimity. Nevertheless, he began X-ray crystallography, and thereafter he had a hand in almost every major step in its development. Sir David Phillips told me that in determining crystal structures Lawrence was an unparalleled problem-solver, with a wonderful sense of space.

So, despite all that has been said against him, (William) Lawrence Bragg was surely one of the greatest scientists of the twentieth century. With his father he influenced a wider range of disciplines more profoundly than anyone else, and their achievements transformed our understanding of both the natural and the man-made worlds. I believe he will be remembered and honoured around the world long after his detractors and their words are forgotten.

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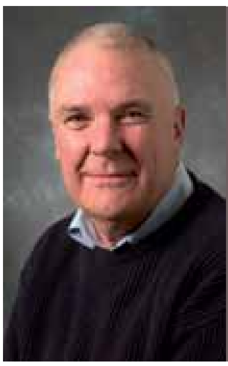


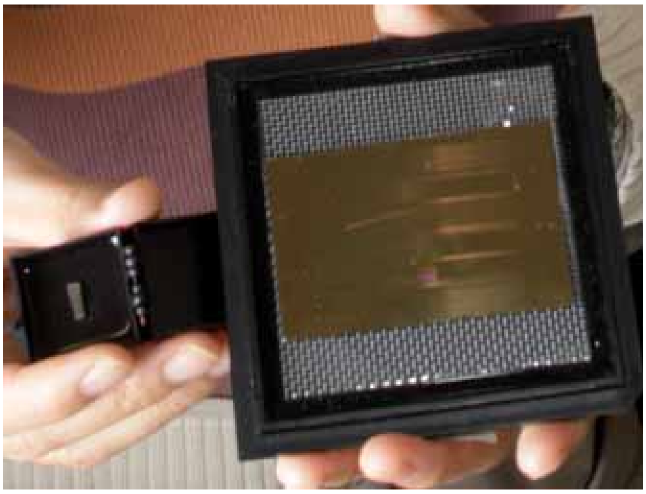
AUTHOR BIO

John Jenkin is a graduate of the University of Adelaide (BSc(Hons)) and the ANU (PhD), and held post-doctoral appointments in the UK and USA. In 1968 he joined the Physics Department of La Trobe University, where he became a Reader and Head of Department. He spent the last decade of his career within the history and philosophy of science program in the Faculty of Humanities at La Trobe. In physics his research explored the electronic properties of materials, and in the humanities the history of the physical sciences in Australia, with an emphasis on biography. Long retired, he is an Emeritus Scholar of La Trobe University.

Victorian Branch

Professor Ben Eggleton from the University of Sydney, and acting director of the ARC Centre of Excellence for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), gave a fascinating 2011 Walter Boas Medal Lecture on 'Nonlinear Photonic Circuits transforming the New Information Age: Faster, Smaller and Smarter' at the University of Melbourne on 27 March. He reviewed recent progress by his group and collaborators in demonstrating nonlinear photonic circuits (photonic chips) for ultra-fast all-optical signal processing at Terabaud rates (equivalent to 1000 Gigabits per second), based on highly nonlinear materials and nanophotonic circuits and structures [see *AP* **49**, 41 (2012)].

The review covered the underlying principles of the optical nonlinearity and showed how it can be massively enhanced using slow light in photonic crystal circuits. In particular, he reviewed recent breakthroughs which demonstrate ultra-fast all-optical signal processing and emerging applications of photonic chip based all-optical processing in quantum processing and nonlinear optical phononics (opto-acoustic interactions).



Left: ultra-compact silicon photonic circuit based on photonic crystals; right: chalcogenide photonic integrated circuit developed by the CUDOS collaboration between Sydney and the ANU.

The novel methods being developed by Eggleton's group will enable the Internet to transfer vast amounts of data at Tb/sec; they will lead to secure transmission using quantum photonics-based devices; and to the detection of mid-infrared signatures of light from distant stars and complex molecules of environmental or biochemical importance. One of the most exciting results reported by Eggleton was the unexpected discovery of 3ω harmonic light generation caused by the slowing down of laser pulses in photonic crystals.

Dr Andrew Stevenson, Chair of AIP Victorian Branch, presented the Walter Boas Medal to Professor Eggleton after the lecture on behalf of the AIP. [from Wen Xin Tang]

South Australian Branch

The SA branch held a 'Meet & Greet' for physics students on 22 March, with students from all three SA universities invited, along with AIP members. About 80 people attended, with the majority being staff and students from the Universities of Adelaide and South Australia, but also a couple of AIP members from industry. The branch vice-chair Kristopher Rowland welcomed everyone and described the role of the AIP. The branch thanks its committee members from the University of Adelaide for running the event, particularly postgraduate student Phiala Shanahan. [from Laurence Campbell]

SA branch vice-chair Kristopher Rowland welcomes physics students and AIP members to a 'Meet & Greet' in March.

Tasmanian Branch

New Branch prize. The branch is glad to report that a new prize for fourth year students at the University of Tasmania has been instituted. The AIP–University of Tasmania Prize for Honours Physics graduates from the University of Tasmania will be called the Ken McCracken Honours Prize. It was created by the Tasmanian Branch of the AIP and has been now been approved by the University of Tasmania.

The Prize will be available for the first time in November 2012 and will be awarded at the AGM of the Tasmanian Branch of the AIP. It will consist of a $400 monetary prize in the first instance (but this will be assessed on a year-by-year basis). There will also be a perpetual plaque to be mounted in the School of Mathematics and Physics, with the names of recipients and years being added progressively. The Branch will have the plaque made and physics staff will arrange for the board to be appropriately displayed. [from Raymond Haynes]

This image at Monash University Lake was taken with a specially modified digital camera. The camera was made sensitive to light radiation with wavelengths from 400 nm to beyond 1000 nm, ie. beyond the human visible range. Using an external filter this particular image was restrained to wavelengths greater than 850 nm, the near infra-red part of the solar spectrum. Grass and foliage are strong reflectors of the NIR so they appear white and the lake and sky appear dark. Originally this work was related to CSIRO's development of Security Technologies for protecting banknotes, pharmaceuticals, etc., from forgery. More recently CSIRO's Flexible Electronics group is visualising novel Solar Cells that utilise particular parts of the solar spectrum. The modified camera has the potential for observing characteristics of these special solar cells. [Camera modification and image by Lawry McCarthy in 2011.]

This year's activities. The first of the Branch's public lectures for 2012 was presented by Professor Allan Clark in Hobart on 14 February and repeated in Launceston the following day. Professor Clark, an Honours graduate from the University of Tasmania and now Director of the Department of Nuclear and Particle Physics at the University of Geneva, is a senior researcher at CERN.

The subject of his talk, 'The Large Hadron Collider: Revealing the Fundamental Nature of our World', attracted larger than expected audiences. Twenty minutes before the start of the Hobart lecture the booked lecture theatre was already nearly full and the talk – and audience! – had to be quickly moved to the largest theatre on campus to accommodate the 330 people who attended. About 130 people heard the presentation in Launceston.

In a fascinating talk, Professor Clark described the purpose and design of the Large Hadron Collider (LHC) in the 27 kilometre-long circular tunnel beneath the Franco-Swiss border. This experiment aims to uncover some of the remaining secrets of our Universe, illuminating the nature of the fundamental forces and particles that make up our world. This talk outlined the Standard Model and then described some of the first physics results from colliding protons close to the speed of light inside the LHC. The audience, of course, wanted to know if the Higgs boson had yet been found. The answer was tantalising. Its possible mass has been constrained to within quite small limits, but at the time of the talk positive identification has not been firmly established.

On 17 April Dr Kelvin Michael, of the Institute for Marine and Antarctic Studies at the University of Tasmania, gave a public talk 'Solar Radiation and the Antarctic Sea Ice Environment'. Opening with an illustrated description of the formation and growth of the various types of sea-ice, he went on discuss how solar radiation interacts with sea-ice and its snow-cover. Clearly, the amount of radiation penetrating to the water beneath is a function of ice depth and snow-cover. Access for direct measurement of under-ice radiation levels is by ship and can only be made at a few places.

