

Nanoscale

Characterisation & Fabrication



Warsash Scientific

Advanced Instruments for Research & Industry

Advanced Functional Coatings

Scalable Atomic Layer Deposition (ALD) Thin Film
Deposition Systems
Thermal and Plasma Enhanced ALD

Thin Film Measurement

Non-contact Thin-film Measurement using Spectral
Reflectance: 1nm to 3.5mm
Refractive Index, Absorption and Deposition Rate
Measurement

Nanopositioning

Piezoelectric Flexure Stages
High Speed Scanning Systems
Nanometrology & Nanomaterials Testing

Raman Spectroscopy

Raman Microspectrometers
Combined Raman-SEM, PL, CL, NSOM, AFM, TERS, FTIR
Confocal Fluorescence Systems

Advanced Mechanical Testing

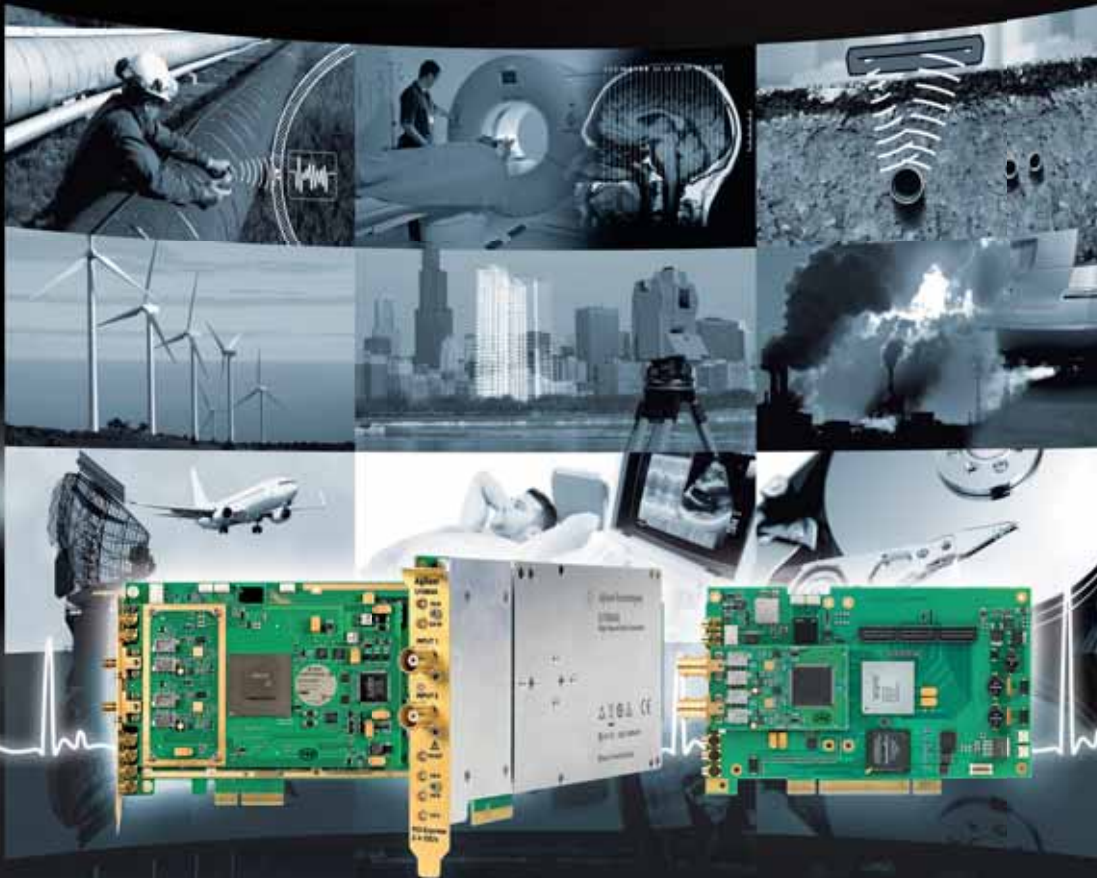
Nano and Micro Scale Instrumented Indentation
Nano, Micro and Macro Scratch Systems
Ball/Pin-on Disk, High Temperature, Nano and Vacuum
Tribology Systems

Contact

Warsash Scientific Pty Ltd
t: +61 2 9319 0122
sales@warsash.com.au



Integrate Agilent's proven analog-to-digital technology into your design.



Seamlessly design-in Agilent's high-speed technology to fulfill your product requirements, while maintaining your in-house technical know-how and intellectual property. Reuse and upgradability of both hardware and software reduces your risk, protects your investment and gets your products to market faster.

Be First — with Agilent

Explore the range of high-speed digitizers

500 MSa/s to 8 GSa/s on one or more channels

Resolution of 8, 10, 12 or 14 bits

Bandwidths of up to 3 GHz

Flexible acquisition memory

Fast throughput with on-board real-time processing

Discover the Alternatives ...  ... Agilent Modular Products

Select and compare the digitizer that best fits your need.

www.agilent.com/find/embedded-digitizers



CONTENTS

- 100 Editorial**
Congratulations to the SKA team

- 101 President's Column**
The SKA – A bright future for Australian science

- 102 News & Comment**
Centenary of Antarctic science
Rethink on the origin of cosmic rays
New upper limit to the neutrino mass
Jim Williams awarded Academy's Lyle Medal

- 104 Letters to Editor**

- 106 The missing Apollo 11 tapes**
John Sarkissian recounts the attempt by his team of sleuths in Australia and the United States to track down the original high-quality TV footage of the Apollo 11 moonwalk

- 113 Samplings**
Physics news that caught the eye of Don Price

- 116 Space weather**
Dave Neudegg describes the work of Australia's Ionospheric Prediction Service in monitoring and forecasting the solar-terrestrial space environment

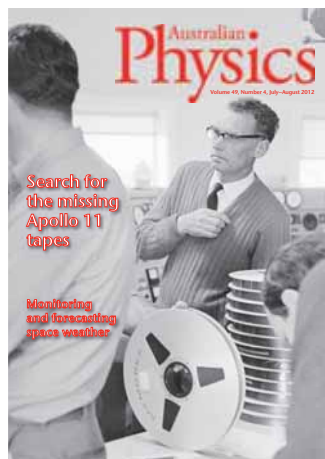
- 121 Obituary**
Jak Kelly (1928–2012) by David Mills

- 123 Book Reviews**
Joss Bland-Hawthorn on 'Celebrating the AAO: Past, Present and Future' by Russell Cannon and David Malin (eds)
Ben Watson on 'Emu Dreaming: An Introduction to Australian Aboriginal Astronomy' by Ray and Cilla Norris

- 125 Product News**
A review of new products from Lastek, Warsash Scientific, Coherent Scientific and Agilent Technologies

Inside Back Cover

Australian Institute of Physics Congress for 2012



Cover

Chief of the CSIRO Division of Radiophysics, Taffy Bowen, in the control room at Parkes during Apollo 11 [see p.106]. Bowen was the driving force behind the construction of the Dish. [courtesy: CASS]

