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CONTENTS

6 Editorial
Welcome to Aust Phys 2015!

7 President’s Column
A Look Back Over the Last Two Years

8 News & Comment

9 Branch News

10 Report on 2014 women in physics tour

11 Images from 21st AIP Congress

12 What is IUPAP?

13 The Murchison Widefield Array delivers for Australian astrophysics
Stephen Tingay

18 3D X-ray art

23 Aleksandr Prokhorov, Australian-born Nobel laureate in physics
Stephen Collins

25 Samplings
Physics news that caught the eye of the editor

28 Book reviews
Greg LeBlanc reviews Engines of Discovery: A Century of Particle Accelerators by Andrew M. Sessler and Edmund Wilson
Peter Robertson reviews A Single Sky: How an International Community forged the Science of Radio Astronomy by David P.D. Munns

29 Conferences

30 Product Reviews
New products from Coherent Scientific, Lastek, and Warsash Scientific.

33 Obituary: Arthur William Pryor 1928-2014

34 Obituary: John Gilbert Greenhill 1933-2014
EDITORIAL

Welcome to Aust Phys 2015!

Welcome to the first issue of Australian Physics for 2015. On page 11 there is a selection images from the 21st AIP Congress held at the ANU 7-11 December 2014. I enjoyed attending, this time as editor, as this large gathering of Australian physicists provides a happy hunting ground for potential authors of articles for Australian Physics.

An important event at the Congress was the revival of the AIP’s Women in Physics (WIP) group, with Helen Maynard-Casely elected as chair. On WIP matters, this issue contains a report on the 2014 WIP lecture tour by Prof Sheila Rowan (University of Glasgow) and also a call for nominations for the 2015 WIP lecturer.

The first article, The Murchison Widefield Array delivers for Australian astrophysics, by Steven Tingay describes early science results from the Murchison Widefield Array (MWA), which is paving the way for the 50 times larger SKA-low, the low frequency component of the SKA.

The second article, 3D X-ray art by Erica Secombe and Vanessa Robins continues the theme of the 2014 AIP Congress, The Art of Physics. I expect to publish at least one more article on this theme during the year. To quote from Erica and Vanessa’s article: There is no doubt Science is the new black in Art!

As 2014 has been designated the International Year of Light and Light-based Technologies, it is timely to note that 2016 is the centenary of the birth near Atherton, Queensland, of Aleksandr Prokhorov, who shared with Nicolay Basov and Charles Townes the Nobel Prize for Physics in 1964 - for fundamental work in quantum electronics that led to masers and lasers. The fascinating story of the circumstances that led to his birth and early school education in Australia is recounted by Stephen Collins in his article Aleksandr Prokhorov, Australian-born Nobel Laureate in physics.

What is IUPAP – the International Union of Pure and Applied Physics – and what does it do? With Prof Bruce McKellar (University of Melbourne) starting a three-year term as president I felt it appropriate to include a short explainer about IUPAP. I see the provision of such information to be an important role for Australian Physics, and would welcome suggestions for other topics. Based on my own, at least partial, ignorance, I have a few in mind!

Brian James
A Look Back Over the Last Two Years

This will be my final column as President of the Institute, as I hand over to Warrick Couch, who will succeed me as President following the Council Meeting and Annual General Meeting in Melbourne in early February 2015. Warrick will be joined by Andrew Peele, from the Australian Synchrotron, as the incoming Vice-President. I wish them both well in representing us as members and in advancing the goals of the society. As I said at the Congress dinner in Canberra, it has been a huge privilege to serve you, our members, as President over the last two years, and I thought I might use this column to reflect on what we have achieved over the last two years.

The first major thing relates to the viability of the Institute and the service that it gives to the members. Most professional societies are struggling with falling membership rolls and that has been an issue for AIP. There is some evidence that we may have now turned the trend around. A key decision that we made around a year ago was to change our back-office service provider to Professional and Management Services (PAMS), a Melbourne-based company whose core business is association management. I’m sure that many of you will have opinions on this change, especially with the current round of membership renewals, so please let us know what you think. The feedback so far from within your Executive, and from the state branches, has been pretty good. We are also thinking of outsourcing our website, rather than doing it ourselves, through volunteers. That change, if it takes place, could be within the coming year. I would strongly urge you to make sure that you do renew, and also to encourage your colleagues, students and physicists into this. One of the ways that you can do this is to encourage your colleagues to join (and participate in) the Institute and its activities. We are also “cleaning up” our membership categories to make it easier for students, and physicists employed in other parts of the economy, play a role in the Institute and not feel like “second-class citizens.” In the end, higher membership levels will ensure that we can afford to do all of these things and to offer better services to our members.

A second thing is engagement with our physics colleagues in Asia. Early in my term, we made a pitch to bring the major pan-Asian physics conference to Australia. This was successful, and the net result is that the “13th Asia-Pacific Physics Conference and 22nd Australian Institute of Physics Congress” will be held as a joint meeting between 4th and 8th December 2016, in Brisbane. This will be under the chair(s) of Halina Rubinsztein-Dunlop and Warrick Couch. The conference will inevitably have a slightly different flavour compared with our normal Congress, and I would encourage everyone (along with our collaborators in other Asian countries) to come and participate. I also serve on the Council of the Association of Asia-Pacific Physics Societies, and have recently joined the Editorial Board for the AAPP Magazine. My own belief is that the current trend towards intra-regional science collaboration in the Asia-Pacific region is an irreversible tide of history, and that we should be trying to influence how it evolves – things will inevitably evolve in a way different from that in Europe and North America.

We have also succeeded in revitalising our Women in Physics Group. Not only did we send three of our members to the IUPAP International Conference on Women in Physics in Canada in mid-2014, but we also made a major effort at the recent Congress to revitalise the Group. There was a very strong session, with people sitting on the floor, in the main program, and Jodie Bradby organised a very successful breakfast on “Women in Physics”, at which a new team, with representatives from all states, was elected to re-energise the group: Helen Maynard-Casey (ANSTO) as chair, Joanna Turner (USQ) as vice-chair and Joe Hope (ANU) as secretary, along with the following other members - Sarah Maddison (Swinburne), Solmaz Sabooohi and Sophie Hollitt (UniSA), Elizabeth Chelkowska (Tasmania), Elaine Walker (Murdoch), Mario Zadnik (UWA), Kirrily Rule (ANSTO) and Jodie Bradby (ANU).

Finally, I think we all need to continue to keep our eyes and minds on political developments, but it is heartening that, in the recent cabinet reshuffle, Ian Macfarlane was named as Minister for Industry and Science. And at the Congress, I also had the opportunity to thank Education Minister Christopher Pyne for his soothing words on both the Future Fellowship and the NCRIS funding schemes, as part of his speech opening the Congress.

Rob Robinson
NEWS & COMMENT

2014 AIP Education Medal

The 2014 AIP Education Medal has been awarded to Professor Les Kirkup from the School of Physics and Advanced Materials at the University of Technology, Sydney. The Medal was presented at the AIP Congress in Canberra, December 2014.

The award recognises his significant contributions to physics education over 30 years of working in tertiary institutions, particularly in laboratory-based, inquiry-oriented learning, and for developing activities to engage students who are unlikely to pursue a career in physics. Les has also written several textbooks on experimental methods and data analysis, which, along with his enthusiasm for mentoring younger teachers, inspired the development of new teaching methods and new approaches to experimental design.

His contributions to education have previously been recognised with a Carrick Associate Fellowship in 2007, an ALTC National Teaching Fellowship in 2011 and the UTS Medal for Teaching and Research Integration in 2012.

2014 Harrie Massey Medal

Professor Yuri Kivshar from the Australian National University has been awarded the AIP’s 2014 Harrie Massey Medal for his work on nonlinear optics, metamaterials and metadevices. Yuri has pioneered a number of concepts in metamaterials, including nanoengineered structures smaller than the wavelength of light that can manipulate the magnetic component of the electromagnetic waves. The Medal was presented at the AIP Congress in Canberra, December 2014.

Revival of the Women in Physics group

At the recent AIP congress, the Women in Physics group was revived with enthusiasm, at the Women in Physics (WIP) breakfast, organised by Jodie Bradby. The breakfast, following on from the earlier well-attended conference session on WIP, was a great event with 70 attendees demonstrating the support for women in Australia’s physics community. The breakfast was enjoyed by all, with Cathy Foley and Jodie Bradby speaking about the goals of WIP. Additionally Lisa Harvey-Smith shared the Australian Society for Astronomy (ASA) recent excellent undertaking with their Pleiades awards. Inspired by the UK’s Athena SWAN program, the Pleiades awards recognise organisations that encourage and support the careers of women in Astronomy.

The packed Women in Physics Conference session, standing room only, with 50 people attending int a room booked for 30 (photo by Jodie Bradby).

Attendees at the breakfast were encouraged to nominate as office bearers, which resulted in the following members: Helen Maynard-Casely (Chair), Joanna Turner (Vice-chair), Joseph Hope (Secretary), Jodie Bradby, Elizabeth Chelkowska, Chris Creagh, Sophie Hollitt, Kirrily Rule, and Solmaz Saboohi. The make-up of the committee includes representatives from across Australia, but a Treasurer is still being sought. Additional members would be welcome (especially from the Northern Territory!) and should contact Helen or another member of the committee.