Continent-wide modelling based on these measurements depends on knowledge of ice thickness, which in turn is sparse and approximate. Satellite estimations of ice thickness are not yet available. Progress is being made but there is still plenty of work remaining to be done before large scale quantitative data are available and the effect of UV changes due to the ozone hole can be evaluated. [from John Humble]

The Cosmic Spacetime

Is the Universe much simpler than we thought?

Fulvio Melia

Cosmology today is confronted with several seemingly insoluble puzzles and strange, inexplicable coincidences. But a careful re-examination of the Cosmological Principle and the Weyl postulate, foundational elements in this subject, suggests that we may be missing the point. The observations actually reveal a simpler and more elegant Universe than anyone could have imagined.

The Polish priest Nicolaus Copernicus (1473–1543) started a revolution with his heliocentric cosmology that displaced the Earth from the centre of the Universe. His remarkable shift in paradigm continues to this day, the cornerstone of a concept we now call the Cosmological Principle, in which the Universe is assumed to be homogeneous and isotropic, without a centre or boundary. But few realise that even this high degree of symmetry is insufficient for cosmologists to build a practical model of the Universe from the equations of General Relativity.

The missing ingredient emerged from the work of mathematician Hermann Weyl (1885–1955), who reasoned that on large scales the Universe must be expanding in an orderly fashion. He argued that all galaxies move away from each other, except for the odd collision or two due to some peculiar motion on top of the 'Hubble flow' (Fig. 1). In this view, the evolution of the Universe is a time-ordered sequence of three-dimensional spacelike hypersurfaces, each of which satisfies the Cosmological Principle – an intuitive picture of regularity formally expressed as the *Weyl postulate*.

Together, these two philosophical inputs allow us to use a special time coordinate, called the *cosmic* time t, to represent how much change has occurred since the Big Bang, irrespective of location. In special relativity, this approach can be confusing because t is the proper time on a clock at rest with respect to the observer, but is not the time she would measure on her synchronised clocks at other locations. But since the physical conditions are presumably the same everywhere, t should track the evolution of the Universe as seen from any vantage point, since the same degree of change will have occurred anywhere on a given time slice shown in Fig. 1.

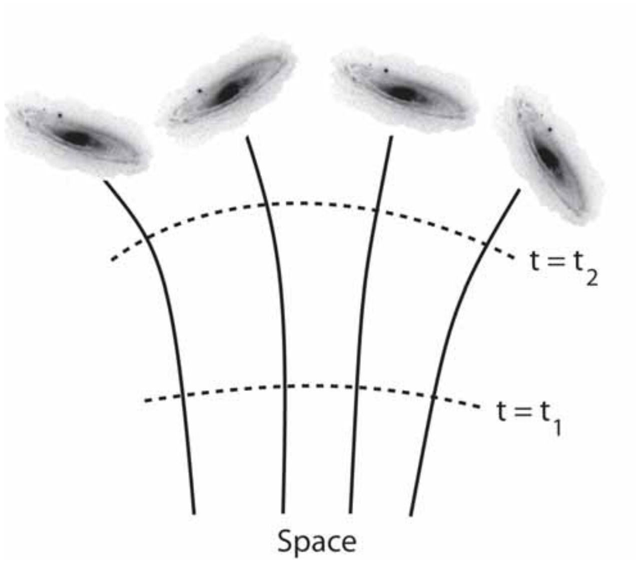


Fig. 1. Illustration of the Weyl postulate.

Of course, the Weyl postulate has several other important consequences, particularly in terms of how we interpret the separation between any two points in the

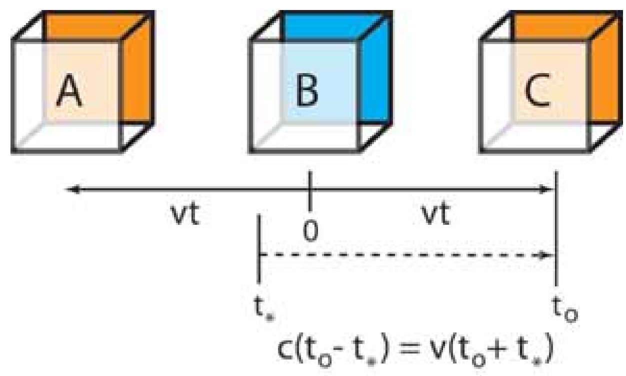


Fig. 2. A and C recede from us (in B) at the same speed *v*. At time t_* a light pulse is emitted by A that arrives at C at time t_o. All times in this diagram are measured on our clock.

cosmic flow. In relativity, the *proper* distance $R(t)$ between two points is their separation measured simultaneously in a given frame. It is not difficult to convince oneself that if the distance R_{AC} between frames A and C (Fig. 2) is twice R_{AB}, then A and C must be receding from each other at twice the rate of A and B. The Weyl postulate therefore reduces formally to the mathematical expression $R(t) = a(t)r$, meaning that the proper distance $R(t)$ between any two spacetime points must be the product of a fixed, co-moving distance r – which never changes even as the Universe expands – and a universal function of time $a(t)$ independent of position, but not necessarily of time.

> **"Cosmology today is confronted with several seemingly insoluble puzzles and strange, inexplicable coincidences."**

A galaxy a proper distance $R(t)$ from us must therefore be receding at speed $\dot{R} = \dot{a}\,r$ or $\dot{R} = (\dot{a}/a)\,a\,r$, conventionally written as $\dot{R} = HR$ (the 'Hubble Law'). The Hubble constant $H = \dot{a}/a$ is independent of position. Notice how easily such a simple consequence of the Weyl postulate accounts for all of Hubble's famous observations, which convinced even Einstein – an early advocate of the static Universe – that the cosmos is expanding at a speed proportional to proper distance. There is much to learn about the Universe – perhaps even its beginnings – by understanding H or $a(t)$, and so much of the effort in cosmological research is dedicated to this task.

The earliest moments

But when we attempt to follow what happened in the earliest moments, we immediately hit a roadblock because General Relativity is a theory of precision, whereas quantum mechanics imposes an irreducible fuzziness on any measurement of distance or time. Quantum physicists argue that the precision of particle location is no better than its Compton wavelength λ_C, the wavelength that a photon would have if its energy were equal to that of the particle with rest mass m (ie. mc^2). This makes sense because to locate the particle, you would want to shine the highest frequency light on it, except that if the photon's energy is too high, the particle recoils and you again lose track of where it is. The ideal compromise is realised when their energies are equal, so that $\lambda_C = h/mc$.

But what value of m should one use to calculate λ_C? Although we don't yet have a theory of quantum gravity, it is nonetheless reasonable to suppose that such a unification would exhibit its strongest effects in the early Universe. Thus, instead of using any particular particle's mass to define the Compton wavelength, cosmologists equate it to a length scale from relativity, the argument being that there must have been a mutual consistency between the various physical factors that define each theory. So they use the radius of curvature associated with a mass so compact that it wraps itself with an event horizon. This radius R_h, formally derived by Karl Schwarzschild (1873–1916), was actually known classically as the radius a mass would need to have in order for the escape speed at its surface to equal the speed of light, so that $c^2/2 = Gm/R_h$, or $R_h = 2Gm/c^2$.

Equating the Compton wavelength to the Schwarzschild radius yields a unique value for m, ie. $m_P = 5\times10^{-8}$ kg, known as the Planck mass. And the Compton wavelength for this mass, known as the Planck length, is therefore $l_P = \lambda_C(m_P) = 10^{-33}$ m, roughly 10^{-20} times the radius of the proton. This is believed to be the smallest distance about which anything can be known. We can also estimate the shortest time interval associated with the Planck scale, essentially the light-crossing time of a Planck length, known as the Planck time, $t_P = l_P/c \approx 10^{-43}$ seconds.