Australian Institute of Physics

Promoting the role of physics in research, education, industry and the community

AIP website: www.aip.org.au

AIP Executive

President Dr Marc Duldig

Marc.Duldig@utas.edu.au

Vice President Dr Robert Robinson *Robert.Robinson@ansto.gov.au*

Secretary Dr Andrew Greentree *andrewg@animelb.edu.au*

Treasurer Dr Judith Pollard

judith.pollard@adelaide.edu.au

Registrar Dr John Humble

john.humble@utas.edu.au

Immediate Past President A/Prof Brian James

b.james@physics.usyd.edu.au

Special Projects Officers

Prof Warwick Couch

wcouch@swin.edu.au

Dr Olivia Samardzic

olivia.samardzic@dsto.defence.gov.au

AIP ACT Branch

Chair Dr Anna Wilson

anna.wilson@anu.edu.au

Secretary Joe Hope

joseph.hope@anu.edu.au

AIP NSW Branch

Chair Dr Scott Martin *Scott.Martin@csiro.au*

Secretary Dr Frederick Osman

fred_osman@exemail.com.au

AIP QLD Branch

Chair Dr Joel Corney

corney@physics.uq.edu.au

Secretary Dr Till Weinhold *weinhold@physics.uq.edu.au*

AIP SA Branch

Chair Dr Scott Foster

scott.foster@dsto.defence.gov.au

Secretary Dr Laurence Campbell *laurence.campbell@flinders.edu.au*

AIP TAS Branch

Chair Dr Elizabeth Chelkowska

Elizabeth.Chelkowska@environment.tas.gov.au

Secretary Dr Stephen Newbury *Stephen.Newbury@dhhs.tas.gov.au*

AIP VIC Branch

Chair Dr Andrew Stevenson *Andrew.Stevenson@csiro.au*

Secretary Dr Mark Boland *Mark.Boland@synchrotron.org.au*

AIP WA Branch

Chair A/Prof Marjan Zadnik *m.zadnik@curtin.edu.au*

Secretary Dr Andrea Biondo *andreaatuni@gmail.com*

Printing

Pinnacle Print Group

288 Dundas Street, Thornbury VIC 3071

www.pinnacleprintgroup.com.au

Australian Physics

A Publication of the Australian Institute of Physics

EDITOR

Peter Robertson
prob@unimelb.edu.au

ASSISTANT EDITOR

Dr Akin Budi
abudi@unimelb.edu.au

BOOK REVIEWS EDITOR

Dr John Macfarlane
jcmacfarlane@netspace.net.au

SAMPLINGS EDITOR

Dr Don Price
don.price@csiro.au

EDITORIAL BOARD

A/Prof Brian James (Chair)
brian.james@sydney.edu.au

Dr M. A. Box

Dr J. Holdsworth

A/Prof R. J. Stening

Prof H. A. Bachor

Prof H. Rubinsztein-Dunlop

Prof S. Tingay

ASSOCIATE EDITORS

Dr John Humble John.Humble@utas.edu.au

Dr Laurence Campbell laurence.campbell@flinders.edu.au

Dr Frederick Osman fred_osman@exemail.com.au

Dr Wen Xin Tang wenxin.tang@monash.edu

SUBMISSION GUIDELINES

Articles for submission to *Australian Physics* should be sent by email to the Editor: prob@unimelb.edu.au. The text should be sent as a Word file and authors are advised to consult a recent issue as a guide to style. Images should not be embedded in the document, but should be sent as high resolution attachments in JPG or PNG format. Authors should also send a short bio and a recent photo. The Editor reserves the right to edit articles based on space requirements and editorial content. Contributions should be sent to the Editor.

ADVERTISING

Enquiries should be sent to the Editor.

Published six times a year.

© 2012 Australian Institute of Physics Inc. Unless otherwise stated, all written content in *Australian Physics* magazine is subject to copyright of the AIP and must not be reproduced wholly or in part without written permission.

The statements made and the opinions expressed in *Australian Physics* do not necessarily reflect the views of the Australian Institute of Physics or its Council or Committees.

Print Post approved PP 224960 / 00008

ISSN 1837-5375

PRODUCTION

Control Publications Pty Ltd
 Box 2155 Wattletree Rd PO, VIC 3145.
science@control.com.au

100 AUSTRALIAN PHYSICS

EDITORIAL

Congratulations to the SKA team



With the recent announcement that the Square Kilometre Array will be shared between Australia–New Zealand and southern Africa, I felt similar to the way I did after the AFL Grand Final in 2010. My team St Kilda had just drawn the game with its arch-rival Collingwood. On the one hand I felt relief that we had not lost the game, but on the other hand a sort of hollow despair that we had come so agonisingly close to the ultimate prize.

And so it was with the SKA. The relief was genuine, especially after news was leaked in mid-March that the SKA Site Advisory Committee had narrowly recommended southern Africa to the SKA governing board. Until then most commentators had believed that the Australasian bid was the superior one – at least on scientific grounds, though not necessarily political grounds. At that stage there had been no talk about splitting the SKA between the two sites, so it looked likely that we might miss out altogether.

I would like to echo Marc's words opposite and say what a tremendous boost the SKA will be to Australian physics and astronomy. The SKA will undoubtedly be the biggest thing that has ever happened in Australian science. We heartily thank Professor Brian Boyle and the large bidding team from CSIRO and several universities for their efforts over a long period of time in securing our share of the SKA. Our warmest congratulations go to you all.

The theme of this issue is decidedly space science and astronomy and I can recommend both our feature articles. Operations scientist at Parkes, John Sarkissian, tells the fascinating story of the attempts to hunt down the missing tapes of the Apollo 11 moonwalk. Next, Dave Neudegg from the Ionospheric Prediction Service describes Australia's contribution to monitoring and forecasting space weather.

This will be my last issue as Editor of *Australian Physics*. It has been both a privilege and a very rewarding experience to be Editor. The publication of the magazine has been very much a team effort. In particular, I would like to thank our Book Review Editor John Macfarlane, Samplings Editor Don Price, and Editorial Board chair Brian James. Thanks also to Guy Nolch whose talent and experience as a publisher have done much to improve the quality and presentation of the magazine. Finally, a special thanks to our Production Editor Akin Budi who I have enjoyed working with very much. I wish him well in his future career in physics.

Peter Robertson

49(4) | JULY–AUGUST 2012

PRESIDENT'S COLUMN

The SKA – A bright future for Australian science

And so the SKA site decision is in! One media commentator described it as a 'Solomonic' decision. Perhaps that was written for the wrong reasons – the decision was most certainly not simply a politically expedient one. It also made a lot of sense on many other levels. Both the Australasian and Southern African bids for the Square Kilometre Array had already expended significant capital on their respective 'pathfinder' systems and infrastructure. The decision to split the SKA by frequency took advantage of these existing systems and the expertise already in place for them.

instrument on the planet at our front door.

It will be critical in answering questions best addressed by deep large scale survey work for which the low frequency arrays are most suited, such as the evolution of matter, dark matter and dark energy and the epoch of first star and galaxy formation. These are fundamental questions in astrophysics and cosmology that when addressed will influence many other branches of physics.

It is an exciting time for Australian science and the SKA will be the training ground for a fair percentage of our physical science postgraduates for



Australian science and Australian international prestige.

On another matter, some of you will have seen a call to AIP members for expressions of interest in becoming the Editor of this magazine in my last monthly electronic bulletin. Peter Robertson has decided to move on from the Editor's role and we owe him an enormous debt of gratitude for his services over the past two years. When Peter took over we were a long way behind schedule in publishing issues and had to catch up six months (three issues) in as short a time as possible. Peter established a team approach that saw the backlog of three issues plus a further nine produced in 18 months so that today we are pretty much publishing the issues in the first month of the bi-monthly cover date.

On top of that we have seen further design improvements continuing the process started by his predecessor that have given us an extremely professional magazine that we can all be proud of. Thank you Peter plus your able team of Akin and Guy for the developments, the quality work and the dedication to professionalism in publishing that has set us in such good stead for your successors to follow on with.

Marc Duldig

“The SKA will likely be the Australian focus of radio astronomy for the next several decades with the most advanced low frequency instrument on the planet at our front door.”