The primary goal of the committee will be to consider ways in which women can be encouraged and supported in the Australian Physics community. First steps in 2015 will be to rejuvenate the WIP website (as a repository of statistics, links and information on women in physics) and to discuss other potential undertakings. Additionally, the Women in Physics committee is currently seeking nominations for the Women in Physics lecturer and assisting with the selection of the successful lecturer.
**BRANCH NEWS**

**New South Wales**
The NSW Branch of the AIP in conjunction with the Royal Society of NSW held its annual Postgraduate Awards Day on Tuesday 18 November 2014 at the University of Sydney. Each New South Wales University was invited to nominate one student to compete for the $500 prize and Postgraduate medal on that day. This year we would like to thank the generous support of The Royal Society of NSW as the co-sponsor of the Jak Kelly Scholarship prize of $500 as a separate award category for this event.

Nominated students and their topics were:

- **Donghan Seo**, University of Sydney *(Single Step Plasma Enabled Transformation of Natural Precursors into Graphenes and their Applications in Energy Storage Devices)*
- **Romana Lester**, Australian National University *(Snapshot imaging of a cool, flowing plasma)*
- **Margaret Sharpe**, University of New England *(Coal Sack and Sky Emu – Towards a survey of magnetic fields in southern Milky Way dust clouds)*
- **Noel Hanna**, University of New South Wales *(Direct measurements of the sourcefilter model for voice production)*
- **Keith Motes**, Macquarie University *(How to Build the World’s First Quantum Computer)*
- **Linh Tran**, University of Wollongong *(Development of 3D semiconductor microdosimetric sensors for RBE determination in $^{12}$C heavy ion therapy)*

Students were asked to make a 20-minute presentation on their postgraduate research in Physics, and the presentation was judged on the criteria (1) content and scientific quality, (2) clarity and (3) presentation.

The winner of the AIP Postgraduate Presentation for 2014 was Michael Seo, University of Sydney; the winner of the Royal Society of NSW Jak Kelly Award for 2014 was Linh Tran, University of Wollongong.

**Victoria**
This report highlights some of the activities during 2014 of the Victorian Branch Education sub-committee.

A detailed proposal was submitted to the Review Panel established in late 2013 by the Victorian Curriculum and Assessment Authority (VCAA) to consider how the Australian Curriculum would be implemented in Victoria. A series of consultation forums was organized around the state for teachers to discuss the proposed curriculum with their colleagues following the release of the Panel’s draft report in August 2014. The results of these deliberations were submitted to the VCAA as well as a detailed submission from the sub-committee itself. The final report from the VCAA Panel is due in February 2015.

The AIP/STAV Physics Teachers Conference was held on 15 February at Monash. About 300 teachers plus presenters attended. The evaluation of participants indicated a very positive response to all aspects of the program.

A full-day in-service program for beginning teachers was held during the first term school holidays. There were 27 participants this year, more than last year and also greater than the year before. This year there were a few experienced teachers from other disciplines, such as Biology in attendance.

A full-day program of practical activities workshops with an all-day equipment fair, was extended this year to include Dip Ed students and lab technicians. It was held during the school holidays and, with over 70 participants, was a very popular event. Participants were able to see a range of physics demonstrations as well as try various hands-on activities.

The Sub-Committee established an Equipment Grants Scheme for under-resourced schools with negligible equipment budgets. Grants have been made to 15 schools totalling $5,000.

Physics Days for VCE Physics students were held at Luna Park on each of three days at the beginning of March. Nearly 2000 Year 12 Physics students, accompanied by their Physics teachers, participated. The response to the worksheets and the day itself was very positive from both students and teachers alike. All the worksheets and other material are made available to teachers through our website.

Again the Victorian Young Physicists’ Tournament was held. Students, in teams of three, carry out experimental investigations of three topics, then later in the year present and defend their findings in scientific discussions with other teams. The value of the event is that it involves experimental investigations, students working in teams and explaining their results in a debate-style format. There were separate competitions for Year 10 and Year 11 students.

The sub-committee’s web page at www.vicphysics.org continues to be well used by teachers, both here and overseas. It has become an important source of curriculum materials. There are now over 1000 sessions per day, each accessing an average of 4 pages for about 10 minutes in total.
Report on 2014 Women in Physics tour

The 2014 Women in Physics lecture tour by Prof. Sheila Rowan from the University of Glasgow, started late this year and was divided into the October part, with presentations between the 15th and 25th of October, and the November part, with presentations between the 10th and 21st of November 2014.

The late start prevented some branches from initiating more extensive student programs nevertheless, the statistics of the 2014 Women in Physics Lecture Tour are very impressive (see figure below).

Prof. Rowan presented 30 engaging lectures entitled “The search for gravitational waves - Ripples from the dark side of the Universe” to various audiences. The clever use of props, such as a yo-yo and a whistle and ball bearings on a rubber sheet, helped her audiences visualise the physics she was explaining. Her October presentations attracted over 1000 participants and in the November ones there were nearly 1700 attendees with more than 70% of them high school students.

The talks were especially highly regarded by high school students as they were pitched at the right level. Year 10 students indicated that it allowed them to see the links between different areas of physics as well as helping them to realise that current science classroom learning is not only important but also relevant. Senior students mentioned that it enabled them to tie a lot of their course work together; that this area of research brings together many topics they have been studying as discrete units.

All the presentations by Prof. Rowan received very favourable reviews. The NSW coordinator summarised that Prof. Sheila Rowan’s enthusiasm and passion for an exciting area of physics, along with her keen communication skills and pleasant personality, ensured her tour of Australia was an outstanding success. The packed audiences testified to this. All branches of the Australian Institute of Physics would like to sincerely thank Prof. Rowan for her time and expert knowledge.

As a national coordinator of the WiP lecture tour I would like to thank all of the branch coordinators: Dr Dan O’Keeffe, Dr Wayne Hutchison, Dr Chris Creagh, Dr Graeme Melville, A/Prof. Peter Veitch, Dr Kris Rowland, Dr Joanna Turner and Prof. Igor Litvinyuk, as well as their local assistants for their willing cooperation, great help and understanding. Additional thanks go to “Science in Public” for organising interviews and their immense help with the publicity for the events. I would also like to acknowledge the help of Ms. Dominique Emmett, Drs Olivia Samardzic, Judith Pollard and Chris Deller. I hope the preparation for the 2015 WiP lecture tour will start soon.

Elizabeth Chelkowska

Prof Sheila Rowan lecturing during the 2014 Women in Physics lecture tour.
Images from 21st AIP Congress, 7-11 December 2014

Prior to Congress dinner, National Gallery of Australia (credit Bernhard Seiwald)
Conference chair John Howard (credit Megan Girdler)

Harrie Massey Medal presented to Yuri Kivshar (credit Bernhard Seiwald)
Conference dinner, National Gallery of Australia (credit Bernhard Seiwald)

Plenary speaker Lisa Harvey-Smith (credit Bernhard Seiwald)
AIP president Rob Robinson (credit Megan Girdler)
IOP president Frances Saunders (credit Megan Girdler)
Plenary speaker Steve Chu (credit Megan Girdler)

Poster session (credit Bernhard Seiwald)
Women in Physics breakfast (credit Megan Girdler)
What is IUPAP?

In November 2014, Professor Bruce McKellar (University of Melbourne) began a three-year term as president of the International Union of Pure and Applied Physics (IUPAP).

IUPAP was established in 1922 in Brussels with 13 Member countries (Australia joined in 1925; there are now 60 members) and the first General Assembly was held in 1923 in Paris. IUPAP is now moving its office to Singapore in recognition of the growth in physics research in Asia.

The mission of the Union is to assist in the worldwide development of physics, to foster international cooperation in physics, and to help in the application of physics toward solving problems of concern to humanity.

The Union is governed by its General Assembly, which meets every three years. The Council is its top executive body, supervising the activities of the eighteen specialized International Commissions, four Affiliated Commissions and eight working groups.

As one of the basic sciences, physics relates to all branches of natural science. Many of the exciting developments take place in the border areas between different disciplines. To cover interdisciplinary activities IUPAP maintains close liaison with several of the other Unions. In some cases members of other Unions are associate members of IUPAP Commissions. IUPAP also participates in many of the Inter Union Commissions and global projects of the International Council of Science, which is in a sense its parent body. The proposal to establish IUPAP in 1922 was made by a group of physicists at the meeting of the International Research Council, and that body was transformed into the International Council of Science.

Conferences and meetings of the International Commissions are supported from funds derived from the members of IUPAP. These funds are also used to meet the administrative expenses of the Union. In 2014 IUPAP supported 32 international conferences, which were organised through 18 IUPAP Commissions.

Australia’s Connection

The Australian Academy of Science is the Australian body that adheres to IUPAP, and pays the subscription. The National Committee for Physics acts as the Australian Liaison Committee for IUPAP, nominating members of Commissions, delegate to the IUPAP General Assembly, etc. Marc Oliphant, Walter Boas, Bob Street and Bruce McKellar were Australian Vice Presidents of IUPAP.