These physical scales constitute the starting point for any discussion of the cosmic spacetime. But notice their dependence on the Schwarzschild radius, which *delimits* the volume of interest. Today we know that the Universe is infinite, so it must always have been infinite, even at the beginning. What relevance, then, can the Schwarzschild radius have to the cosmic spacetime?

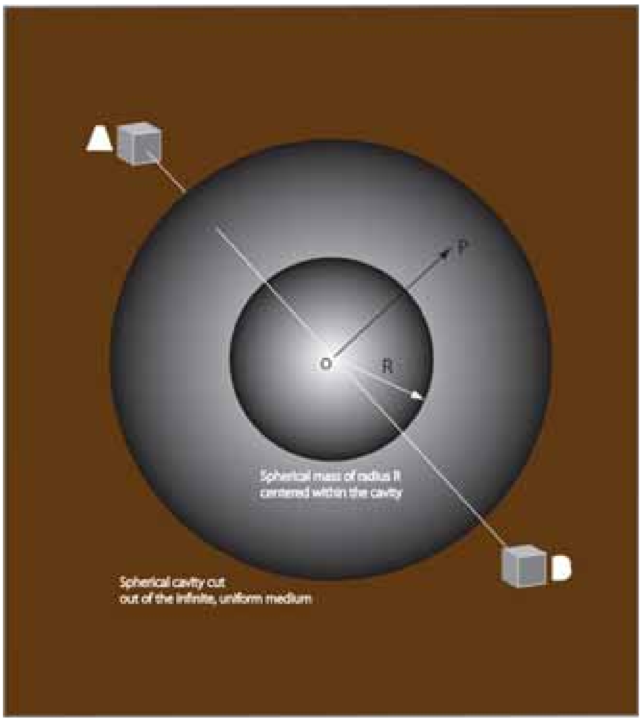


Fig. 3. Spherical mass of proper radius R_S inside a spherical cavity cut out of an otherwise uniform, infinite medium. A and C are two small parcels of mass–energy contributing to the gravitational field inside the cavity.

The Universe's gravitational radius

The answer may be found in a theorem published in 1923 by George David Birkhoff (1884–1944), a preeminent mathematician at Harvard University [1]. Our intuition tells us that because of the Cosmological Principle, an observer must experience zero *net* acceleration from a mass distributed isotropically around him. But in fact the *relative* acceleration between an observer and any other point in the cosmos is not zero; it depends on the mass–energy content between himself and that other point. The Birkhoff theorem, and its corollary, can help us understand the difference between these two viewpoints.

Birkhoff's theorem is a relativistic generalisation of Sir Isaac Newton's (1642–1727) theorem – that the gravitational field outside of a spherically symmetric body is indistinguishable from that of the same mass concentrated at its centre. The corollary to this theorem states that the metric inside a spherical cavity (see Fig. 3) cut out of a uniform medium is equivalent to the flat-space Minkowski metric (ie. a spacetime without any curvature induced by mass–energy). A simple heuristic argument for this result is based on the fact that for every parcel of mass–energy A outside the cavity (Fig. 3), there exists an equal, but opposite, parcel C that – due to the symmetry – completely cancels the effect of the former.

To understand the emergence of a gravitational radius in cosmology, let us now imagine placing an observer at the centre of this spherical cavity (whose proper radius is R_{cav}), and then surrounding her with a spherically-symmetric mass with a surface of proper radius $R_S < R_{cav}$. The metric in the space between the mass and the edge of the cavity is given by the Schwarzschild solution describing the spacetime surrounding a compact mass, and the relative acceleration between the observer and R_S is simply due to the mass, $M(R_S) = V\rho/c^2$, enclosed within this radius, where $V = (4\pi/3)R_S^3$ is the proper volume. If we keep increasing R_S while keeping ρ constant, we eventually reach a threshold of enclosed mass for which R_S becomes the gravitational horizon $R_h = (3c^2/4\pi\rho)^{1/2}$.

Observational cosmology is now in a position to actually measure this radius, but before we consider this, let us first examine several other aspects of the cosmic spacetime, including a rather surprising connection between R_h and the Hubble law.

Dynamics

To fully account for the expansion of the Universe in terms of its constituents we must introduce dynamical equations. We can arrive at the most important of these using the Birkhoff theorem in the Newtonian limit. Known as the Friedmann equation, after Alexander Friedmann (1888–1925), this equation is an expression of the (classical) conservation of energy.

Imagine placing a particle of mass m on the surface of the spherical mass in Fig. 3. Because of the Birkhoff theorem, the behaviour of this particle relative to the observer at the origin is dictated solely by the mass–energy contained within R_S. Classically, the particle's energy is

$$E = \frac{1}{2} m \dot{R}_S^2 - \frac{GM(R_S)\, m}{R_S} \,.$$

Replacing R_S with its Weyl form $R_S = a(t)r_S$, one gets

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3c^2}\rho - \frac{kc^2}{a^2} \,,$$

where k is a constant proportional to the total energy E of the particle. This equation is identical to that formally derived from General Relativity.

The cosmological observations [2] seem to indicate that the Universe is flat, meaning that $k = 0$. However, based on what we now know about k, we conclude that the total energy in the Universe must be exactly zero, since every particle in the cosmos will satisfy the Friedmann equation. The Big Bang somehow separated positive

kinetic energy from negative potential energy, but balanced precisely, lending support to the notion that the Universe began as a quantum fluctuation in vacuum.

Setting $k = 0$, it is easy to see that $R_h = c/H$, another easily recognisable (and observationally important) quantity known as the 'Hubble' radius. Notice in the Hubble law, $\dot{R} = HR$, that the speed of recession reaches c at the radius $R = c/H$, which we now understand is simply the Universe's gravitational horizon R_h. Physicists who study black holes already know that an event horizon approaches an observer in free fall at speed c. And now we recognise the same phenomenon occurring in cosmology, since $\dot{R} = c$ at the Universe's own gravitational horizon R_h.

But here is perhaps the most telling indicator of what the Universe may be doing. Since we now know that $R_h = c/H$, we can determine the Universe's current gravitational radius from the measured Hubble constant $H \approx 70$ km/s/Mpc [3]. Thus, $R_h \approx 13.3$ billion light-years, oddly (one should say, amazingly) close to the estimated maximum distance ct_0 light could have travelled during the time t_0 since the Big Bang, because in the standard model of cosmology (which we will introduce shortly), the estimated age of the Universe is $t_0 \approx 13.7$ billion years. The gravitational radius R_h could have been anything; its apparent equality to ct_0 must be telling us something that we should not ignore. We shall see shortly that the identification of the Hubble radius as the Universe's gravitational horizon unavoidably implies a rather profound conclusion concerning the Universal expansion.

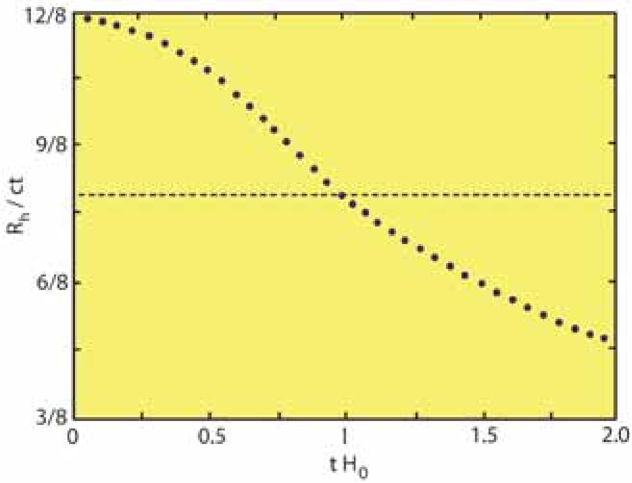


Fig. 4. The Universe's gravitational radius R_h, in units of the distance light could have travelled during a time t, as a function of cosmic time, in units of H_0^{-1}.