Although the overall cost of the SKA will be slightly higher than a single site solution, due to the duplication of some infrastructure, there will be little if any loss of science. Partnerships on both sides of the Indian Ocean will have a major international facility and both will see construction and development expenditure. It will be a huge impetus for science in Southern Africa but the impact here shouldn't be underestimated either. The SKA will likely be the Australian focus of radio astronomy for the next several decades with the most advanced low frequency

the next 30–50 years. It will also see us having to develop advanced communication and large data processing capabilities, some of which cannot be constructed with today's technology. This will draw from and in turn will feed back into industry and the solutions will generate commercial applications that we are yet to imagine. We should recognise the insight and support of the Federal Government and several Science Ministers in seeing this through and committing funding to the project precursors and to the next stage. All in all this is a wonderful and welcome outcome that will boost

NEWS & COMMENT

Centenary of Antarctic science

As to the Antarctic ... almost every observation would be fresh material added to the sum of human knowledge

These are the words of explorer Douglas Mawson, who led a team of men (mostly scientists) into an unknown part of Antarctica in 1911. His venture, the Australasian Antarctic Expedition of 1911–14, opened new and exciting opportunities for scientific exploration and endeavour.

To mark the centenary the Australian Academy of Science organised a one-day symposium ‘100 Years of Antarctic Science’, held at the Shine Dome in Canberra in early May. Mawson was a founding Fellow of the Academy. He knew that Antarctica and the Southern Ocean are significant influences on Australia’s weather. The symposium celebrated a century of scientific endeavour and also acknowledged that, 100 years after Mawson’s pioneering expedition, there is still much to learn.

One of the speakers was Dr Charles Barton from the Research School of Earth Sciences at the Australian National University. Barton has the unique distinction of being first and only person to reach both the Earth’s magnetic poles.



Dr Charles Barton (ANU) with the magnetic field sensor used to detect the South Magnetic Pole in the year 2000.

Both North and South Magnetic Poles drift gradually from year to year at a rate varying from a few to tens of kilometres per year. Superimposed on this, is a daily motion varying from 10 km to hundreds of kilometres depending on the state of magnetic disturbance produced by the Sun.

Barton notes: “As the poles are in continuous motion, it is not possible to get an exact spot measurement of a

pole’s position, or claim that you are precisely at a magnetic pole. I’ve been very fortunate in having the opportunity to get close to both magnetic poles.”

“The first journey to the North Magnetic Pole by James Ross in 1831 and that of Douglas Mawson, Edgeworth David, and Alistair Mackay to the South Magnetic Pole in 1909 were both astonishing epics.” While the Englishman Ross succeeded in the north, he was thwarted in 1840 from reaching the South Magnetic Pole when his path was barred by the Transantarctic Mountains.

Barton’s story started in 1985 when an invitation by entrepreneur Dick Smith to be the ‘magnetician’ aboard his inaugural Australian tourist flight over Antarctica, triggered his interest. He developed a novel, low-cost magnetic field sensor for locating the South Magnetic Pole at sea. Unfortunately he had to withdraw from the expedition for medical reasons, but his technique was used successfully by his team to get within 11 km of the pole.

In 1994, Barton reached the North Magnetic Pole with Larry Newitt of the Canadian Geological Survey when they came within 3 km of the pole – the closest ever recorded, beating Ross’ record set 169 years earlier by a small margin.

Success in the south finally came in 2000 when he and Don McIntyre came within 1.6 km of the South Magnetic Pole in a private expedition aboard the *Sir Hubert Wilkins*, sponsored by Dick Smith Foods.

The Academy symposium brought together national and international experts who have worked in Antarctica on subjects as diverse as physics, genetics, geology, meteorology, biology, glaciology and climate change. There was also a book launch of ‘Still no Mawson: Frank Stillwell’s 1911–13 Antarctic Diaries’, published by the Academy.

Rethink on the origin of cosmic rays

An international team has produced surprising results about one of the most enduring mysteries in physics – the origin of cosmic rays. First discovered 100 years ago by Victor Hess (Nobel Prize for Physics in 1936), cosmic rays are electrically charged particles, such as protons, with energies up to 100 million times higher than those produced in accelerators such as CERN in Switzerland.

Physicists have focused their interest on two potential sources: the massive black holes at the centre of active galaxies, and the exploding fireballs observed by astronomers known as gamma-ray bursts. The most powerful explosions known in the Universe, GRBs are usually de-

tected initially by satellites observing their X-ray and/or gamma-ray emission. New GRBs are seen about once per day, and are so bright that they can be detected halfway across the visible Universe. The explosions usually last only a few seconds, and during this brief time they can outshine anything else in the Universe.



Dr Gary Hill (University of Adelaide) and one of the C130 planes used to ferry personnel and equipment from the coastal McMurdo station to the IceCube Neutrino Observatory at the South Pole [credit: John Jacobsen].

The IceCube Neutrino Observatory, a massive detector in Antarctica, is studying the neutrinos which are believed to accompany cosmic ray production. IceCube observes neutrinos by detecting the faint blue light produced by neutrino interactions in ice. To detect these interactions, IceCube is built on an enormous scale with 5160 optical sensors embedded up to 2.5 km deep in the ice, spanning a volume of one cubic kilometre of glacial ice. Completed in December 2010, IceCube is operated by a collaboration of ten countries, including Australia and New Zealand.

Dr Gary Hill, an ARC Future Fellow in the School of Chemistry & Physics at the University of Adelaide, is a member of the IceCube collaboration. He has spent seven Antarctic summers working at the observatory and has visited Antarctica a total of 12 times.

In a paper published in April in *Nature*, the IceCube collaboration describes a search for neutrinos emitted from 300 GRBs, observed between May 2008 and April 2010. Surprisingly, they have found no evidence of neutrinos – a result that contradicts a long-standing prediction.

“This is the most important result so far from the IceCube Observatory,” says Hill. “Gamma-ray bursts don’t seem to make neutrinos as we previously thought, which means they probably aren’t making cosmic rays either.”

The unexpected absence of neutrinos has forced a re-evaluation of the theory on production of cosmic rays

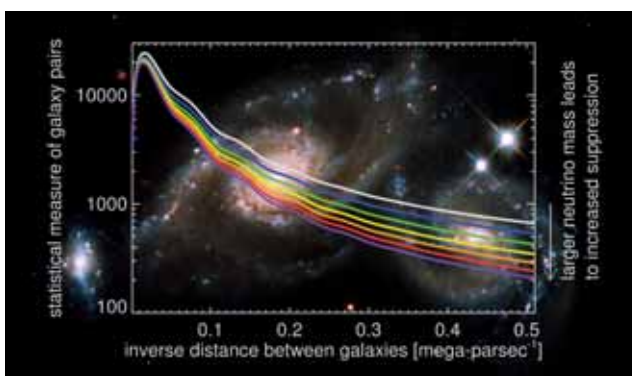
and neutrinos in a GRB fireball. Hill adds: “This result has implications for other experiments around the world, including experiments like the Auger cosmic ray observatory in western Argentina that researchers in Adelaide are involved in. It will help to focus the search for the origin of cosmic rays even further.”

New upper limit to the neutrino mass

An international team lead by Australian researchers has provided evidence that the neutrino mass can be no larger than 0.29 eV, the tightest constraint placed so far on its mass. The study, published in May in *Physical Review D*, concludes that cosmological galaxy measurements are more effective than terrestrial laboratory experiments when it comes to constraining the neutrino mass.