Australian Members of Commissions

Andre Luiten (U Adel), member of Commission on Symbols, Units, Nomenclature, Atomic Masses and Fundamental Constants
Robert Robinson (ANSTO), member of Commission on Structure and Dynamics of Condensed Matter
Raymond Volkas (U Melb), member of Commission on Particles and Fields
Mahananda Dasgupta (ANU), member of Commission on Nuclear Physics
Peter Drummond (UQ), member of Commission on Atomic, Molecular, and Optical Physics
Deb Kane (Macq U), chair of Commission on Laser Physics and Photonics
Marion Burgess (UNSW, Canberra) is the President of the International Commission for Acoustics, an Affiliated Commission of IUPAP.
The Murchison Widefield Array delivers for Australian astrophysics

Steven Tingay

MWA Director
Curtin University, Bentley, WA 6102, Australia

The Murchison Widefield Array (MWA) is a low frequency (80 - 300 MHz) radio telescope that has recently become operational in remote Western Australia, a pristine radio quiet environment that allows the MWA to detect cosmic radio waves. I briefly illustrate the MWA’s the early science outputs, revealing new information about the Earth’s ionosphere and the Sun, enabling unique studies of our galaxy and its constituents, undertaking surveys of hundreds of thousands of other galaxies, and peering back in time 13 billion years to watch the birth of the first stars and galaxies after the Big Bang. The MWA is the first operational precursor for the multi-billion dollar Square Kilometre Array.

From aspiration to delivery

Back in 2009 I wrote an article for Australian Physics on the Square Kilometre Array (SKA), an aspirational piece that outlined some of the big questions in astrophysics and cosmology that this global mega-science radio astronomy project hoped to answer (http://www.skatelescope.org).

In September 2012, Peter Hall and I contributed the next installment, continuing the story and focusing on the large component of the SKA to be built in Australia, consisting of hundreds of thousands to millions of antennas operating at low radio frequencies (50 – 350 MHz). This component of the SKA is known as SKA-low. We zeroed in on a science and technology path toward SKA-low that was becoming less aspirational and more real with time.

We described the transformational science behind SKA-low, the ability to open up the last remaining unexplored epoch in the evolution of the Universe, the first billion years after the Big Bang. In this period the first stars and galaxies were formed and the Universe was “re-ionised” by the radiation that these stars and galaxies produced.

“In the middle of 2013, the MWA was brought into its full science operations mode.”

We also described technology prototyping steps being taken toward building SKA-low. One step was the international work being done as part of the SKA pre-construction program, funded by the Australian Government. A second step was the establishment of the $50m Murchison Widefield Array (MWA: http://www.mwatelescope.org; http://www.facebook.com/Murchison.Widefield.Array; Tingay et al. 2013 [2]), one of three official “precursor” instruments for the SKA and the only low frequency precursor. The MWA has been built in the remote Murchison Shire of Western Australia. The MWA consortium of 15 institutions from India, New Zealand, the US and Australia is led by Curtin University in Perth.

Our September 2012 article was written during the final throes of the construction of the MWA, which was completed by the end of 2012. In the first half of 2013, the MWA successfully negotiated engineering and science commissioning phases. In the middle of 2013, the MWA was brought into its full science operations mode. The MWA has now operated for almost two years and
it is very pleasing to now be in a position to report on some of the outstanding science already being produced by the MWA science teams.

In the world of the SKA, the last five years have brought us from an aspirational notion of what the SKA may be capable of, to a point where SKA precursors are now realising the first phases of these aspirations. Telescopes like the MWA are starting to show us what the SKA will do for astrophysics and cosmology. The MWA is strongly informing technology and science planning for the SKA and is building a sizable cohort of young scientists and engineers cutting their teeth on these new types of facilities. These young people will be the leaders in the SKA era, a decade down the track, and Australian investments are placing them at the forefront of the field internationally.

In this article I'll briefly describe, with heavy reliance on some of the beautiful imagery emerging, a few of the science highlights now flowing from the MWA. A taste of what is to come from the SKA.

What makes the Murchison Widefield Array special?
The MWA is configured to work at low radio frequencies, 80 – 300 MHz, which tunes in to the Doppler shifted (redshifted to astronomers) radio emission produced by the neutral hydrogen gas that was formed after the Big Bang, approximately 14 billion years ago. We want to watch the distribution of hydrogen evolve as the first stars and galaxies formed during the first billion years of the Universe.

To do this, we need to build a telescope that has a wide field of view (hence the name), such that we can quickly survey massive volumes of the Universe, properly sampling the signals we are interested in. Figure 2 shows the amazing field of view that the MWA forms, covering hundreds of square degrees of the sky in a single observation.

A by-product of this wide field configuration is that we can also undertake very fast surveys of hundreds of thousands of galaxies in the Universe and unprecedented surveys of the Milky Way (the galaxy in which we live). We can also repeat these surveys many times over in order to investigate the largely unexplored dynamic Universe, targeting rare classes of objects that have variable or transient radio emission.

“...we can also undertake very fast surveys of hundreds of thousands of galaxies...”

Additionally, the MWA has a lot of antennas, especially a lot of antennas closely packed together. Because we have so many antennas and so many close together, we can make high fidelity images of the sky, reproducing structures over a wide range of angular scales, including the largest scales (~10 degrees) that include many of the most interesting features of our own galaxy, the Milky Way.

These excellent observational capabilities come at a cost, however. The MWA produces raw data at a rate of several gigabits per second. All these data are transported on an optical fibre network, 800 km from the Murchison to Perth, where they are stored at the brand new $80m Pawsey Centre. As of writing, the MWA archive at the Pawsey Centre is well over 3 petabytes, making the MWA one of the first radio astronomy entrants into the world of seriously Big Data.

Finally, a really special aspect of the MWA is its location, at the supremely radio quiet Murchison Radio-astronomy Observatory (MRO) established by CSIRO as a site for the SKA. Very low levels of human-made radio noise at the MRO allow the MWA to listen to the Universe for the incredibly weak signals we are interested in.

So, what are some of the early science highlights?
Let's start close by, very close by. The Earth's ionosphere lies approximately 100 km above the surface of the Earth, a layer of plasma caused by the ionisation of the...
upper atmosphere. At low radio frequencies, the ionosphere distorts the radio waves that the MWA receives, shifting the apparent positions of radio sources on the sky. This is something of a nuisance for the MWA and needs to be accounted for when we process our data. We can measure the position shifts for all the radio sources we see and compare them to where we expect them to be from previous observations.

However, a by-product is an incredibly rich dataset for ionospheric physics. Over our very wide field of view and with the angular resolution of the MWA, we can make images such as those in Figure 3, revealing the structure and evolution of the ionosphere on minute time-scales and kilometre size scales, scales not before explored in this detail. Figure 3 shows vectors representing the position shifts of radio sources in an MWA field at one snapshot in time. The position shifts are caused by gradients in the line-of-sight electron content of the ionosphere and we can see very strong changes in these gradients as functions of time and location in the ionosphere. To see a movie showing a sequence of these snapshot observations, go to: http://www.physics.usyd.edu.au/~cloi/ionosphere_movies/

“...a key science program for the MWA is the study of our Sun”

Stepping slightly further away, a key science program for the MWA is the study of our Sun. The MWA is able to image the Sun in great detail across a wide range in frequency with high frequency resolution and with high temporal cadence, to investigate solar radio flares and, importantly, enigmatic weak variations seen for the first time on the quiet Sun by the MWA [1]. Figure 4 shows a novel image of the Sun made using data from the MWA, during the partial solar eclipse of April 2014.

Moving out of the Solar System and into the Milky Way galaxy, the MWA can survey the entire portion of the Milky Way visible from the MRO in superb detail. Figure 5 shows one tiny patch of the Milky Way, made by combining MWA images at three different frequencies into a Red-Green-Blue-style, three-colour image, revealing the “radio colours” of the Milky Way. Immediately apparent are highly complex structures formed by...
relativistic electrons and magnetic fields, regions where significant absorption of radio emission takes place, emission from the ionised regions around massive stars, and very large numbers (more than have ever been seen before) of the remnants of exploded stars, supernova remnants.

Rather astonishingly, when the MWA looks at the Milky Way in polarised radio emission (Figure 5 is a total intensity image), highly complex structures appear (Figure 6). The gradient of the polarised radio emission forms what appear to be twisted and intertwined filaments, thought to mark real structures in the magnetised plasma that pervades our local volume of the Milky Way.

“...the first billion years of the Universe is the big science goal for the MWA...”

Beyond the Milky Way, the MWA can see hundreds of thousands of other galaxies, lit up in radio waves by supermassive black hole and accretion disk systems that lie at their hearts. Figure 7 shows just one field from an MWA observation, representing approximately 1% of the celestial sphere. One can see a vast multitude of unresolved radio galaxies, a rich dataset for studying radio galaxy populations. The occasional radio galaxy is close enough to be can be resolved in detail, including the famous radio galaxy Centaurus A, also seen in Figure 7. The MWA has started to discover new very low
surface brightness radio galaxies for the first time, such as shown in Figure 8. These galaxies are thought to be in the process of “dying”, fading away from view because their Black Holes are no longer active.