"But when we attempt to follow what happened in the earliest moments, we immediately hit a roadblock because General Relativity is a theory of precision, whereas Quantum Mechanics imposes an irreducible fuzziness on any measurement of distance or time."

The $R_h = ct$ Universe

The Weyl postulate compels us to treat every proper distance as the product of the universal expansion factor $a(t)$ and an unchanging co-moving distance r. Therefore, since we defined R_h in terms of the proper volume enclosing the mass $M(R_h)$, the gravitational radius must itself be a proper distance $R_h = a(t)r_h$, where r_h remains constant as the Universe expands. But then $R_h = c\,(a/\dot{a})$, and so $\dot{a}$ itself must be a constant in time. The Weyl postulate thus implies that $a(t) \propto t$, which in turn means that $R_h = ct$ [4].

Could the Universe really be this simple? Well, let's look at the evidence. The standard model of cosmology, known as ΛCDM, is a specific choice of ρ, comprising matter (visible and dark), radiation, and an unknown 'dark energy'. Each of these ingredients changes with $a(t)$ in a different way, so it is not easy to obtain a simple analytic solution for the expansion factor. What is known, however, is that radiation probably dominated early on, whereas matter and – more recently – dark energy, seem to be dominating today. And since $\rho \sim a^{-4}$ for radiation, while $\rho \sim a^{-3}$ for matter, and $\rho \sim$ constant if dark matter were a cosmological constant Λ, one can easily show that $a(t) \sim t^{1/2}$ early on, transitioning to $t^{2/3}$ in the matter-dominated era, and finally becoming an exponential in the future.

The standard model of cosmology therefore predicts quite a complex pattern of behaviour – and yet, through it all, the Universe appears to have undergone just the right amount of deceleration at the beginning, followed

by just a precise amount of acceleration in recent times, in order for it to be left with an observed value of R_h equal to ct_0 today, which is what we would have gotten anyway if the Universe had simply expanded at a constant rate all along. One may chalk this up to mere coincidence, but closer scrutiny shows that this is simply untenable. One can easily calculate the ratio R_h/ct as a function of time (Fig. 4), since we know how ρ changes with $a(t)$. The horizontal dashed line corresponds to the observed value $R_h(t_0)/ct_0 = 1$. Clearly, within the context of ΛCDM, this special condition can be met only once in the entire history of the Universe, *right now*, when we just happen to be looking. Really?

Though one cannot completely rule out such an amazing coincidence, it is far more satisfying philosophically to interpret these observations as meaning that, though ΛCDM may be a workable approximation to the 'real' Universe in some instances, the actual behaviour of the Universe is more in line with the Weyl postulate, which requires that R_h be always equal to ct, and $a(t) \propto t$. This would then explain why we see $R_h(t_0) = ct_0$ today (because these two distances are *always* equal to each other), and it would explain why the physical conditions in the early Universe were consistent with the use of the Schwarzschild radius to balance the Compton wavelength.

Inflation

Several other arguments in favour of the $R_h = ct$ Universe are documented in the references cited at the end of this article. One particular consequence of the $R_h = ct$ condition stands out because it would immediately obviate a major, long-standing problem with the standard model, having to do with cosmology's 30-year (unsuccessful) odyssey with inflation.

The so-called horizon problem in cosmology is viewed as a major shortcoming of the standard model because the Universe seems to have required special initial conditions that are highly improbable. The horizon problem arises from the observed uniformity of the microwave background radiation, which has the same temperature everywhere, save for fluctuations at the level of one part in 100,000. Regions on opposite sides of the sky, the argument goes, lie beyond each other's horizon, yet their present temperature is identical, even though they could not possibly have ever been in thermal equilibrium.

This deficiency of the standard model is best understood with the diagram in Fig. 5. Within the context of ΛCDM, one can solve for $a(t)$ and determine the trajectories of light reaching the observer. With reference to elements

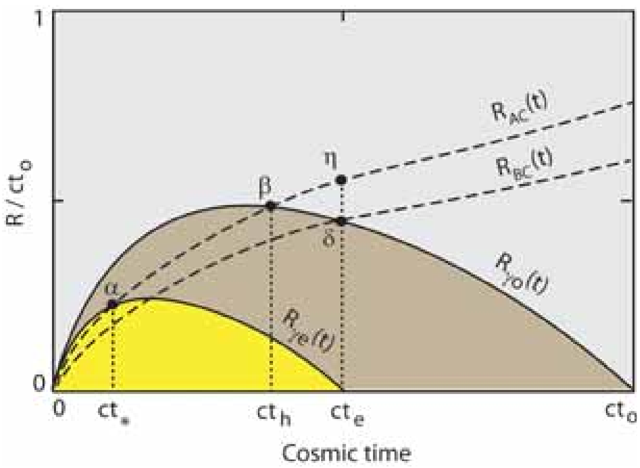


Fig. 5. Proper distance for light $R_{\gamma o}$ and $R_{\gamma e}$, approaching the observer C (in Fig. 2) at times t_o and t_e, respectively, as a function of cosmic time, together with the proper distances (relative to C) of sources A and B as functions of this same *t*.

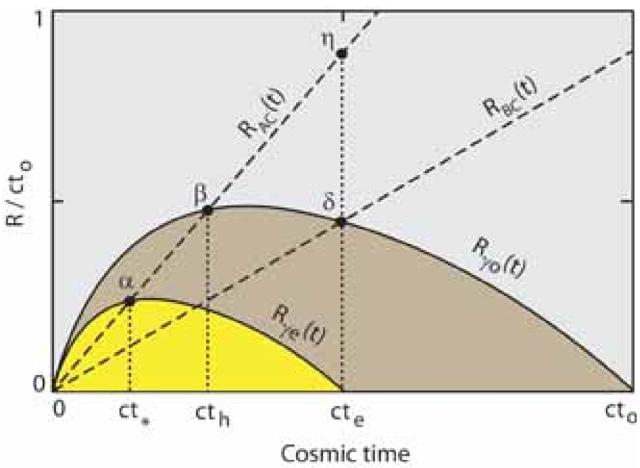


Fig. 6. Same as Fig. 5, except for the case of the $R_h = ct$ Universe. Note that here $R_{AC}(t_e) = 2R_{BC}(t_e)$, which means that A and C (in Fig. 2) were equidistant from us (in B) at the time they emitted the light we see today as the cosmic microwave background radiation.

A, B and C in Fig. 2, this diagram shows which sources (A or B) could have emitted light at specific times (corresponding to, say, points α and δ) that reaches C at either time t_e or t_o. From our perspective in B, we see light emitted by A and C at time t_e, when they were apparently in equilibrium. Therefore, light emitted by one of them, say A at time t_*, must have reached the other by the time t_e they produced the cosmic microwave background we see today at time t_o. But in ΛCDM, the deceleration that occurred following the Big Bang would have made it impossible for R_{AB} to have been equal to R_{BC} at t_e.

So serious has this shortcoming become that the inflationary model of cosmology [5] was invented to resolve

“What is known, however, is that radiation probably dominated early on, whereas matter and – more recently – dark energy, seem to be dominating today.”

this possible discrepancy. In this picture, an inflationary spurt occurred at 10^{-35} seconds following the Big Bang, carrying causally connected regions beyond the horizon each would have had in the absence of this temporary acceleration.

But after three decades of struggling with this ‘fix’, it is now clear that inflation may not be the solution after all. The idea of inflation is itself fraught with many apparently insurmountable problems. For example, monopoles should have been produced copiously in Grand Unified Theories at high temperature in the early Universe, and should be so prevalent today that they should be the primary constituent of the Universe. Yet they have never been found.

The $R_h = ct$ Universe easily resolves this issue because it completely does away with the so-called horizon problem [6]. This simple Universe therefore does not need inflation to have occurred. To understand why, we need to consider the diagram shown in Fig. 6. The principal difference between the two cases is that, here, there was no early deceleration in the Universe, and therefore it was possible for $R_{AB}(t_e) = R_{BC}(t_e)$, while still maintaining causal contact between A and C before they emitted the light we see today.