Lead author of the study, Dr Signe Riemer-Sørensen of the School of Mathematics and Physics at the University of Queensland, said this new study would allow researchers to gain a more accurate picture of the neutrino mass, and this could ultimately lead to new cosmological understanding. “This research paves the way for more sensitive future galaxy surveys to understand the mysterious workings of the Universe, and will help in new advancements such as improved models of supernova explosions and in designing neutrino telescopes that can probe much more distant objects than classical telescopes,” said Riemer-Sørensen.

Although laboratory experiments on Earth so far have been able to measure the differences in the masses between the various types of neutrinos, they have been



From the three-dimensional WiggleZ galaxy map, the team measured a statistical number related to the number of galaxy pairs with a given separation. The tail of this distribution depends theoretically on the neutrino mass as illustrated by the different coloured lines. The greater the mass, the more neutrinos will suppress the formation of galaxy pairs with short distances (ie. large inverse distances measured in inverse mega-parsec). [credit: NASA, ESA and M. Livio and the Hubble Heritage Team (STScI/AURA)]

LETTERS

Dear Editor,

The March/April issue of *AP* contains much thought-provoking material. We read first in the President's Column ('Where are the legislative checks and balances?') of a potentially disastrous piece of legislation that was narrowly avoided. It would have placed serious constraints on the carrying out of much research and teaching involving overseas collaborators. Then we have two outstanding feature articles, 'Electromagnetism: Does its strength vary across the Universe?' by Michael Murphy, and 'Precision sensing: A new role for trapped ions' by Michael J. Biercuk. Both these articles convincingly demonstrate that world-class leading-edge research is alive and well in Australian physics. They also give due warning that the above-mentioned legislation, if allowed to pass into law, could so easily have stifled such work, relying as it does, on strong interactions between Australian and overseas personnel and establishments.

Sincerely,
Dr John Macfarlane
Launceston, TAS

Dear Editor,

I have recently published a research paper in the *Sri Lankan Journal of Physics*, a refereed web-based open-access journal. The existence of this journal was brought to my attention by its editor, a former workplace colleague.

Sri Lanka is not a rich country, and a civil war that has riven it for many decades has only recently ended. By contrast, due to the mining bubble, Australia is one of the richest of countries and its political stability is the envy of the world. It is therefore strange, some might think regrettable, that Sri Lanka has a national physics journal while Australia, with a much greater physics base, does not.

Sincerely,
Dr Andrew Stewart
(<http://grapevine.net.au/~a-stewart/index.html>)

Editor's note: The *Australian Journal of Physics*, Australia's only research journal for physics, ceased publication in 2001. The journal had its origins in the *Australian Journal of Scientific Research, Series A*, begun by CSIRO in 1948. In 1953 this journal was split into the *Aust. J. Phys.* and the *Australian Journal of Chemistry*. In turn, these two journals became part of a stable of eleven national journals published by CSIRO Publishing under a long-standing agreement between CSIRO and the Australian Academy of Science. In 2001 the management of CSIRO Publishing claimed that publishing the *Aust. J. Phys.* was no longer economically viable. Despite strong arguments that the journal should continue in the national interest of physics in Australia, CSIRO Publishing decided to shut the journal down.

unsuccessful in measuring the absolute neutrino mass with sufficient sensitivity.

Using the Universe as a large particle physics experiment, the team was able to limit the range of possible neutrino masses by understanding how galaxies form. "One of the major challenges is that galaxy formation is not well-described theoretically. We have tested a range of previously used theories and demonstrated that most of them are not precise enough to use with present and upcoming galaxy surveys, with the much-desired higher level of sensitivity to the neutrino mass," said Riemer-Sørensen.

Using high-quality data from the team's WiggleZ Dark Energy Survey – a massive three-dimensional galaxy

map of 240,000 galaxies [see the article by Chris Blake in *AP* **48**, 149–53 (2011)] – the researchers applied a mixture of analytical modelling and simulation to achieve their results. "Despite the modelling challenges, cosmology does a much better job than laboratory experiments when it comes to constraining the neutrino mass," she said. The team is currently working on refining the neutrino mass measurement by combining its results with other independent data sets, using measurements from other groups. The team includes researchers from the US, Canada and South Africa, as well as from the Australian Astronomical Observatory, CSIRO, and the ANU, Monash, Sydney and Swinburne universities.

Lyle Medal awarded to Jim Williams

Professor Jim Williams has been awarded the Lyle Medal for 2011 by the Australian Academy of Science. The medal commemorates the contribution of Sir Thomas Ranken Lyle (FRS) to Australian science and industry generally, and in particular to his own fields of physics and mathematics.

Williams obtained his PhD from the University of NSW in 1973 and spent several years in Europe and the US (including the Bell Telephone Labs) before returning to Australia in the late 1970s. He was Director of a Centre of Excellence at RMIT from 1982 before joining the ANU as the Founding Professor of the Department of Electronic Materials in 1988. He is currently the Director of the Research School of Physics and Engineering at the ANU. His research is in the broad field of condensed matter physics with a focus on semiconductors and applications. He has published over 450 journal papers and has served on the editorial board of more than ten international journals.

It is well known that carbon possesses a number of allotropes such as diamond and graphite that have distinctly different structures and properties. Silicon also has up to 13 allotropes with distinctly different structures, which is not as well known probably because they are only accessible by the application of high pressure. It is the diamond cubic form of silicon, the only truly stable phase, that exhibits the attractive suite of properties



Professor Jim Williams (ANU)

that give the current functionality of the silicon chip.

However, it has recently been shown that at ambient temperatures and pressure there are up to four other phases of silicon that are metastable. Research by Williams' group over the past 15 years has provided the basis for understanding the transformation processes that lead to these phases, their stability and in some cases their unusual properties.

Editor's choice

We can highly recommend the DVD featured in the following article by John Sarkissian. The DVD contains the complete 2009 restoration of the historic TV broadcast, produced by NASA for the Apollo 11 40th Anniversary. It includes newly discovered footage not seen by the public since 1969.

The bulk of the footage was sourced from signals received by the CSIRO Parkes dish, but it also includes new, never-before-seen footage sourced from the Honeysuckle Creek tracking station near Canberra.

In 2009 NASA contracted the Californian company Lowry Digital – a pioneer in video enhancement – to process and restore the recordings. The result is the best and most complete video record yet of the three-hour moonwalk. The stereo soundtrack records the conversations between Armstrong and Aldrin on the lunar surface and Flight Command in Houston.

At \$24.95, including handling and postage, the DVD is a bargain. All proceeds will go toward the continued search and restoration of the other Apollo mission videos. You can order your copy at www.apollo11video.com.



Search for the Missing Apollo 11 Tapes

John Sarkissian

It was one giant leap for mankind and it was taken at 12:56 PM (AEST) on 21 July 1969. Six hundred million people, one sixth of mankind at the time, witnessed the Apollo 11 moonwalk live on television. As a six-year old school boy, I was one of those millions. Sitting cross-legged on the floor of the school assembly room with my fellow first graders, we watched the events unfold on a small black and white television screen perched at the front of the assembly room. We were spellbound by the dark, fuzzy images flickering on the screen. How did they do it? How did those pictures get from the Moon to my Sydney school? Why were the pictures so dark and ghostly looking?

Little did I know then, but three decades later I would find myself working at the CSIRO Parkes Observatory, at the very place those images were received and that I would have the opportunity to answer those childhood questions. This article is a personal account of my research into the Parkes support of Apollo 11 and how it eventually morphed into a search for the missing Apollo 11 tapes. It's been a roller-coaster ride, with many highs and lows plus a few twists and turns to make it interesting. Along the way, I've met many fine and dedicated people, some of whom are now close friends. This is our story.