Finally, the first billion years of the Universe is the big science goal for the MWA, part of an international race to be the first to uncover hints of the last remaining unexplored epoch in the evolution of the Universe. Pretty pictures of this period are well beyond the MWA – that is why we need to build SKA-low. Rather than achieving a direct detection, the MWA (and other competing experiments) are aiming at making a statistical detection of the fluctuations of the redshifted neutral hydrogen signals. This is an incredibly difficult experiment. The fluctuations are expected to have an amplitude of tens of millikelvin (the equivalent black body temperature of the radio emission) and occur on angular scales of degrees.

It turns out that Figures 3 through 8 of this article represent objects that all lie between us and that early hydrogen we are looking for and have equivalent temperatures of hundreds to thousands of Kelvin; they also have structure on degree angular scales. Thus, the experiment to uncover the first billion years of the Universe is a classic needle in a haystack enterprise, looking for the 1 part in $10^5-6$ signal buried in the “foreground” signals generated by most of the Universe. Control of experimental systematic errors, understanding the statistics of the data, and understanding the foregrounds are all vitally important. And after that, thousands of hours of observations will likely be required to achieve the raw sensitivity required. This is ambitious in the same way that Cosmic Microwave Background experiments such as COBE, WMAP and Planck have been in the past (with massive scientific returns).

So, the final word on the MWA experiment to uncover the first billion years of the Universe will have to wait for a future article, likely a few years down the track. At this point, the MWA team has collected over a thousand hours of data, over a petabyte in total, and are churning through them, peeling back the layers of understanding in order to uncover the signals of interest.

**“Our community will then apply their hard won MWA skills and wisdom to SKA-low, a facility 50 times larger than the MWA....”**

Where to next?”

The MWA is more than half way through its initial science operations phase, which will run through 2015. Beyond 2015, further operational funding will be required in order to keep the MWA facility alive for continued observations. Already the discussion in the radio astronomy community has turned to various upgrades and extensions to the MWA, in order to greatly increase its scientific capabilities in key areas. These discussions will result in new project plans and funding proposals in 2015/16. Assuming that operations and extensions are undertaken over the next 3 – 4 years, the MWA should carry the growing low frequency community into the era of SKA construction and operations. Our community will then apply their hard won MWA skills and wisdom to SKA-low, a facility 50 times larger than the MWA, with a commensurate increase in science capabilities and commensurate challenges in data management and processing.

That future is certainly a compelling one for those interested in the forefront of astrophysics and cosmology, and compelling for those who enjoy the technical challenges of Big Data.

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**Prof. Steven Tingay** is Director of the Curtin Institute of Radio Astronomy, a Director of the International Centre for Radio Astronomy Research, and Director of the Murchison Widefield Array (MWA) project. Steven has authored or co-authored over 130 papers in international refereed journals in radio astronomy and astrophysics. He leads the MWA project, a $50m international radio telescope recently completed and brought into its operational phase in the remote Murchison region of Western Australia. The MWA is the low frequency Precursor for the multi-billion dollar Square Kilometre Array (SKA). Steven is an alumnus of The University of Melbourne and of the Australian National University.
3D X-ray art

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The micro-CT facility at the ANU Department of Applied Mathematics has hosted Erica Seccombe as an artist-in-residence since 2006. This article gives an overview of the techniques required to produce the images and a brief art-historical context for the work.

Introduction

One of us, Erica, began working in the ANU Department of Applied Mathematics in 2006 when she was awarded an *artsACT* project [1] for a three-month residency. She had contacted and met Professor Tim Senden the year before and had discussed with him her objectives to explore scientific technology via an artistic practice. Through 2D prints and large-scale photocopy assemblages of small plastic toys she had already emulated electron microscopy and X-ray images (see Figure 1). She predicted the hollow plastic, industrially designed structures would translate interestingly with actual X-ray imaging.

Tim and other members of Applied Maths enthusiastically welcomed the residency. Just two years earlier, the department had completed building a custom X-ray computed tomography (CT) facility capable of imaging materials with a wide variety of densities and sizes from 5 cm cores of rock, imaged at 20 micron resolution, down to samples around 5 mm across imaged with a voxel size of less than 2 microns. Tim saw the collaboration initially as a chance to increase the public profile of the facility. The residency produced a body of work titled *Nanoplastica* (see Figure 2) and was so successful that Erica returned in 2010 with a second *artsACT* grant and a Synapse residency from ANAT [2] to image germinating seeds (see Figure 3), and again in 2013 with support from the Centenary of Canberra [3] to produce renderings and 3D printed objects from a CT image of a woodlouse (slater) - see Figure 4. This essay details some of the technical aspects required to produce the images and the broader artistic context of the work.

The ANU X-ray micro-CT facility

In 1967 an idea occurred to Sir Godfrey Newbold Hounsfield (1919-2004), a brilliant English electrical engineer, that one could determine what was inside a box by taking X-ray readings at all angles around the object (these X-ray shadows are called projection data). Prior to this he was involved the development of early computer technology where, in the late 1950s, he led a team that built the first all-transistor computer to be constructed in Britain, the EMIDEC 1100. Combining his knowledge of computer technology and his interest in automatic pattern recognition, Hounsfield’s realization led to his invention of the computer-aided tomography (CT or CAT) scanner. ‘Temos’ means ‘slice’; in the past, three-dimensional structures could only be studied by making physical slices through an object. In CT, the X-ray density at each point inside the object is reconstructed from the projection data using a mathematical relationship called the Radon transform: slices through a specimen are computed by virtual means, rather than being made by the doctor’s scalpel.

“...to produce renderings and 3D printed objects from a CT image...”

Bizarrely Hounsfield’s invention is also attributed as a direct result of the Beatles booming record sales in the
early 1960s. It turns out that the EMI record company, an arm of the EMI Group (Electric & Musical Industries Ltd), also owned the Central Research Laboratory in London of which Hounsfield was an employee. Benefiting from the Beatles lucrative success, EMI was able to fund Hounsfield's pioneering work on this scanning device, for which he was awarded the Nobel Prize in 1979 [4].

Since the 1970s, CT scanners have revolutionized medical diagnostic radiology methods. However the early technology could not support the resolutions required for quantitative analysis of materials. It took the advent of affordable high-performance computing power (GPU computing, for example) and improvements in the components for X-ray generation and detection to make possible studies of structure at the micron scale in sedimentary rocks, bone, composite materials, wood, fossils and insects over the past 10-20 years. The laboratory-based micro-CT at ANU currently uses a transmission-type X-ray source, a large-area amorphous-silicon flat panel detector and reaches a resolution of 1.5 microns with scan times of 10-20 hours [5]. In comparison, the most efficient synchrotron beamlines with their high beam flux can acquire datasets of 2000³ voxels at 2-5 micron resolution in less than one minute, and have a maximum resolution of 100 nm.

There are three steps involved in creating the volume data that Erica uses for her artistic renderings. The projection images are acquired using a helical-scanning cone-beam tomography configuration. This is significantly different to the circular-scanning parallel-beam method first developed by Hounsfield that assumes the X-ray source is a large distance from the sample and detector. The “cone-beam” configuration means the X-ray source can be brought close to the sample being scanned to increase the amount of flux reaching the detector. Projection data from high cone angles can only be transformed accurately into volume data with a helical scanning trajectory.

The reconstruction process uses a theoretically exact algorithm based on the Katsevich inversion formula (a generalization of the Radon transform). The group at ANU was the first to implement this method and it involved solving a range of technical issues including thermal drift causing relative movement between source and sample, system alignment, inhomogeneous magnification and secondary radiation sources. The amount of data and computations used to produce these images is staggering. A typical helical trajectory acquisition involves up to 15,000 X-ray projection images, each with 2048x1536 16-bit pixels, amounting to 90 GB of data. The reconstructed 3D volume is approximately 2000x2000x4000 voxels, with 32 GB of data. The reconstruction takes about 3 hours on 192 processors of the Raijin supercomputer at NCI (the National Computational Infrastructure).

“The projection images are acquired using a helical-scanning cone-beam tomography configuration.”

The final stage is image processing. Various filtering techniques can help to remove high-frequency noise in the image, and image gradients can highlight boundaries between phases. One of the most important techniques is image segmentation, the process of classifying voxels into discrete “phases” such as plastic and air in the case of Erica’s first toy objects. There may also be mounts and glue that can be identified and digitally removed. Ideally, the different materials have significantly distinct X-ray densities, so that each phase may be clearly identified. But even for the simplest objects, reconstructed images can be blurred and noisy and voxels representing the boundary between two phases take intermediate values. These factors make image segmentation a labour intensive task.

Erica’s second residency was an ambitious project to capture seed sprouting to first-leaf stage, inspired by new
research into dynamic CT imaging within the Department. This required Erica to embark on a significant amount of research into types of seeds, growth beds, water content, and containers. The seeds needed to sprout quickly and withstand the harsh environment of the X-ray room, while the container and growth bed needed to provide a stable base that could nurture the seed without any intervention for the duration of the imaging process. After many trials she settled on mung beans and alfalfa growing in a test-tube with a gelatin growth bed containing a small amount of iodine staining to assist with contrasts between different structures in the seeds. She eventually acquired three usable time-lapse sequences of volume images; the longest has 40 volumes taken at regular intervals over four days and nights [6].