Conclusion

The observed equality between R_h and ct today may be hinting at a great simplification to our view of the Universe. In fact, the Cosmological Principle and Weyl’s postulate together require a constant expansion rate $a(t) \propto t$. With this simplification, we inherit several significant improvements to our understanding of how the Universe began and how it has evolved to this day. We understand why the Schwarzschild radius was relevant to the early Universe (because it is always relevant), we understand why $R_h = ct$ today (because they are always equal), and we can understand how the Universe could have functioned without inflation, an idea that has never quite solidified into a fully consistent theory. How simple. Who would have thought?

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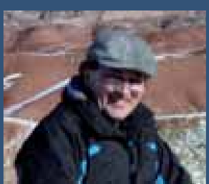
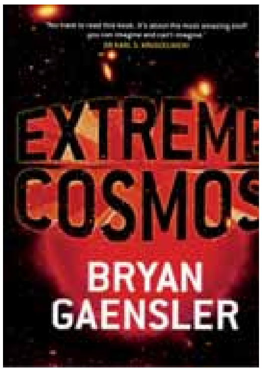


AUTHOR BIO

Fulvio Melia is Professor of Physics, Astronomy, and the Applied Math Program at the University of Arizona, in Tucson, and John Woodruff Simpson Fellow at Amherst College, a chair formerly held by the Nobel Laureate Niels Bohr and noted American poet Robert Frost. Born in Gorizia, Italy, he was raised in Melbourne and received his BSc and MSc degrees from Melbourne University. He completed his graduate studies at the Massachusetts Institute of Technology, receiving a PhD in Physics. Since then, he has been a Presidential Young Investigator (under Ronald Reagan) and an Alfred P. Sloan Research Fellow. He has published over 250 journal articles in high-energy astrophysics, including topics on black holes, relativistic matter, and cosmology. He is also the author of six books, most recently *Cracking the Einstein Code*, the story of how New Zealander Roy Kerr and his colleagues finally managed to solve Einstein’s equations of General Relativity.



Extreme Cosmos

By Bryan Gaensler
New South Books, Sydney, 2011, 202 pp.
ISBN 978-1-74-22111-2
Reviewed by Bart Pindor, Astrophysics Group, University of Melbourne

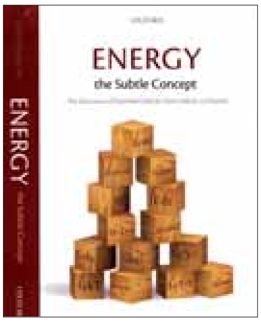
'Extreme Cosmos' is the first popular science book by Bryan Gaensler, a Professor of Astronomy at the University of Sydney. Gaensler is the director of the ARC Centre of Excellence in All-sky Astronomy, has been on the Harvard faculty, and even found time to be named Young Australian of the Year in 1999. As a scientist, his research interests include studying polarised radio emission, a subject which even many professional astronomers find technically challenging. How does this impressive pedigree translate to the somewhat different task of science popularisation? The answer is very nicely, thank you very much.

'Extreme Cosmos' does what it promises; in ten chapters Gaensler surveys the extreme examples of ten different physical quantities in the Universe. Obvious choices like mass and size are covered, but so are more obscure ones like magnetic fields and sound. In each case, our familiar terrestrial experiences with these phenomena are used as a starting point for a tour through increasingly extreme cosmic environments. It is here that 'Extreme Cosmos' is at its best; rather than rushing through to unmask each cosmic record-holder, Gaensler takes his time to digress and dwell upon the menagerie of fascinating astrophysical tidbits which his story happens across. Cosmology, nuclear physics, and stellar evolution all get a star turn providing interesting twists in the cosmic plot.

Gaensler's exemplary familiarity with the field is on display here as numerous cutting-edge discoveries are mixed in with the well-known textbook results, so as to give the book a very contemporary feel. Interestingly, following perhaps the advice of the sales department, the book has no equations and also foregoes scientific notation. While this does sometimes give a more 'human' feel to the unavoidable astronomical numbers in question, it leads to lots of 'hundreds of millions' and 'billion trillions' which eventually begin to all look rather alike.

The book is nicely illustrated with a glossy inset of 40 colour figures. Many of these have been very well chosen to complement the text; the eerie blackness of Barnard 68 makes a strong impression, as does the truly striking image of Mira literally streaking across the sky. However, one minor shortcoming is that the book does not contain any original illustrations; a well-designed diagram is one of the joys of a good science book.

As a final recommendation, a technically-minded non-scientist friend of mine happened to peruse my copy during a lengthy drive along the Western Highway. Despite having a very serviceable fantasy novel on hand as an alternative, he instead chose to read several chapters of 'Extreme Cosmos', declaring it to be 'very interesting'. A sample size of one, perhaps, but I expect most members of Bryan Gaensler's target audience will find his book good company.



Energy: The Subtle Concept

By Jennifer Coopersmith
Oxford University Press, 2010, 400 pp.
ISBN 978-0-19-954650-3
Reviewed by Charles Jenkins, CSIRO Earth Sciences & Resource Engineering, Canberra

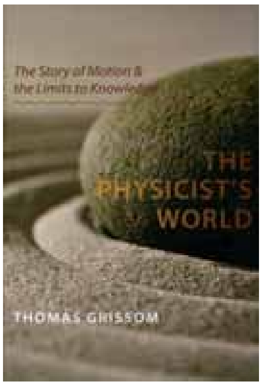
This book makes me proud to be a physicist, for two reasons. First it is a tale of the giants of the past who contributed to our present understanding of energy, people whose astonishing intuition took them from gossamer clues to the understanding we have today of one of the most basic explanatory concepts in physics. We've had some pretty good players in 'our team'. More than this – and this is the second reason – this is a story as much about invention as discovery. Coopersmith emphasises again and again that energy wasn't just lying there, waiting to be discovered. It was a concept that had to be conjured into existence by successive generations of scientists, sometimes arriving at modern ideas by very unfamiliar routes; and also, arriving at modern ideas again and again at the wrong time to be heard.

Starting with Bernoulli and Priestley, at least four scientists (too early to call them 'physicists') had the essence of the kinetic theory of gases before Maxwell had the idea at the right time. Part of the reason for this is perhaps that many important concepts were arrived at by (to us) strange and diverse routes: consider Helmholtz, writing his landmark paper on the conservation of energy, reasoning from Kant's transcendental idealism.

Coopersmith weaves history, personalities and physics together in a fascinating pattern as we journey from Aristotle to Schrödinger. I am not enough of a historian to judge the book from this perspective, but the story seems complicated, amusing, and muddled enough to be es-

sentially true. The physics is always fascinating, although sometimes covered a little too quickly to be clear, and with a few small errors. But if all the physics were spelt out in detail, this book would run to many volumes, and the treatment admirably backs up the history. As for the personalities, my favourite would have to be the flamboyant Count Rumford. The blind Euler – dictating 'Elements of Algebra' to his tailor – would be a close second.

I am sure all physicists would enjoy this book and indeed learn from it. 'Energy: The Subtle Concept' would also be an excellent resource in the history and especially philosophy of science.



The Physicist's World: The Story of Motion and the Limits to Knowledge

By Thomas Grissom
Johns Hopkins University Press, Baltimore, 2011, 300 pp.
ISBN 978-1-4214-0084-6 (paperback)
Reviewed by Don Koks, DSTO, Adelaide

This book is based on a course given to liberal arts students, and I've reviewed it with that audience in mind. Its stated aim is to teach a broad sweep of physics with almost no mathematics, to give a taste of the subject to non-physicists wishing to expand their horizons.

The first 65 pages describe the physical world as seen through the eyes of the ancient Greeks. I found this arduous to read, and welcomed the discussion that followed of how the drifting calendar was fixed, marking the beginning of the modern physics story. Even so, after those 65 pages, I was disappointed to find that a description of the epochal work of Brahe and Kepler is relegated to a single paragraph.