Some background

At 12:54 PM (AEST) Buzz Aldrin switched on the lunar module camera that would transmit the TV pictures of Armstrong descending the lunar module ladder. Three tracking stations received the signals simultaneously. They were the 64-metre Goldstone antenna in California, the 26-metre antenna at Honeysuckle Creek near Canberra and the CSIRO 64-metre dish at Parkes. The signals were relayed to Houston, where a controller selected what he thought were the best pictures for release to the US television networks and distribution to a worldwide audience.

In the first few minutes of the broadcast, Houston

alternated between its two stations at Goldstone and Honeysuckle Creek, searching for the best quality pictures. When they finally switched to Parkes, the pictures were so much better that they stayed with Parkes for the remainder of the 2½ hour moonwalk. From an analysis of the videotapes of the Extra Vehicular Activity (EVA) and of a recording of the NASA NET 2 communications loop (which controlled the TV reception), the timings for the TV switches are shown in the table.

Time (mm:ss)	Video Transmission
00:00	TV on (upside down) Picture is from Goldstone (GDS). Time is 02:54:00 (GMT)
00:27	Picture is inverted and is now the right way up. Very dark, high contrast image
01:39	Houston TV switches to Honeysuckle Creek (HSK)
02:20	Armstrong steps onto the Moon. The time is 02:56:20 (GMT)
04:42	Houston TV switches back to GDS. Picture is negative
05:36	Houston TV switches back to HSK
06:49	Houston TV switched back to GDS. Picture is positive again but still dark
08:51	Houston TV switches to Parkes (PKS). Remains with Parkes for the remainder of the 2½ hour lunar EVA

From these timings, and other evidence, it is clear that at the start of the EVA, Goldstone was experiencing problems with its TV, resulting in high contrast, dark images. The

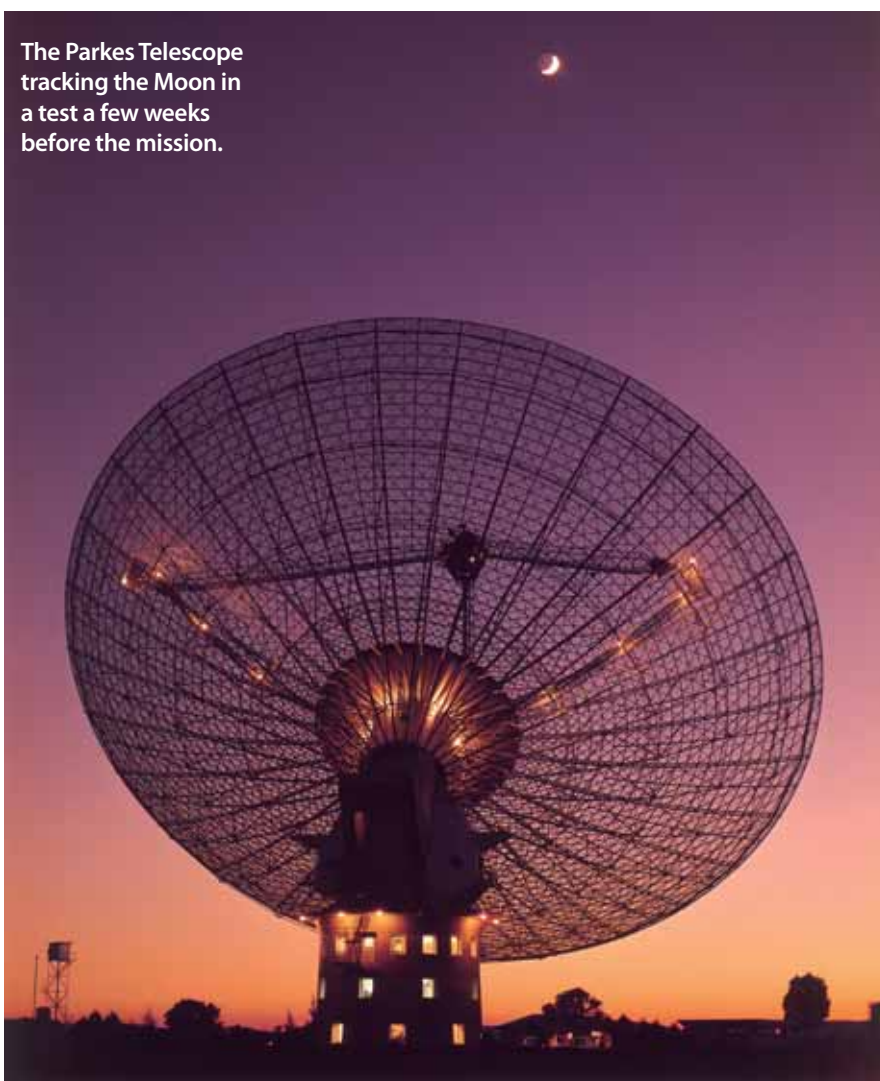
Honeysuckle Creek pictures were better but they suffered from a lower signal-to-noise ratio, thus resulting in grainier images. The pictures from Parkes were the best of the three and it was these that NASA broadcast for the majority of the lunar EVA.

Television from the Moon

The Apollo Lunar Surface Camera was developed by Westinghouse and was a technological marvel of its time. The lunar module was power and bandwidth limited, so it was not possible to transmit commercial standard TV directly from the Moon. Instead, a slow-scan TV (SSTV) system was used that required less power and bandwidth. The SSTV system transmitted b/w pictures at 10 frames-per-second with only 320 lines-per-frame. In order to broadcast this to the watching world, it had to be scan-converted on Earth to commercial TV standards. An RCA scan-converter was used that operated on an optical conversion principle. It was a simple system that worked well on previous Apollo missions. Essentially, as each single SSTV frame was received on Earth, it was displayed on a small 10-inch b/w slow-scan monitor. A Vidicon camera was pointed at the screen and imaged the frame at the standard commercial TV frame rate. It was the output of this camera that was broadcast to the world. In this way, a 30 frames-per-second, 525 lines-per-frame, TV picture was achieved. As you can imagine, it's not an ideal method of scan-converting the pictures but it seemed adequate at the time.

The Goldstone TV was scan-converted on site and relayed directly to Houston via microwave relays and landline. The Honeysuckle Creek TV was scan-converted on site also, and relayed to the Overseas Telecommunications Commission (OTC) Paddington terminal in Sydney, referred to as 'Sydney Video'. Meanwhile, the Parkes baseband signals were relayed to Sydney Video, where the TV was separated from the telemetry stream and scan-converted there. At Sydney Video, a NASA controller would select the best of the Honeysuckle Creek or Parkes pictures, and pass that selection on to Houston. His selection would simultaneously be recorded onto 2-inch videotape on an

The Parkes Telescope tracking the Moon in a test a few weeks before the mission.



Ampex VR660 recorder. The selected TV would be sent via microwave relays to the Moree Earth Station in northern NSW, then via the Intelsat III geostationary satellite to the United States and then finally along the AT&T landlines to Houston. At Houston, the controller would select the best of the Goldstone or Australian feeds for worldwide distribution. In a further twist, the Australian selection at Paddington was split and sent to the ABC Gore Hill studios for distribution to Australian networks. Consequently, the Australian TV did not have to travel via satellite to the US and back again. This meant that a transmission delay was not present, so Australian audiences watched the moonwalk 300 milliseconds before the rest of the world!