During this time Erica was commissioned to create a separate body of work for the exhibition ‘Science Fiction’ as part of the Centenary of Canberra celebrations. She collaborated with Tim Senden using data he had acquired of an Isopoda, more commonly known as a woodlouse. This tiny garden-inhabiting crustacean was soaked in ethanol containing 5% iodine for 24 hours. The solution was preferentially absorbed into the muscle tissue with the result that the musculature and exoskeleton had distinct X-ray densities, assisting with segmentation and the rendering process described below.

**Volume data rendering using Drisht**

After reconstruction and processing the volume data set is still just a three-dimensional array of numbers. The challenge is to display that wealth of information in a meaningful way. The software used by Erica is Drishti, a purpose-designed volume exploration tool written by Dr Ajay Limaye at the ANU Supercomputer Facility VizLab [7]. The name Drishti was knowingly chosen by Ajay for its multiple meanings in Sanskrit as indicative of a different kind of visual experience. In an English translation of ‘drishti’ the word can be used to describe vision, seeing, knowledge and intelligence. It can also mean insight as pertaining to mental knowledge, the outcome of perception. The act of transforming data and mathematical relationships into a picture is a vital part of understanding and communicating our knowledge of the world. Scientists create images and diagrams with the primary goal of conveying information. Artists aim to evoke an emotional response to their work, provoking the viewer to make reflective connections between the artwork and their personal experience. Drishti is versatile enough to encompass both these objectives.

“The challenge is to display that wealth of information in a meaningful way.”

A volumetric image is effectively a function defined over a three-dimensional grid whose value at each point (voxel) is the reconstructed X-ray density. The basic principle in volume rendering is to highlight certain level surfaces (contour surfaces) of this function, or of its gradient, leaving other regions transparent. This is achieved via the transfer function: a map from the X-ray density function and gradient values to colour and opacity values (RGBA). Drishti projects these contour surfaces to the screen display using a hardware texture-based volume rendering method. The user interactively manipulates the transfer functions to enhance or suppress regions of the data and thereby separate various structures within a specimen. Drishti also permits data manipulation through cropping, clipping, lighting and contrast adjustments, and complete freedom to place the software’s camera anywhere inside or outside the virtual specimen.

Since its inception in 2004, Drishti has improved considerably in terms of its user interface and Erica has played a significant role in this development. When she began in 2006, there weren’t many other people actively...
using the program, but this has changed as the use of 3D imaging technology has increased. One of the main groups now using Drishti are paleontologists who can study their fossils with microscopic internal detail without even having to dissolve the rock it has been encased in [8].

**Art-historical context**

Erica’s work references many inter-connected revolutions of invention, discovery and creative developments across optics, physics and computation. The first is Robert Hooke’s use of microscopic lenses to reveal previously unimaginable details of objects invisible to the naked eye. His historic book “Micrographia” (1665) contains hand-drawn engravings of insects at greatly magnified scales and inspired wide public interest in the new science of microscopy. The comparative scale of microscopy offered a unique perspective from which to reflect as observers, creating new meanings across time and circumstance. Two centuries later, Wilhelm Roentgen’s discovery of radioactive waves and the process of making X-ray radiographs revolutionized the very notion of the physical world where previously solid matter was rendered transparent.

The development of photography in the 19th century also had a profound impact on both science and art, particularly in combination with microscopy and X-rays, as demonstrated in the exhibition and book [9] “Brought to Light: photography and the invisible” by Corey Keller. For Keller, the drive to make pictures of imperceptible phenomena highlighted a major shift in a cultural understanding of the world around us that began with ‘an awareness that there was a great deal more to the world than the human senses could perceive’. Scientific photography supported the 19th century movement towards popular science and ‘a belief that to have a healthy citizenry you had to have a population that understood the most important ideas in modern science’ [10]. But Keller also demonstrates that the creation of X-ray photographs of objects impossible to view with the eye posed a cultural challenge that also led to elements of magic and superstition.

**“There is no doubt Science is the new black in Art.”**

Similar tensions exist between science and superstition today. The urgent environmental concerns of our time: global warming, population growth, conservation of biodiversity, tend to be discussed in a polarizing, didactic fashion, leading to public disengagement. RMIT artist and academic Lesley Duxbury has proposed that certain art practices have the potential to engage society with nature emotionally and experientially [11]:

Erica is using cutting-edge 21st century technology to induce awe and wonderment in the viewer, a subjective experience of being in the moment watching a seed as it begins to grow, or by taking a bug and making it beautiful on a gigantic scale. We are lightly encouraged to reflect on our place in the natural world at this precarious point in human history.

**Science-Art Collaboration**

“There is no doubt Science is the new black in Art.” This was the opening statement from Vicky Sowry, Director of the Australian Network for Art and Technology (ANAT), at a recent Vivid Ideas event [12]. Discussions between the panel members and the audience revealed that the most successful collaborations have a genuine personal connection at their core, with mutual respect for the perspectives and methodologies of one another’s disciplines. Scientists must acknowledge the artist as more than an illustrator and artists must engage with the scientists and laboratories as more than service providers.

The collaboration between Erica, Tim, Ajay and other members of Applied Mathematics has certainly been
successful in artistic terms. The scientific benefits are less tangible perhaps, but in addition to her influence on the development of Drishti, the presence of an interested outsider stimulates discussions: hidden assumptions are exposed, ideas are clarified under force of explanation. Exhibitions of scientifically engaged artworks, such as Erica’s, help to engage the public with what can be an otherwise mysterious and impenetrable discipline.

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Aleksandr Prokhorov, Australian-born Nobel laureate in physics

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Aleksandr Prokhorov (1916-2002) was a co-winner of the 1964 Nobel Prize, for the invention of the laser for work undertaken in the then USSR. Nearly 100 years after his birth very few people know that he was born in Australia. This brief article points to where more details about his life and work can be found and its context of Russians finding refuge in Australia around 100 years ago. Additionally, the efforts of a Minister of Science to highlight this curious connection are noted.

Name the Australian-born scientist who won the 1964 Nobel Prize in Physics as a co-inventor of the laser. Although these are not his exact words, the then Minister for Science, Barry Jones, posed this question to the audience as part of his address to open the 3rd International Laser Conference Australia, Melbourne, in Aug/Sep 1983. Most attendees would have been aware that the Nobel Prize in Physics 1964 (“for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle”) was divided between scientists from the USA and the then USSR (half awarded to Charles Hard Townes, the other half jointly to Nicolay Gennadiyevich Basov and Aleksandr Mikhailovich Prokhorov). Surely the Minister, renowned for his knowledge of a very broad range of areas and with a greater passion for science than has often been the case for such ministers, had somehow gotten his facts wrong! But no, the Minister was correct and the Australian physics community can claim Aleksandr Prokhorov (see Figure 1) as an Australian-born Nobel Prize winner.

To obtain a good overview of Prokhorov’s life and his contributions to laser science the Australian Academy of Science commissioned an interesting volume about all Australian Nobel Prize winners [1]. Some years earlier the interesting story of his life and his Australian connection was recounted in a magazine from the former USSR [2].

In brief, the parents of Prokhorov, Mikhail and Maria, came to Australia from Siberia seeking refuge from political difficulties in Russia, along with a number of other Russian families [3]. They and their daughter arrived in Brisbane 1912 and after living at various places in rural Queensland and having two more daughters they eventually joined these other families at a remote location on the Atherton Tablelands, all of whom were hoping to live off the land. Aleksandr was born here on 11 July 1916 (coincidently the same day as Gough Whitlam, Australian Prime Minister 1972-1975), with a Russian neighbour being the midwife. Although in various places Prokhorov’s birthplace is stated as Atherton, his birth certificate states that his place of birth was Peeramon [1] which is around 12 km southeast of Atherton. The birth certificate names him Alexander Michael Prochoroff, representing the then common tendency to Anglicize names. At that time Peeramon may have been the nearest town, as the land was mostly unsettled and heavily forested. An interesting map from this period shows the land allocations amongst these Russian families along Gadaloff Rd [4], sometimes referred to as “Little Siberia” [3], in an area now known as Butcher’s Creek, lying about 8 km southeast of Peeramon and not far from Mt Bartle Frere. Indeed Aleksandr attended the Butcher’s Creek State School for several years prior to the family’s return to Russia in 1924 where the political climate had become much more to the family’s liking.

In the USSR he eventually attended Leningrad State
University, graduating in physics in 1938. The advent of the Second World War interrupted his education for some years, but eventually he was awarded the equivalent of a master's degree from the PN Lebedev Institute (Russian Academy of Sciences, Moscow) and his PhD was awarded in 1951 for his thesis “Coherent radiation of electrons in the synchrotron accelerator”. He remained at this Institute, becoming its head in 1954, two years after ground-breaking work that led to the development of the maser had been announced. Later in his career he held various senior positions within the Russian Academy of Sciences.