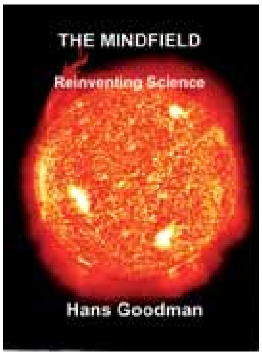
Galileo and Newton next appear in more detail to introduce the concepts of mass and force, which I thought the book analyses well. The remaining chapters discuss the core subjects of physics, and include a chapter on chaos theory that explains the standard concepts in a solid way. However, elsewhere I disagreed outright with the author, partly because I think he takes at extreme face value the idea that physics is all about measurement. Yes, there are measurements, but then there are naïve measurements. For example, he describes the changing time *seen* by a single observer on the face of a moving clock, and concludes that this gives rise to special relativity, even though his argument is non-relativistic. That is, he paints relativity as being nothing more than the non-relativistic Doppler Effect dressed up in fine clothes. After a century of relativity, this apparently common misconception should surely no longer appear in books.

Grissom adds that because we see all events in the past, "For us there is literally no present". Literally? But the notion of a 'present' is fundamental to physics. Similarly baffling is: "General relativity tells us that we are confined to the past in our knowledge of the Universe". Likewise, I felt he trivialised space–time by describing it as (simply) the manifestation of ascribing a time to each event. Space–time is much more than this; it rests on the fact that all observers agree on the 'interval', which can then be viewed as giving space–time an independent reality of the sort that he often maintains barely exists in physics.

Grissom describes the Second Law of Thermodynamics as having no deeper basis than the demand that only entropy-increasing processes are allowed. Not so: the deeper basis is statistical mechanics, which makes utterly no demands on entropy; its observed global increase is simply a numbers game. Picture an imaginary fly that moves randomly, escaping from a thimble into the Universe at large. Though allowed to return to the thimble, to all intents and purposes it never will. The marvel is that statistical mechanics does *not* prescribe rules of what is allowed, and yet what results is a coherent description of thermodynamics and the flow of time. That would surely fascinate the reader more than a simple, but wrong, statement demanding that entropy must increase over time.

Elsewhere, the Heisenberg Uncertainty Principle is described as saying we cannot know an object's position and momentum simultaneously. No; the principle says that an object's position and momentum simply *don't exist* simultaneously. Physicists are aware that there is a big difference between these two concepts, but it's the first and incorrect one that is commonly found in books for non-physicists and which might already be believed by the book's audience. Unfortunately, this book will not be correcting their view.

'The Physicist's World' is not a book for physicists (unless they like Greek philosophy), and while we can applaud an attempt to explain physics to non-physicists, I don't think this book does justice to the topic. At its end, I felt that readers might well be left thinking that physicists have constructed their immense world view using perfunctory arguments that take the world at face value. And as a physicist, I know that not to be true at all.



The Mindfield: Reinventing Science

By Hans Goodman
Ibis Books, 2009, 138 pp.
ISBN 978-0-95-773426-5
Reviewed by Lee Weissel, Wagga Wagga Christian College

This work, although short, is quite confronting in its scope in what it attempts to do. Hans Goodman is a retired electrical engineer whose own journey into understanding the paradoxes of physics led to a formulation of an old understanding wrapped in a new guise. Goodman begins his premise by seeking to understand what gravity is and how it works. Not content to simply impose a 'magical' understanding of forces he revisits the history of our current understanding of gravity and the major contributors to this. It begins to read a little like a senior high school summary, until it reaches the interesting experiment of Michelson and Morley and their attempted aether measurement.

Goodman argues that the usual interpretation leading to the alternative of Einstein's relativity was too quick and flawed. He suggests, and illustrates using a cup of coffee as a metaphor for the solar rotations of the planets, that the Earth is moving through a Universe filled with extremely small particles which create an all pervasive compressible fluid that he calls 'magna'. This name is used to help designate some of their later prescribed properties. Goodman suggests that these particles are extremely small which is why previous experiments have failed to detect this magna. He does provide possible experimental ideas in order to test his theory for the existence of this universal magna.

Using this concept Goodman spends the remainder of the book reinterpreting the major fundamental ideas in physics from gravity to magnetism, to electricity, and to electromagnetic radiation, atomic structure, quantum mechanics and cosmology. Each area is critiqued, with various questions raised before a new understanding is put forward using the magna concept. The scope of the work is indeed grand, nothing short of a reinterpretation of science, and is easily accessible by using the basic concepts related without mathematics in an easy reading style.

As a reader of the book, one can feel a little like being naughty questioning some of the greatest scientific minds, but I suspect that this is the real strength of the work. As we teach these concepts in classrooms and lecture theatres, this book should rightly ask us as teachers where does our questioning end, and what do we require our students simply to accept.

'The Mindfield: Reinventing Science' however lacks the depth of research beyond a first year undergraduate understanding of physics and some general reading, so questions such as how does Quantum Electrodynamics theory fit into this picture have not been addressed. Nor has the Standard Model of matter been tackled, even though there is some potential resonance with it in the use of the magna. The book is though a generally good read.

David Caro (1922 – 2011)

Rod Home

Born in Melbourne on 29 June 1922, David Edmund Caro attended Geelong Grammar School and in 1940 enrolled at the University of Melbourne. During his second year, however, he joined the RAAF, where he and other recruits who knew some physics were introduced to one of the great secrets of WWII – radar. Caro learned a lot about electronics while installing and maintaining radar equipment around Australia and in the islands.

In 1946 he returned to university. After completing his BSc, he undertook a Master's degree under Philip Law, soon to become leader of Australia's Antarctic program, building equipment for measuring cosmic rays in Antarctica. The work led to several publications and an 1851 Exhibition scholarship that in 1949 took Caro to the University of Birmingham, where Marcus Oliphant was overseeing the construction of the world's first proton synchrotron. For his PhD, Caro worked on the radio-frequency electronics that were to drive this.

Caro returned in 1952 to the University of Melbourne, where he proved an excellent lecturer, adept at making complex ideas comprehensible. His experience in Birmingham made him an obvious choice to lead the university's project to build an innovative variable-energy cyclotron. Once completed, this machine gave several generations of postgraduate students excellent experience in nuclear physics research. Caro himself, however, never developed a research program that utilised it. For him, as for Oliphant, the fascination lay in building a machine that worked.

In 1961 Caro became Professor of Experimental Physics and Head of Department. He was an excellent, democratically-minded administrator. New appointments reinvigorated the department, the curriculum was overhauled, and in time a new building – now known as the David Caro Building – provided more satisfactory accommodation.

Caro joined the department's High-Energy Physics group that was running an experiment on the Brookhaven proton synchrotron. This generated hundreds of thousands of bubble-chamber photographs that were brought back to Melbourne for analysis. Caro worked to develop computer-based machines to measure tracks automatically.

In 1972 Caro became Melbourne's Deputy Vice-Chancellor. Then from 1978 to 1982 he was Vice-Chancellor of the University of Tasmania, where he negotiated a successful merger between the University and the Tasmanian College of Advanced Education. Concerned by problems in the University's superannuation scheme, Caro became a leader in the creation of the nation-wide scheme, Unisuper, and served for ten years as Chairman. Thousands of university employees owe him an enormous debt for the retirement funding that the scheme provides them. In 1979, Caro became chairman of the Government's Antarctic Research Policy Advisory Committee. Under his leadership, the committee laid the foundations of Australia's current Antarctic program. Caro himself visited Antarctica twice.

Caro returned to the University of Melbourne in 1982 as Vice-Chancellor. He again proved a strong leader, strongly supporting centralised services such as the Computer Centre and the University Library. He was notably accessible – he regularly appeared in the lunch queue at the university staff club – and committed to a collegial approach to university administration that kept staff morale high even as government funding declined.