It is clear that scan-converting the SSTV and relaying it to the world was not an ideal situation. Firstly, the picture being displayed on the scan-converter monitor had to be adjusted manually. This was a subjective exercise, as the scan-converter operator had to adjust the brightness and contrast settings to what he thought produced the best looking picture. Unfortunately, the operator at Goldstone was inexperienced, and with the pressure of the moment,



Sydney Video at the OTC Paddington Terminal. The RCA scan-converter is in the background with Elmer Fredd seated in front (red jacket). The TV comparison equipment is in the foreground, and the VR660 recorders are just off to the right. [courtesy: Richard Holl].

he got it wrong. At Sydney Video, the operator, Elmer Fredd, was vastly more experienced. He had helped design the scan-converter and knew it well. In December 1968, he had converted the TV pictures from Apollo 8 at Goldstone. It was no accident therefore, that the Parkes pictures looked the best. In addition, the slow-scan monitors in the scan-converters used high persistence phosphor screens so that the pictures could persist long enough for the Vidicon camera to image them. Unfortunately, a side effect of this was that the images, especially of bright, moving objects (like astronauts), persisted between frames, resulting in the ghosting of the images.

Another problem was that the scan-conversion process, introduced additional signal noise and a lower resolution picture. To make matters worse, relaying the signals via microwave relays, landlines and geostationary satellite added even more signal noise and transmission errors. The result of all these systematic problems was that the TV that the world saw was severely degraded and compromised. We could do much better today.

As the video and telemetry downlink was being received at the stations, it was recorded onto 1-inch magnetic data tapes at a rate of 120 inches-per-second. These tapes had to be changed every 15 minutes for the entire duration of the moonwalk. Clearly, if we could find these tapes, we could

replay them and recover the original SSTV pictures. With modern image processing techniques, we could enhance them even further and release them to the public.

The tape search begins

Soon after arriving at Parkes in 1996, I learned of a minor controversy about the exact time that the first TV from the Moon was received at Parkes. The Director of the Parkes Observatory at the time, John Bolton, had always insisted that he had received the TV signal from the very beginning when the camera was switched on at 12:54 PM (AEST). The Moon was not scheduled to come into view at Parkes until 1:02 PM – a full eight minutes later, so there was some doubt. However, I soon learnt that there were two feeds installed in the focus cabin on the day. Realising that the moonwalk was imminent, Bolton was able to receive the signals with the less sensitive off-axis receiver. He carefully aligned the off-axis beam on the Moon and was able to track it until it reached the telescope's 30-degree elevation horizon at 1:02 PM, after which he could track it normally with the main beam.

My calculations showed that this was indeed possible, but I wanted to know for certain. Also, the signal being received by the off-axis feed would have been unstable and probably of a much lower quality, so I wanted to know by

how much. I thought that if I could find the original data tapes that contained the signals recorded at Parkes, I could replay them and confirm my conclusions. At this time also, there was still some doubt about the sequence of switches in the broadcast of the TV, so by finding the tapes from the other stations, I could compare their picture quality with the existing video recordings and determine the sequence for certain. A bonus was that we could also recover the original SSTV, which I knew by then was of a much higher quality.

Beginning in the late 1990s I contacted various NASA centres requesting the whereabouts of the data tape recordings. I made countless phone calls, wrote emails and letters to whomever I thought might know where the tapes were located. But, it was all to no avail. No one seemed to know where the tapes were. In fact, many had trouble understanding what exactly I was after. I was convinced that the tapes must still exist somewhere, but where? In 2001 I obtained a Polaroid picture taken directly off a slow-scan monitor at Sydney Video. When compared to the existing scan-converted video image of the same scene, it clearly showed how much better the original SSTV was to the scan-converted videos. So, I persisted.

Also in 2001, the film *The Dish* premiered in the US and this prompted several past and present NASA personnel to contact me. Three in particular became good friends and search team members. Stan Lebar was the retired Westinghouse engineer who, in 1969, was the program manager for the Apollo Lunar Surface Camera. Dick Nafzger was the Goddard Space Flight Center (GSFC) engineer responsible for all ground systems hardware in support of Apollo TV in 1969, and was still with NASA. Bill Wood was a retired communications engineer who

was based at Goldstone in 1969. The search team was completed when, in 2002, I was contacted by Colin Mackellar, who is an amateur historian and the webmaster of the Honeysuckle Creek website. He is a trained geologist and an Anglican minister in Sydney. Together, we joined forces to search for, and recover, the SSTV recordings.

A breakthrough occurred in 2002 when a former technician from Honeysuckle Creek contacted his former colleagues and Colin Mackellar. He admitted that, in 1969, he had made an unauthorised copy of a data tape that he believed contained telemetry from the Apollo 11 lunar EVA. This caused great excitement. The tape had been stored in his garage for 33 years in less than ideal conditions. If it still contained data, the possibility existed that the SSTV could be recovered from it. Former Honeysuckle Creek personnel, Mike Dinn and John Saxon organised to have the tape transported to the Data Evaluation Lab (DEL) at the GSFC by the NASA representative in Australia, Neal Newman. The DEL contained the only machines in the world that could play and decode the Apollo data tapes. At the DEL, Dick Nafzger replayed the tape with his team. Unfortunately, they discovered that the tape only contained data from a 1967 simulation. The technician had copied the wrong tape. As heartbreaking as this was, it had a positive effect. People suddenly understood what we were after and why we were looking for it. We confirmed that the equipment to replay the data tapes still existed and, most importantly, that even after 34 years the tapes could still retain data.

In 2005, spurred on by this and by new Polaroids from Honeysuckle Creek, Stan and Dick visited the US National Archives in Washington, where all the data tapes from the Apollo era were deposited in the early 1970s – all 250,000



Parkes scan-converted video



Polaroid of SSTV from Sydney Video

A comparison of the Parkes scan-converted and SSTV pictures, illustrating the superiority of SSTV compared to the scan-converted TV witnessed by the world. [courtesy: Bob Goodman]



Director of the Parkes dish, John Bolton, during the filming of an ABC TV documentary in 1967. [courtesy: National Library of Australia]

plus tapes. Unfortunately, their search only uncovered a single box of tapes containing Apollo 9 telemetry. The label on the box had details that allowed us to continue the search. Soon after this discovery, we received the alarming news that the DEL was slated for closure in 2006. This would be a disaster because, without the DEL, there would be no way to replay the tapes, and recover the SSTV, if they were ever found. Something had to be done.

The formal search

In February 2006 I visited the DEL and also gave a series of talks at various NASA centres to explain our search. On my return, I compiled a report which slowly began to stir people's attention. Two months later in July, Stan and Dick were interviewed on national radio on the anniversary of the Apollo 11 mission. Finally in early August, the *Sydney Morning Herald* posted a front-page story with the provocative headline 'One giant blunder for mankind: how NASA lost moon pictures'. This caused a major stir with the story going viral on the internet and news reports appearing on the American TV networks and other news organisations worldwide. Interest became so intense that in August 2006 the NASA Administrator, Michael Griffin, formalised the search and appointed the GSFC deputy director, Dorothy Perkins, to head the search. Dick was the technical lead. The first decision made was to not close the DEL. With the full resources of NASA brought to bear

on our search, we were confident that we would now finally locate the tapes and release the SSTV to the public by Christmas. But it was not to be.

Soon after the formal search began, documents were found that suggested that the tapes may have been erased in the early 1980s. This was disturbing news. We were searching for just 45 tapes from over 250,000 tapes of the Apollo era. Surely, these few would have been put aside for historical reasons. Meanwhile, Colin and I followed up leads from the Australian end and provided advice. In the US, our colleagues Stan, Dick and Bill became first-class sleuths. They tracked down long retired personnel and uncovered dusty documents from NASA archives, people's attics and basements. Slowly and surely, the evidence mounted. We discovered that in the late 1970s and early 1980s NASA had withdrawn all the Apollo era data tapes from the National Archives and erased and recertified them for later use. But why? Apparently, these tapes were manufactured using whale oil to adhere the oxide to the backing. However, in the mid-1970s, the use of whale oil was banned and manufacturers switched to using synthetic oils. The drawback was that if the synthetic oil-based tapes were not stored correctly, they would absorb moisture from the air which made them sticky. Played back at high speed, they would stick to the recording heads and be shredded to pieces. The older Apollo era tapes didn't suffer from this drawback.