Figure 2: Plaque at Butcher’s Creek Primary School, installed in 2006 by the local historical society.

In 2006, 4 years after his death, the local historical society produced a plaque to mark 90 years since his birth that is on display in the Butcher’s Creek Primary School (see Figure 2).

During his time as Minister for Science Barry Jones made further efforts to ensure this Nobel connection with Australia was not forgotten. Thus a plaque highlighting this connection was unveiled at the opening of a new CSIRO facility in Atherton on 13 February 1987 (see Figure 3), and the accompanying communications between the Minister and Prokhorov was reported in “Science in USSR” [5]. Some years later, in 1990, Prokhorov and the Minister were to meet in Moscow [6].

Despite these various efforts to ensure this connection of a Nobel-Prize-winning physicist with Australia is remembered, it would seem that there is little local knowledge of this fact. Three years ago, when the author enquired, the staff at the Atherton Visitors’ Centre had never heard of him. Given that the centenary of his birth is a year away, the AIP and the Australian Optical Society are seeking to highlight this interesting story of how a Nobel laureate began his schooling in far north Queensland. Anyone with further information or ideas as to how to mark this centenary are asked the contact the author.

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Stephen Collins obtained his BSc(Hons) and PhD in physics from the University of Melbourne. In 1986 he joined Victoria University (then Footscray Institute of Technology), and later became Head of Applied Physics. He has around 25 years of experience in research on optical fibre sensors including fluorescence-based temperature sensing and various aspects of fibre Bragg gratings used for sensing. He currently serves as the President of the Australian Optical Society and the Accreditation Manager of Australian Institute of Physics. His interest in the area of this article was, as noted, sparked by a visit to the tourist office in Atherton.
UK unveils £120m quantum-technology hubs

The UK government has announced that four universities – Birmingham, Glasgow, Oxford and York – will serve as hubs in a £120m programme to explore the properties of quantum mechanics and how it can be used to develop new technologies. The four Quantum Technology Hubs, which will involve a total of 17 UK universities and 132 companies, will be funded by the Engineering and Physical Sciences Research Council (EPSRC). The money comes from the £270m investment National Quantum Technologies Programme that was first announced in 2013 by UK chancellor George Osborne and will run across the next five years.

Details of the funding package were unveiled by Greg Clark, the UK’s minister of state for universities, science and cities, who said that quantum technologies “could support multi-billion-pound markets in the UK and globally”. Clark also announced that the National Physical Laboratory will receive £4m towards the creation of a Quantum Metrology Institute (QMI) at its Teddington site near London.

Philip Nelson, EPSRC chief executive, adds that the hubs “will draw together scientists, engineers and technologists from across the UK, who will explore how we can exploit the intriguing properties of the quantum realm”. He adds that “The area offers great promise, and the hubs will keep the UK at the leading edge of this exciting field.”

The Birmingham hub will focus on quantum sensing and metrology, and will partner with researchers at the universities of Glasgow, Nottingham, Southampton, Strathclyde and Sussex. The hub will be led by Kai Bongs, who works on the physics of ultracold atoms, and will aim to develop commercially viable quantum technologies for measuring time, frequency, rotation, magnetic fields, gravity and other fundamental properties. These technologies could find use in a range of fields, including financial trading, medical imaging and navigation.

Quantum sensing and imaging, meanwhile, will be the focus of the hub co-ordinated by Glasgow and led by the optical physicist Miles Padgett. This hub includes Bristol, Edinburgh, Heriot-Watt, Oxford and Strathclyde universities, and aims to build ultrasensitive light detectors for a range of applications including medical imaging, security monitoring and manufacturing. Hub members will also collaborate on the development of quantum sensors capable of detecting tiny signals such as those from single molecules or gravitational fields.

The Oxford hub is led by the optical physicist Ian Walmsley and will focus on quantum computing and simulation. It will include the universities of Bath, Cambridge, Edinburgh, Leeds, Southampton, Strathclyde, Sussex and Warwick, as well as a number of national and international companies. The hub will create quantum-computing systems for applications such as simulating molecules for drug development and processing large quantities of information in disciplines such as economics, climate science and healthcare.

Quantum communications is the focus of the fourth hub, which will be co-ordinated at the University of York. Led by quantum-information specialist Tim Spiller, this hub includes researchers at the universities of Bristol, Cambridge, Heriot-Watt, Leeds, Royal Holloway, Sheffield and Strathclyde. The aim of this hub is to create quantum-encryption systems for secure communications that can be widely and cheaply deployed.

Companies and government organizations that are involved in one or more of the hubs include BT, Toshiba, e2v, M Squared Lasers, Dstl, AWE, the National Physical Laboratory, Thales, Coherent Lasers, BP, Compound Semiconductor, Government Communications Headquarters (GCHQ), Selex, Oxford Instruments and Kelvin Nanotechnology.

Extracted with permission from an article at physicsworld.com by Hamish Johnston, editor of physicsworld.com

SOLEIL scientists create double-slit thought experiment

Physicists using the SOLEIL synchrotron in France are the closest yet to realizing a thought experiment first
proposed in 1927 by Albert Einstein. A variation on the much-loved double-slit experiment, the measurement confirms an aspect of quantum theory that Einstein had sought to discredit. The SOLEIL experiment uses two excited atoms in place of the two slits of Einstein’s experiment and shows that when one can determine which atom has emitted an electron, a quantum interference pattern vanishes.

Einstein made several attempts to refute the inherent uncertainty of quantum mechanics by proposing thought experiments, which could not be performed in the lab at the time. One involved the principle of wave–particle duality, which predicts that a succession of single particles passing through two slits will build up a wave-like diffraction pattern on a screen. This occurs because the wave-like property of each particle allows it to travel through both slits at once. Einstein pointed out that an extremely sensitive sensor could detect the recoil of the individual slit that each electron passed through, while not disturbing the diffraction pattern. This flew in the face of quantum mechanics, and Einstein’s great rival, Niels Bohr, countered by arguing that the diffraction pattern would simply not occur if the experimenter knew which slit each electron had passed through.

While this was a pure thought experiment at the time, its combination of conceptual simplicity and formidable experimental difficulty has provided an irresistible challenge for modern-day experimentalists.

Now, Catalin Miron and colleagues at SOLEIL, together with collaborators in Sweden, Japan and Romania, are the closest yet to recreating the original thought experiment in the lab. They use a diatomic oxygen molecule that is excited by tunable X-ray synchrotron radiation on the PLEIDES beamline. By adjusting the X-ray energy, the researchers can promote an electron from an inner molecular orbital into either a high-energy bound state or a repulsive state in which the molecule breaks apart. After this transition, one of the atoms emits another electron called an Auger electron, recoiling as it does so.

If the first electron has been promoted to the bound state, it relaxes back to the molecular ground state and the two atoms recoil together when the Auger electron is emitted. This means that measuring the recoil of the atoms reveals nothing about which atom emitted the electron. However, if the electron has been promoted to the repulsive state, the molecule breaks apart to create separate oxygen atoms. If the Auger electron is emitted after the molecule breaks apart, the atoms will not recoil together, and measuring the recoil of the atoms will reveal which atom ejected the electron. The two atoms therefore act as the slits of the thought experiment, and the emission of an electron is analogous to a particle emerging from the two slits. If the atoms recoil together, we do not know through which slit the electron passed—but if only one recoils, we do know which slit was used.

In place of the screen, the team used an extremely elaborate, self-built and unique machine called EPI-CEA, which measures all three components of the momenta of both the emitted electron and the recoiling atom left behind.

Theory and experiment

By correlating the emitted electron energy to the angle between the electron emission and the axis of the diatomic molecule for a large number of photon–molecule collisions, the researchers electronically reconstructed the “interference pattern”. By looking at the Doppler shift of the recoiling ion, the researchers could also calculate whether one or both atoms had recoiled. When the two atoms were indistinguishable, interference fringes were produced; whereas when the emission bore a clear signature of having come from one atom or the other, a continuous band was produced with no evidence of fringes. This is in good agreement with high-level theoretical calculations—and shows once again that Bohr’s interpretation of the thought experiment is the correct one.


Extracted with permission from an article at physics-world.com by Tim Wogan, a science writer based in the UK.

**Asteroids, not comets, gave Earth most of its water**

Most of the water that sustains life on Earth probably came from asteroids rather than comets. That is the conclusion of scientists working on the Rosetta space mission, who have measured the levels of hydrogen isotopes in the comet 67P/Churyumov–Gerasimenko. The ratio
of deuterium to hydrogen in the comet is much greater than the ratio found on Earth, which suggests that comets supplied Earth with only a small fraction of its water.

Although water blankets 71% of the Earth’s surface, its abundance puzzles scientists. The Earth formed with the other planets in a disc of gas and dust around the newborn Sun. This protoplanetary disc was hot close to the Sun and cold far away. Because the Earth is close to the Sun, it formed in a hot region that should have been fairly dry.

So how did the Earth get its water? Comets had once seemed to be a promising source: they come from the solar system’s frozen outer reaches and harbour ice that vaporizes when they approach the Sun. If comets struck the Earth after its formation, they could have delivered the water that makes up the oceans and our bodies. If this happened, water on comets should have the same isotope composition as water here on Earth. In particular, comets should have the same ratio of deuterium to hydrogen as found on Earth.