Caro retired in 1987 but his advice was much sought after by other higher-education institutions that were being transformed into universities during this period. All of them benefited from his wisdom, born of long experience of university administration and his capacity for strategic analysis informed by a clear vision of what a university should be.

David Caro passed away on 15 August 2011. He is survived by his wife Fiona (née Macleod), who he married in 1954, their children Richard and Catriona, and their granddaughter Marguerite.

Rod Home is Emeritus Professor of History and Philosophy of Science at the University of Melbourne.

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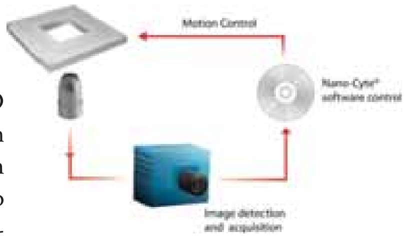

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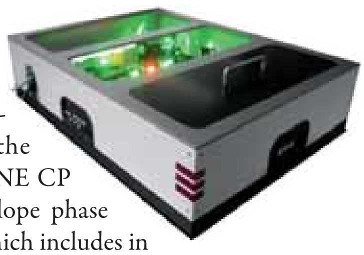

Based on Venteon's Octave-Spanning (OS) Edition the VENTEON | PULSE : ONE CP is a complete carrier envelope phase (CEP) stabilised system, which includes in addition to our octave-spanning oscillator an f-to-2f interferometer for generating the required fCEO beat signal with excellent signal-to-noise ratio and all necessary stabilisation and control electronics.

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The identical pulses feature a CE timing jitter of less than 100 as. The stability is high enough to allow for a perfect interference contrast of more than 10^{-11} pulses.

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- Average output power (stabilised) >150 mW
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- CEP-lock without additional spectral broadening
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Energetiq is a developer and manufacturer of advanced light sources that enable the manufacture and analysis of nano-scale structures and products. Used in complex scientific and engineering applications, Energetiq's light products are based on new technology that generates high brightness and high power light in the 1–1000 nm range with high reliability, high stability, and long life, all in a compact package.

Energetiq's innovative LDLS™ technology uses a CW laser to directly heat a xenon plasma to the high temperatures necessary for efficient deep ultraviolet production. In traditional approaches such as arc and deuterium lamps, the brightness, UV power, and lamp lifetime are limited by the use of electrodes to couple power to the plasma. The electrode-less LDLS technology creates small, high brightness plasma that allows efficient light collection, broad spectral range from the deepest UV through visible and beyond, and long lamp life. LDLS™ Laser-Driven Light Source enables extreme high brightness over a broad spectral range, from 170 to 2100 nm, combined with lifetimes an order of magnitude longer than traditional lamps.

Features and benefits:

- CW laser plasma discharge
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Warsash Scientific delivers even greater flexibility for sintering conductive Cu and Ag metallic inks, curing thin-film substrates and for solar and surface modifications with the Sinteron 2010 from Xenon Corporation. The new **Sinteron 2010** now allows for digitally programmable pulse widths, making it extremely flexible and valuable to process development.

A number of attractive features are designed into this 19 inch rack-based stand-alone system. The pulse width is adjustable in increments of 5 μs in the range 100 to 2000 μs. With total control of the pulse amplitude and pulse width, the optical energy delivered by the system can be precisely controlled. As the pulse profile is very linear at maximum amplitude, a relationship of 1000 J/ms can be assumed. The **Sinteron 2010** allows connection for either Spiral or Linear Lamp housings. These can provide optical footprints of 19×305 mm or 127 mm diameter areas.

Sinteron 2010 is welcome news for those involved in photonic sintering of conductive inks for printed electronics in areas such as displays, smart cards, RFID and solar applications. The non-contact, low thermal characteristics for this process make it suitable for web-based printing techniques such as inkjet, flexography, gravure, and screen print.

In addition to offering sintering systems for the printed electronics industry (making it possible to print, at room temperature, on substrates such as paper and PET), Warsash Scientific offers high performance pulsed UV systems for decontamination, UV curing and food enhancement.

Fast Piezo Focusing Systems for Microscopy

Warsash Scientific offers a more affordable series of fast piezo focusing devices with the new PIFOC system packages from PI. These packages are designed to improve results in fast focussing and lens positioning, as well as in deconvolution/3D imaging, and reduce costs at the same time.

System packages consist of closed-loop, piezo-mechanic objective positioners and custom-tuned, compact digital servo controller/driver units. This combination provides higher performance at reduced costs. The integrated, frictionless and high-stiffness piezo flexure drive ensures fast response and short settling times, as well as exceptional guiding accuracy. The settling time of less than 10 ms increases throughput and allows for rapid Z-stack acquisition.

The digital controller provides several advantages compared with the conventional analogue controllers of the fast focussing systems currently available. Higher linearity, improved settling performance, quick adaptation to changing motion requirements and access to advanced automation are all benefits.

The included software facilitates system setup and allows swift switching between different sets of parameters. For the user this means extracting the maximum performance from the piezo focusing mechanism all the time, no matter what size objective is used or whether aggressive long-travel stepping or smooth nanometre size dithering motion is needed. Since jumpers and trim pots no longer have to be accessed to make changes, system integration becomes much more straightforward.

Key features:

- Complete and affordable system with fast digital controller and software
- Choice of travel ranges: 100, 250 or 400 μm
- Ideal for fast autofocus applications
- Sub-nm resolution
- Choice of position feedback sensors: piezoresistive or capacitive
- Improved performance and easy system integration.

M-660: Low Profile Rotation Stage

One of the lowest profile rotary tables on the market, the M-660, available from Warsash Scientific, is now complemented by a higher performing model providing more than eight times the position resolution of the existing version.

The compact design with minimised mass and inertia provides high precision, bidirectional speed and position control, as well as high speed motion contouring. The M-660 is based on the new U-164 Piezo Motor and outperforms the stability, acceleration and settling speed of traditional servo motor direct drives and gear-driven mechanisms. The innovative motor drive can provide significantly higher speeds, shorter positioning times and a very high positioning accuracy when moving the measuring optics.

The stage can accelerate to velocities of 720 degrees/sec and resolves positions down to 4 μrad (8 arcsec). Its self-clamping

ceramic drive provides very high stability, with no energy consumption at rest and no heat generation. A directly coupled precision optical encoder provides phase lag-free, backlash-free feedback to the servo controller.

The newly designed piezo motor controller is available to take advantage of the specific motion characteristics of ultrasonic ceramic motors. USB interfacing and a solid software and driver package for seamless integration are included.

For datasheets and more information on all three products, please contact Warsash Scientific at sales@warsash.com.au
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COHERENT SCIENTIFIC

Fibre Laser for Atom Cooling

Quantel has released the EYLSA 780 fibre laser designed specifically for rubidium atom cooling.

EYLSA is a single-frequency laser delivering 1 W at 780 nm with linewidth less than 2.5 MHz (200 kHz option is also available). The wavelength is tunable over a 100 GHz range covering both the Rb-85 and Rb-87 D2 lines. A wavelength locking control loop is included and may be connected to a commercially available PID device.

The EYLSA laser comes in a compact package with 19-inch rackmount and touchscreen control.

Fully Automated, Ultrashort Pulse Ti:Sapphire Laser

Coherent's Vitara is the first widely tunable, ultrafast laser to deliver pulsewidths shorter than 12 fs, while also offering true hands-free and fully automated operation. This includes automated wavelength tuning from 755 to 860 nm and push-button bandwidth adjustment from 30 to 125 nm.

The Vitara family has recently been expanded with the addition of Vitara-S, a cost-effective model designed specifically for seeding Coherent's range of Legend Elite ultrafast amplifiers. Vitara-S delivers bandwidth of over 70 nm at a fixed wavelength of 800 nm.

The Vitara-T and Vitara-T-HP are available for applications requiring higher power.