As NASA's budget was cut back severely in the late 1970s, the need for more tapes to record the increasing volume of data from satellite programs became acute. The enormous number of tapes in the National Archives were now seen as valuable assets. Over a period of several years, they were all removed, erased and recertified. The labels on the tape canisters were cryptic and there was little way of knowing what each of the tapes contained. Our team didn't find any evidence that the tapes containing the Apollo 11 lunar EVA data were treated differently to the others. We reluctantly concluded that the tapes were, in all likelihood, erased and reused with the rest. You can imagine how we felt.

To understand why the tapes were treated this way, it's important to realise that they were never intended to be the primary archival media. In fact, there was never any expectation that the magnetic data would survive more than a few decades. They were only meant to act as backups for the real-time communications relays and other data. If there was a failure during a mission, the tapes could be used to recover the information. If however, all went well, then the tapes were no longer necessary. All the vital infor-

mation was extracted in real-time and archived for analysis at the relevant NASA centres. The TV was successfully seen by the world and the scan-converted video was properly recorded onto archival b/w film that would last for centuries. Few people outside of the tracking stations were even aware of the SSTV or how much better it was. As far as everyone was concerned, all the data was believed to be properly archived – at least until we came along.

The restoration

What to do next? In late 2006 Colin noticed a video clip on Eric Jones' Apollo Lunar Surface Journal website. It showed Armstrong descending the lunar module ladder that was much clearer than anything we'd seen before. We learnt that the clip was sourced from someone who had previously worked at the GSFC. It appears that he found an old 2-inch videotape of the lunar EVA and made a crude VHS video copy of it. We obtained a copy of this videotape and found that it was most likely a copy of the video recording made at Sydney Video of the Australian selection. It contained the clearest pictures of Armstrong descending the ladder sourced from Honeysuckle. It also showed the switch to Parkes earlier than in any other known recording. Unfortunately, when the original copy was made, the Ampex recorder was not setup properly and this produced a jittery image with many defects. We spent the next few months searching for the original 2-inch tape, but it has mysteriously gone missing.

Early in the search Colin was contacted by Ed von Renouard, the former scan-converter operator from Honeysuckle. On the day of the lunar EVA, Ed had brought his home movie camera to work and recorded footage directly off the screens of his console. One of those scenes was the dumping of the astronauts' portable life support systems, or backpacks. This occurred several hours after the astronauts had re-entered the lunar module and the TV networks had by then ended their broadcasts. Consequently, as far as we could determine, no other footage existed of the dumping.

During the search, we came across many archived copies of the scan-converted TV. We decided to switch our search to finding the best of these scan-converted videos and have them archived properly. We also decided to digitise them along with the Sydney Video and Honeysuckle footage. We would take the best parts of each and compile and restore them into a single video of the lunar EVA. In 2008 we had a demo restoration produced of selected scenes, which we used to convince NASA to underwrite the \$245,000 cost of the full restoration.

In 2009 NASA contracted Lowry Digital in California, a pioneer in video enhancement, to process and restore this recording for the 40th anniversary of Apollo 11. The restoration involved digitally repairing damaged sections of the recordings, removing noise from the video, correcting for vignetting, stabilising and brightening the TV picture and other adjustments. The restoration was announced at a special news conference in Washington on 16 July 2009. The full restoration was completed in December 2009 and is the best and most complete video record to date.

The NASA GSFC produced three archival sets of hard drives containing the complete restored video – one set was sent to the National Archives in Washington and another went to the Johnson Space Center in Houston. The third set was destined for Australia in recognition of the substantial involvement of the Australian tracking stations. They arrived in Australia in August 2011 and were delivered to the Canberra Deep Space Communication Complex at Tidbinbilla, having been previously organised by the former Director, Dr Miriam Baltuck.



Colin Mackellar (left), Neil Armstrong and John Sarkissian in Sydney on 23 August 2011.

A week later, Neil Armstrong visited Sydney to address the CPA Australia 125th anniversary celebrations. During his address, Neil Armstrong paid a glowing tribute to the many Australians who worked at the tracking stations and helped to ensure the success of the Apollo 11 mission. Some were present in the audience and were individually acknowledged by him. In a brief ceremony following the event, Armstrong symbolically handed over the Australian disks to Dr Phil Diamond, Director of CSIRO Astronomy and Space Science (CASS) – the custodian of the disks in Australia. He noted that 'the restored video is a valuable contribution to space exploration and space communication history'. This ceremony effectively brought the restoration effort to a close.

The Australian disks will eventually be deposited in permanent archival storage, most likely with the National

Film and Sound Archive in Canberra. The restored Apollo 11 video can now be purchased online from www.apollo11video.com. The proceeds will go toward the continued search and restoration of the other Apollo mission videos.

Hope remains

In early September 2006, soon after we first received news that the tapes may have been erased, I received a phone call from Peter Robertson, the editor of this magazine. He had seen the news items regarding the missing Apollo 11 tapes. He phoned to tell me of a letter he had received from John Bolton in the early 1990s. Bolton had mentioned some videotape players that were in the Parkes control room during the Apollo 11 mission. I informed Peter, that we weren't looking for videotapes but rather magnetic data tapes containing telemetry of the mission. I asked him to send me a copy of the letter anyway.

For many years, I had photographs from the CASS Photo Archive of scenes taken inside the Parkes control room during Apollo 11. Several photos showed a man standing beside Ampex VR660 2-inch videotape players. The Ampex players could only record standard television pictures, so I had no idea what they were doing at Parkes. I also didn't know who the man standing beside them was, or what he was doing there. A few days after Peter phoned, the Bolton letter arrived and I was stunned. The letter did indeed describe the Ampex video recorders and, more importantly, Bolton mentioned that they came with their own engineer from Johns Hopkins University in Baltimore. Could this engineer be the mystery man? I knew that Johns Hopkins was the home of the Applied Physics Laboratory (APL), a regular NASA contractor. In late November 2006, we received definitive evidence that the tapes had been erased. It was then that I sent the information on the possible identity of the engineer to my US colleagues. They immediately set out to find him. Within a few weeks, they found old newsletters from APL that positively identified him. He was contacted and interviewed by Bill and Stan. What he told them lifted our spirits.

According to the engineer, in April 1969, the APL was contracted by the GSFC to modify existing Ampex VR660 video recorders to record the non-standard SSTV at Parkes. He was put in charge of this crash program. It was to be an experimental backup recording in case the TV could not be relayed to Houston. This secondary recording was only made at Parkes and if it worked, it could be used on future missions. He reported that the recording succeeded and that he returned to the US with two reels of 2-inch videotape containing the SSTV. The whereabouts of this videotape was now a mystery. An extensive search was conducted at APL that turned up two tapes that seemed to match the description. Dick organised the loan of an Ampex VR660 video player and a slow-scan monitor from two museums. His team played back the tapes at DEL and found that they were all blank. Again, we were disappointed. Importantly, there was no documentation to suggest the tapes were erased or destroyed. We are working on the assumption that they still exist somewhere, so our search for them continues.

The most striking thing for me was how, just as we were at our lowest ebb, John Bolton appeared, from beyond the grave, to direct us in our search. It was like he was saying, "Hey, look over there. That's where you'll find what you're looking for." Hope remains.