In 1986 scientists got a chance to determine the origin of terrestrial water when the best known comet of all – Halley’s Comet – approached the Earth. Surprisingly, the comet’s deuterium to hydrogen ratio was twice the terrestrial ratio. Rather than abandon an attractive theory, however, many scientists dismissed the Halley result as a fluke.

Blue planet: most water probably came from asteroids

But then in 1996 and 1997, two other bright comets lit up the sky as they passed near to Earth: Hyakutake and Hale–Bopp. Both also had twice the terrestrial deuterium to hydrogen ratio, providing even more evidence that comets did not give the Earth most of its water.

But there was still hope for the comet model. All three comets – Halley, Hyakutake and Hale–Bopp – originated in the Oort cloud, a reservoir of comets far beyond the orbit of Pluto. But some comets come from the Edgeworth–Kuiper belt, which is just past Neptune’s orbit and whose largest members are Pluto and Eris, the latter discovered in 2005. Comets from this reservoir might have terrestrial deuterium levels, but these are usually faint and hard to observe.

In 2010 astronomers succeeded in detecting deuterium in a comet from the Edgeworth–Kuiper belt. Unlike the other comets, this one, named Hartley 2, had a deuterium level matching terrestrial water, reviving the idea that comets delivered water to the Earth.

“It was a nice story, wasn’t it?” says Kathrin Altwegg, a Rosetta scientist at the University of Bern in Switzerland. “Now with our finding, I guess this idea is going to disappear again.”

In August, and to great fanfare, the European Space Agency’s Rosetta spacecraft arrived at an Edgeworth–Kuiper comet named 67P/Churyumov–Gerasimenko. Altwegg’s team reports that this comet also has high levels of deuterium. In fact, the level is even higher than Halley’s Comet, coming in at 3.4 times the terrestrial level – making it the largest deuterium to hydrogen ratio ever seen in a comet.

At the very least, the finding means that Edgeworth–Kuiper comets span a range of deuterium ratios. Altwegg says that most terrestrial water likely arose from asteroids that hit the Earth. By studying meteorites – most of which come from asteroids – scientists know that asteroids have terrestrial deuterium levels. The Earth was also born with some water as well. Of course, asteroid impacts can be deadly – just ask a dinosaur – but if asteroids did indeed give us most of our water, we might not exist without them.

[K. Altwegg et al, Science, DOI: 10.1126/science.1261952 (2014)]

Extracted with permission from an article at physics-world.com by Ken Croswell, a US-based astronomer and author of eight books on astronomy
BOOK REVIEWS

Engines of Discovery: A Century of Particle Accelerators
(Revised and Expanded Edition)
by Andrew M. Sessler and Edmund Wilson
World Scientific (2014)
Paperback, 280 pages

Reviewed by Greg LeBlanc
Head of Accelerator Science and operations, Australian Synchrotron

This book is a revised and expanded version which aims to address more thoroughly than the first version the many particle accelerators being used in practical applications rather than in the pursuit of knowledge in basic and applied research. Since the first edition the discovery of the Higgs particle and the worldwide attention to it will surely have caused more people to want to learn more about particle accelerators. This book is a good introduction to not only the particle accelerators and the different principles employed in their development, but also to the people that contribute to the constantly evolving field of accelerator physics. The first part of the book is a chronological history of the developments which ultimately aimed at more intense beams of particles at higher and higher energies. The second part of the book describes in more detail the applications of modern particle accelerators. The third part then looks forward to the future of particle accelerators.

The authors recognize in the preface that errors are inevitable in printing and there are quite a few. If one can ignore them then the text flows fairly well. The many biographical sidebars provide more information on the backgrounds of the people involved, both past and present, in particle accelerator development to those that are interested, but are not necessary to get the story. The sidebars on the technical concepts and laboratories add more to the overall reading experience.

It is interesting to note the statements about the LHC being the last of the large circular colliders at a time when China has just announced their intention to build an even larger one, while at the same time the authors point out instances where ‘conventional wisdom’ delayed some of the most important developments as people were discouraged from pursuing ideas thought to be dead ends by their seniors. The overall message that particle accelerators are and will continue to be important tools for civilization and enhance the collaborations between scientists and engineers around the globe still comes through and I would hope, as the authors intended, that this book will inspire people to enter the field and funding agencies to get a sense of the benefits of accelerators to society, both at home and as members of international collaborations.

A Single Sky: How an International Community forged the Science of Radio Astronomy
by David P. D. Munns
The MIT Press (2013)
Hardback, 247 pages

Reviewed by Peter Robertson, School of Physics, University of Melbourne

A Single Sky traces the emergence of radio astronomy after World War II. It examines the relationships among the various radio astronomy groups and, in turn, their relationship with the established community of optical astronomers. Munns is an Australian, a graduate of both the ANU and the University of Sydney, and currently teaches history at the City University of New York.

Munns states his thesis in the Introduction: “A Single Sky takes issue with the idea that recent science has been driven by competition. The radio astronomers understood science as an open, inclusive, international, interdisciplinary process, and their community succeeded because of cooperation. … Instead of a fractious world of science, the radio astronomers saw a single sky, unifying both nations and disciplines.”

Radio waves from space were discovered by the American radio engineer Karl Jansky in 1931, but the new branch of radio astronomy did not develop significantly until after the war, largely a result of major wartime advances in radio and radar technology. Much of Munns’ analysis focuses on the three major groups that emerged in the immediate postwar years: the CSIRO group in Sydney led by Joe Pawsey (the largest of the three), the group at the Cavendish Laboratory in Cambridge led by Martin Ryle and the group at the University of Manchester led by Bernard Lovell. It is interesting to note that all three group leaders were involved in wartime radar research, as indeed were many of the other early pioneers.

By the early 1950s new groups emerged in countries such as France, Germany and the Netherlands, while after a slow start the United States soon became a major player. According to Munns, the fact that radio and
optical astronomy relied on completely different technologies encouraged a culture of interdisciplinary and international integration and cooperation. The book has been thoroughly researched with Munns drawing on extensive archival material in Australia, England and the US. There is also a detailed bibliography which will be of value to other researchers working in this field.

Although I largely agree with Munns’s thesis, he has swept at least one inconvenient truth under the rug. It is well documented that Martin Ryle was obsessively secretive about his research, reluctant to visit other groups, and guarded as to who could visit the Cavendish Laboratory. Rather than the collegiate style of radio astronomy groups claimed by Munns, the cooperative model won out despite Ryle’s combative and competitive style.

Although there is a wealth of available material, the book has only a handful of photos and some are rather dull shots of radio telescopes. Perhaps the most interesting photo is the one on the cover (see above), showing the Australian radio astronomer John Bolton and a 32 ft dish on Palomar Mountain. In 1955 Bolton and his close colleague Gordon Stanley were hired by the California Institute of Technology (Caltech) to start a radio astronomy program. The dome of the 200-inch Hale telescope can be seen in the background, then the largest optical telescope in the world. Munns argues that the photo is strongly symbolic of the spirit of cooperation that arose between traditional optical astronomers and the new generation of radio astronomers.

The book follows in the footsteps of the well-known book Astronomy Transformed by David Edge and Michael Mulkay, published in 1976. Both books are primarily studies in the sociology of science where the development of radio astronomy is essentially a case study, one used to argue a particular point of view on the nature of science. As a result there is a fair amount of sociology jargon in the Munns book. As one example, Munns constantly refers to new recruits to the growing field of radio astronomy as ‘disciples’, a term that I’m sure will grate with some readers. Although the book is well written, there is some unnecessary repetition which could have been avoided with tighter editing by the publisher.

No doubt A Single Sky will be of interest to sociologists of science, but I suspect the readership of those interested in the history of radio astronomy may be somewhat limited.
PRODUCT NEWS

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WARSASH SCIENTIFIC

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FLEX™ is designed as a multi-functional tool able to acquire micro-scale images and spectra from the deep UV
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Warsash Scientific is proud to introduce the FLEX™ UV-visible-NIR microspectrophotometer concept from CRAIC Technologies. FLEX™ is designed to be, as its name suggests, flexible in configuration, capabilities and pricing. Tailored for cost effective spectroscopic analysis of many types of microscopic samples, FLEX™ operates from the deep ultraviolet to the near infrared. Depending upon the configuration of FLEX™, samples can be analysed by absorbance, reflectance, luminescence and fluorescence with high speed and accuracy. With FLEX™, you can also image microscopic samples directly with DirecVu™ optics and with high resolution colour digital imaging. There are also a number of packages that can be added to allow you to measure everything from the refractive index of microscopic samples to thin film thickness. Combined with CRAIC Technologies Traceable Standards, which are specifically designed for use with microspectrophotometers and calibrated using Standard Reference Materials from NIST, FLEX™ from CRAIC is built as a multi-functional tool for your laboratory and manufacturing facility.

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M²-200S now with USB 3.0 camera
Warsash Scientific are pleased to announce the release of the new M²-200S with USB 3.0 beam profiling camera from Ophir Photonics, global leader in precision laser measurement equipment and a Newport Corporation brand.