Verdi G Series Lasers Now Available with 18 W Output

Coherent's Verdi G series is a family of optically pumped semiconductor lasers, where the traditional rod-based gain material is replaced with a semiconductor chip. The result is a compact, robust and economical product with noise specifications identical to the original Verdi V. The Verdi G series is ideal for Ti:Sapphire pumping and other applications that do not require single longitudinal mode output.

Verdi G series is now available with new high-power options of 12, 15 and 18 W. All Verdi G lasers come with a two-year comprehensive warranty and trade-ins are available for existing solid-state lasers or ion lasers (dead or alive!).

Fianium Introduce Compact, Low-cost Supercontinuum Laser

Fianium has released its newly designed, WhiteLase micro™ supercontinuum source at the recent Photonics West exhibit. WhiteLase micro is a quasi-CW laser producing total power of more than 200 mW over the wavelength range 450 to 2000 nm. The beam may be easily collimated and focused to a diffraction-limited spot for use in a variety of applications. The unit is simple to operate and may be used with Fianium's SuperChrome and AOTF filters for programmable wavelength selection.

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High Resolution Wide Bandwidth Arbitrary Waveform Generator

Agilent Technologies has added a high-resolution, wide-bandwidth, 8- or 12-GSa/s modular instrument to its portfolio of arbitrary waveform generators. The new M8190A arbitrary waveform generator is able to deliver simultaneous high resolution and wide bandwidth along with spurious-free dynamic range and very low harmonic distortion.

This functionality allows radar, satellite and electronic warfare device designers to make reliable, repeatable measurements and create highly realistic signal scenarios to test their products.

The M8190A helps engineers:

- build a strong foundation for highly reliable satellite communications
- generate multilevel signals with programmable ISI and jitter up to 3 Gb/s.

The M8190A offers:

- 14 bits of resolution and up to 5 GHz of analog bandwidth per channel simultaneously
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- reduced system size, weight and footprint with compact modular AXIe AWG capability.

The high performance of the M8190A arbitrary waveform generator is made possible by a proprietary digital-to-analog converter (DAC) designed by the Agilent Measurement Research Lab. Fabricated with an advanced silicon–germanium BiCMOS process, the DAC operates at 8 GSa/s with 14-bit resolution and at 12 GSa/s with 12-bit resolution. At 8 GSa/s, the Agilent DAC delivers up to 80c-dB SFDR.

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Agilent U1084A is a dual-channel, 8-bit PCIe digitiser with up to 4 GS/s sampling rates, 1.5 GHz bandwidth and incorporates a 15 ps trigger time interpolator for accurate timing measurement.

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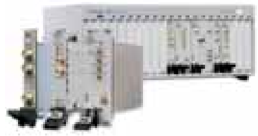
More information is available at www.agilent.com.au/find/u1084a.

One Box EMI Receiver that Enhances Compliance Testing



Agilent Technologies has announced the introduction of the N9038A MXE EMI receiver, which is designed for laboratories that perform compliance testing of electrical and electronic products. The MXE enhances electromagnetic interference (EMI) measurement accuracy and repeatability with a displayed average noise level of -163 dBm at 1 GHz. This represents excellent input sensitivity, an essential receiver attribute that reduces the effects of electrical noise.

The MXE is fully compliant with CISPR 16-1-1 2010, the International Electrotechnical Commission recommendation that covers measurement receivers used to test conducted and radiated electromagnetic compatibility of electrical and electronic devices. With outstanding measurement accuracy of ±0.78 dB, the MXE exceeds CISPR 16-*1*-1 2010 requirements.

The built-in suite of diagnostic tools, including meters, signal and measurement lists, markers, span zoom, zone span and spectrogram displays, makes it easy to monitor and investigate problem signals. The MXE is also an X-Series signal analyser capable of running a variety of measurement applications such as phase noise. By enhancing the analysis of noncompliant emissions, these capabilities enable EMI test engineers and consultants to evaluate signal details and deliver new insights about the products they test.

More information is available at www.agilent.com.au/find/MXE.
For further details, contact tm_ap@agilent.com.
Agilent Technologies Australia Pty Ltd
Tel: 1800 629 485
Web: www.agilent.com.au/find/promotion

CONFERENCES IN AUSTRALIA 2012

4 – 11 July 2012
Thirty-sixth International Conference on High Energy Physics, ICHEP2012
Melbourne Convention and Exhibition Centre, VIC

30 July – 3 August 2012
ANU Nuclei in the Cosmos Winter School
ANU, Canberra, ACT

5 – 10 August 2012
Nuclei in the Cosmos 2012
Cairns Convention Centre, QLD

12 – 17 August 2012
Seventy-fifth Annual Meeting of the Meteoritical Society
Cairns Convention Centre, QLD

23 – 28 September 2012
Thirty-seventh International Conference on Infrared, Millimetre and Terahertz Waves
Wollongong, NSW

25 – 28 September 2012
Twentieth International Workshop on Electron Cyclotron Resonance Ion Sources (ECRIS 2012)
Darling Harbour, Sydney, NSW

16 – 19 October 2012
Twelfth Conference of the South Pacific Environmental Radioactivity Association (SPERA 2012)
ANSTO, Lucas Heights, NSW

18 – 23 November 2012
Fifteenth International Conference on Small-angle Scattering, SAS 2012
Sydney, NSW

2 – 5 December 2012
Joint Meeting of the Asian Crystallographic Association (AsCA) and the Society of Crystallographers in Australia and New Zealand (SCANZ)
Adelaide Convention Centre, SA

2 – 6 December 2012
Engineering & Physical Sciences in Medicine Conference (EPSM 2012)
Gold Coast, QLD

6 December 2012
Bragg Symposium: Celebrating 100 Years of Crystallography
University of Adelaide, SA

9 – 13 December 2012
Twentieth Australian Institute of Physics Congress
University of NSW, Sydney, NSW

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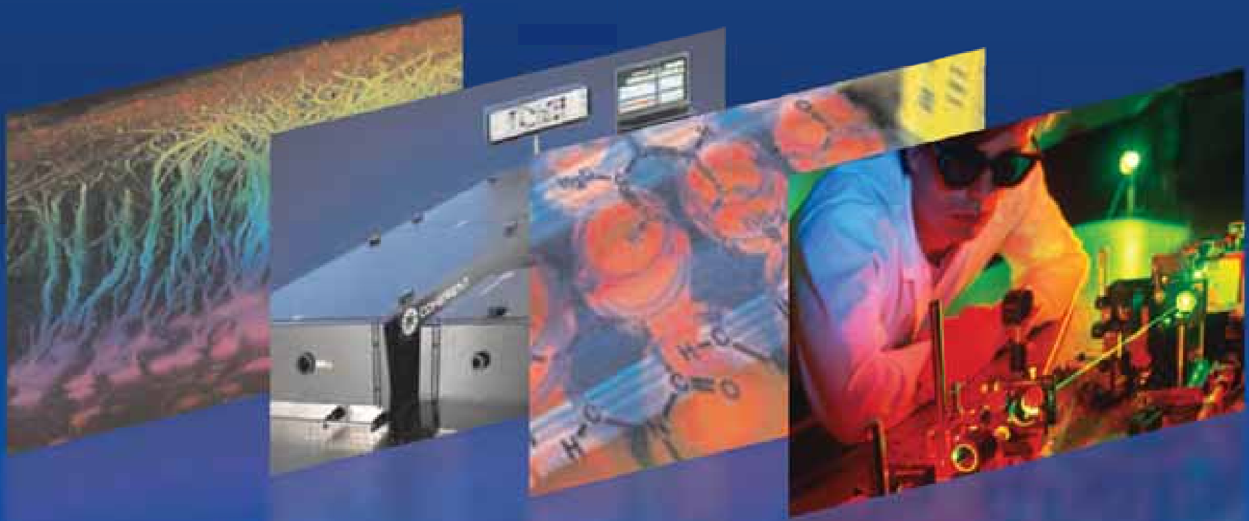

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