The M²-200S is a compact automated M² measurement system for UV-NIR laser beams. Integrating the new USB 3.0 based SP300 camera the upgraded M²-200S offers even more convenience for researchers and manufacturers alike. The M²-200S offers the following benefits:

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Not all commercial M² measuring instruments conform to the ISO 11146 method of employing a fixed position lens and moving detector. Instead, some manufacturers use a fixed position detector and a moving lens. If the laser beam is diverging or converging within the travel range of a moving lens, the reported M² value and other results can be significantly compromised. Spiricon’s M²-200s Beam Propagation Analyzer is fully ISO 11146 compliant.

For more information contact Warsash Scientific at sales@warsash.com.au

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John Greenhill passed away on 28 September 2014 after a short illness. John was a long-time member of the AIP and academic staff member at the University of Tasmania. A pioneer of X-ray astronomy in Australia as well as a determined hunter of planets via gravitational microlensing, his legacy is reflected in the naming of the “Greenhill Observatory” at Bisdee Tier, 60 km north of Hobart, officially opened on 23 February 2013.

John was the eldest of 7 children in a farming family from the north-west of Tasmania. After national service John chose to pursue an academic career, and graduated with honours in 1960 and a PhD in 1966 from the University of Tasmania.

John married Julia in April 1962 and in December that year travelled to Wilkes, Antarctica for the summer with ANARE. The ship, Nella Dan, couldn't get close enough to Wilkes to pick him up and he was told that he would have to stay for a year. This was not a great prospect for a recently married man but John had a way of overcoming adversity. At the end of March 1963 a Russian party flew in to Wilkes on a visit and took John with them back to the Mirny base. In Australia Julia and close friends were not allowed to talk to the press about his rescue due to tense relations following the expulsion of a Russian diplomat. The Russian icebreaker Ob also had difficulty getting close but eventually John left on 20th April for Cape Town, arriving on 2nd May. He then flew to Perth via Cocos Island, where he was reunited with Julia.

John was heavily involved in the University’s X-ray astronomy rocket program, conducted jointly with Adelaide University, launching from Woomera. Subsequently he led the balloon-borne X-ray program of the University of Tasmania. At this time (in the mid-1970s to early 80s) satellites were beginning to provide valuable observations below about 15-20 keV, but the observations above this energy were sparse. John’s group designed and built a 1-m X-ray telescope observing in the range 20-120 keV with good spectral resolution and fair spatial resolution. The telescope was successfully flown from Mildura and Alice Springs, and as a joint payload with instruments from Imperial College from Alice Springs and Brazil. Although dogged with setbacks, including parachute failures and a lab fire that destroyed most of the equipment, John always managed to recover the situation.

By the mid-1980s it was clear that satellites would dominate X-ray astronomy, and John switched fields to take over the operation of the University’s optical telescope facility at Mt Canopus adjacent to Hobart. John’s drive and leadership led to the observatory joining the international PLANET consortium in their searches for exoplanets using the gravitational microlensing technique. His optical work continued into his retirement from the mid-1990s. The observatory was increasingly compromised by the encroaching city lights, and John set about planning a new observatory at a better site. He successfully sourced donations of a 1.27 m primary mirror and funding, and negotiated with a farming land owner for a site on which to build the new observatory. John was involved in the management, construction and commissioning of the new “Greenhill Observatory”, which was opened on 23 February 2013 by the Governor of Tasmania, His Excellency the Honourable Peter Underwood. For his voluntary service to the University after his retirement John was, in 2012, the inaugural winner of the Vice-Chancellor’s Award for Outstanding Contributions by a Voluntary Position Holder.

John was an avid sailor, having sailed his new yacht with his young family from the UK to Australia, and regularly sailing around coastal Australia. He often took friends out on sailing trips. He was also a keen bushwalker. A man of great principles John had a strong social ethic. He was a Labor party member in his earlier years and a passionate advocate for the environment and renewable energy systems. John's death is a great loss to the Tasmanian astronomical community and the University of Tasmania, but he will be fondly remembered. He is survived by his wife Julia and daughters Lisa and Susie, and three grandchildren.
Arthur William Pryor

26 November 1928 – 31 August 2014

Arthur Pryor, can be described as a true Renaissance man who was involved in cutting edge physics/engineering, an educator and mentor, passionate about music and theatre and an avid reader. While he never married his personal life revolved around family and close friends. He was born in Baralaba (near Mt Morgan) in Queensland, the first son and third child to Joseph and Ivy (nee Gore) Pryor. His childhood while impoverished even by depression standards was largely happy and intellectually stimulating. Details can be found in his memoir http://hewat.net/science/Arthur_Pryor_Memoirs-SCIENTIST_FROM_A_QUEENSLAND_BUSH_TOWN.html

At the end of 1941, Arthur won a scholarship to attend high school in Rockhampton. He completed the Queensland Senior Public Examination in 1945 coming 5th in the State and won an Open Scholarship to the University of Queensland where he studied Engineering and Science.

In late 1950 he was employed by the Department of Supply who sent him to Kings College of Durham University to undertake his PhD studies in field of ultrasonics. The period from 1953 to 1956 Arthur worked in the UK and later in New Zealand on underwater acoustics. He joined the Australian Atomic Energy Commission in January 1957 and remained there until August 1984.

At the Commission, Arthur initially worked on the electronics of neutron detection, then became involved with the Beryllium Oxide program and published papers in ‘Nature’ for which he was jointly awarded the 1964 Syme Prize of the University of Melbourne. He designed and constructed several computer controlled diffractometers. Despite his early use of computers for engineering purposes he never owned a personal computer and refused to get email.

In 1966 and 1969 he went to Harwell to work on thermal vibrations in crystals that lead to a book which he co-authored with Terry Willis, ‘Thermal Vibrations in Crystallography’. By 1975, Arthur became attracted to the new method of uranium enrichment by lasers, for the next five years he worked on this. In 1980’s the Commission went through a number of administrative changes and Arthur finally left the Commission in 1984.

From 1970, Arthur had a part time appointment at Macquarie University where he remained until his retirement in 2005. One of his lecture courses, ‘The Traditions of Science’ attracted a steady stream of students from all disciplines for over 20 years! From August 1980 to March 1983 Arthur gave a number of talks on the History of Science on the radio station 2SER-FM. Arthur also had me as his only research student who after completing a research Masters continued with a Scholarship to complete a PhD. This PhD was awarded a Vice Chancellor’s Commendation and was short listed in the Eureka Awards for Science Communication. He was quite proud of me and we remained friends.

Arthur was recognised for his historical scholarship by being invited to write the entry on Stuart Butler for the Australian Dictionary of Biography (ADB).

Arthur was a member of the AIP from its beginnings, serving as NSW Branch Chair in 1968 and 1969 and on the National Executive as Registrar from 1985 to 1989. During his period as Registrar he noticed that a large number of graduates had not upgraded their membership to full membership, so he decided to send them a congratulatory letter on their promotion to member of the AIP and a new membership renewal. Most were flattered and paid their full membership.

By 2013 he knew that the cancer he had developed would be terminal, he slowly divested himself of his extensive library, carefully matching books with their recipients and even commissioned me to write this Obituary. Arthur, like many physicists, felt that much of his work was no longer relevant. He had worked at the cutting edge of technology which never remains the same and he forgot that his work and that of his contemporaries are the giants on whose shoulders the young can stand and look into the future. Arthur’s was a life well lived; he had a close band of friends and family, he had the freedom to choose many of his research projects work pursuits and he had the time to experience the cultural aspects of life.

Anna Binnie
2015 WOMEN IN PHYSICS LECTURE TOUR
CALL FOR NOMINATIONS

The Australian Institute of Physics Women in Physics Lecture Tour celebrates the contribution of women to advances in physics. Under this scheme, a woman who has made a significant contribution in a field of physics will be selected to present lectures in venues arranged by each participating state branch of the AIP. Nominations are currently sought for the AIP WIP Lecturer for 2015. We are seeking a woman working in Australia who

- has made a significant contribution in a field of physics research
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Presentations will include school lectures, public lectures and research colloquia, subject to negotiation with the various AIP state branches and their contacts. School and public lectures are expected to be of interest to non-specialist physics audiences, and to increase awareness among students and their families of the possibilities offered by continuing to study physics. University lectures will be presented at a level suitable for the individual audience (professional or graduate). Air travel and accommodation will be provided.

Nominations should be sent via mail or email to the AIP Special Projects Officer (see information below) via the nomination form available from the Women in Physics Lecturer page of the AIP website, http://www.aip.org.au/info/. Self-nomination is welcomed, as are nominations from branches or employers/colleagues. Self-nominations should include names of two referees who can attest to the ability of the nominee to give lectures appropriate for the target audience.

Closing Date: 27th February 2015

Applications and nominations should be sent by email or mail to:
AIP Special Projects Officer,
Dr Olivia Samardzic,
205 Labs, EWRD, DSTO,
P.O. Box 1500,
Edinburgh, SA 5111.
Email: olivia.samardzic@dsto.defence.gov.au

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