Acknowledgments

I wish to express my gratitude to Professor Marcus Price, officer-in-charge of the Parkes Observatory in 1997, for asking me to research the Observatory's support of the Apollo 11 mission, and to Dr John Reynolds, officer-in-charge from 1999–2008, for his continued support throughout. I also thank Marshall Cloyd for giving me the opportunity to search for the tapes a little closer to the source in the United States. Finally, to my friends Bill, Dick, Colin and Stan – thank you.

Photos are courtesy of the CASS Photo Archive and author unless indicated otherwise. For more detailed information on the Parkes Observatory's support of Apollo 11, and of the Honeysuckle Creek Tracking Station, see www.parkes.atnf.csiro.au and www.honeysucklecreek.net.

AUTHOR BIO

John Sarkissian is an Operations Scientist at the CSIRO Parkes Radio Observatory. His main responsibilities are operations and systems development, and the support of visiting astronomers with their observations. John is a member of the Parkes Pulsar Timing Array team that is endeavouring to use precision pulsar timing to make the first direct detection of gravitational waves. In 1998–99 he acted as a technical advisor for the film *The Dish*. John has received two NASA Group Achievement Awards and, in 2010, received an official NASA commendation for his search for the missing Apollo 11 tapes.

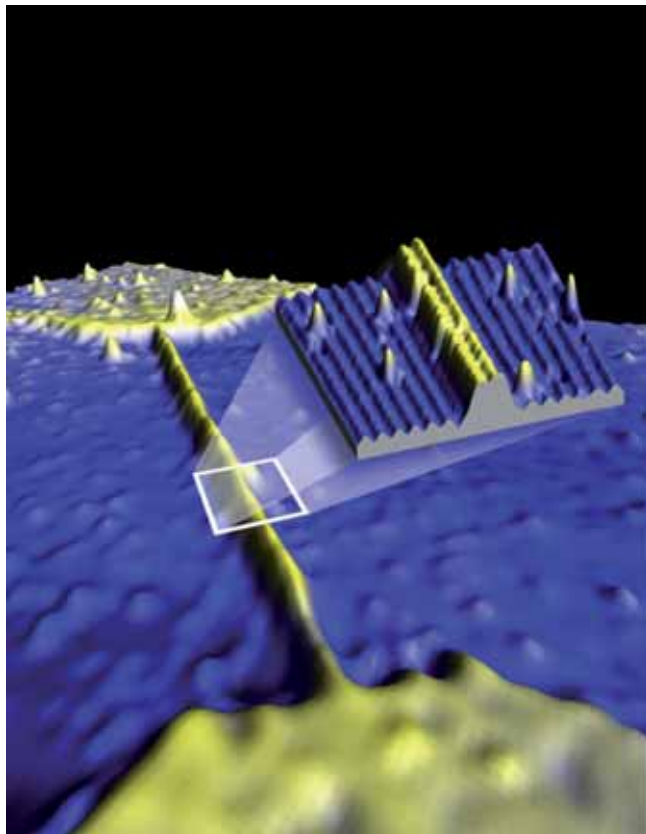
SAMPLINGS

Compiled by Don Price

Ohm's law holds down to atomic scale

A new technique for embedding atomic-scale wires within crystals of silicon has revealed that Ohm's law can hold true for wires just four atoms thick and one atom tall. The result comes as a surprise because conventional wisdom suggests that quantum effects should cause large deviations from Ohm's law for such tiny wires.

To investigate conduction on the atomic scale, Michelle Simmons, Bent Weber and colleagues at the University of NSW have developed a method of using phosphorus atoms to embed atomically thin conducting regions within a crystal of bulk silicon. Phosphorus has one



Scanning-tunnelling-microscope image showing a highly conducting wire that is only four atoms wide [courtesy: Bent Weber, UNSW].

more electron in its outer shell than silicon and if a silicon atom is replaced by a phosphorus atom (a process called n-doping), it donates a free electron to the crystal, thereby raising the conductivity of the doped region.

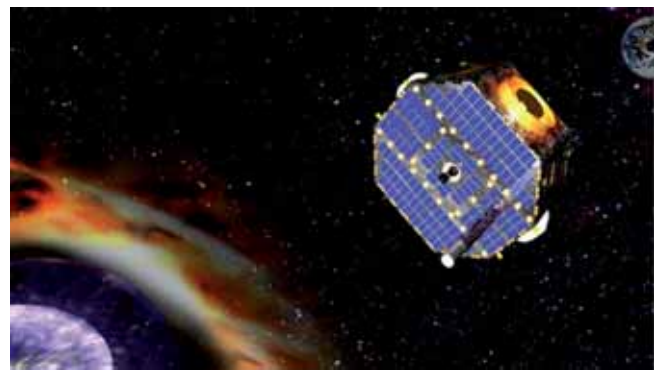
In what has been described as 'a remarkable achievement', Simmons' team used the tip of a scanning probe microscope to create a channel in the silicon by removing layers of silicon atoms. The surface is then exposed to phosphorus gas, followed by the deposition of silicon atoms. The result is a chain of phosphorus atoms embedded inside a silicon crystal – effectively an atomic wire. The team

found that the resistivity of these wires was very low ($\sim 0.3 \text{ m}\Omega\cdot\text{cm}$) and constant right down to the atomic scale. This means that the resistance of such a wire is proportional to its length and inversely proportional to its area, just as you would expect from Ohm's law. The research was published in *Science* **335**, 64 (2012), and accompanied by a Perspective article 'Ohm's Law in a Quantum World' by David K. Ferry.

Bow-shock no-show shocks astronomers

The Sun moves much more slowly relative to nearby interstellar space than was previously thought, according to scientists working on NASA's Interstellar Boundary Explorer (IBEX) mission. Their study casts doubt on the existence of an abrupt 'bow shock' where the edge of the solar system meets the interstellar medium – instead suggesting that the boundary between the two regions is much gentler than previously thought.

The bow shock refers to the region where the heliosphere – the huge bubble of charged particles that surrounds the Sun and planets – is believed to plunge into the interstellar medium. The commonly accepted idea is that the solar system moves faster (relative to the speed of the interstellar medium) than sound itself. Charged particles moving supersonically in the heliosphere therefore pile



Artist's impression of IBEX exploring the edge of the solar system [courtesy: NASA].

up at the front of the shock, with the density of charged particles dropping off rapidly where the heliosphere meets the interstellar medium.

Astronomers have always had good reason to believe the bow shock exists because similar structures can be seen surrounding nearby stars. David McComas of the Southwest Research Institute in Austin, Texas, and an international team used IBEX to characterise neutral atoms from the interstellar medium that cross into the heliosphere. Because these atoms are not electrically charged, they are not affected by magnetic fields – and

so their speed should correspond to the relative velocity of the interstellar medium.

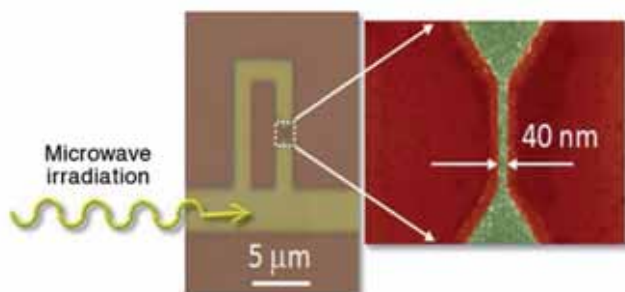
The study suggests that the relative speed is about 84,000 km/h, which is about 11,000 km/h less than previously thought. In addition, data from IBEX and earlier Voyager missions suggest that the magnetic pressure found in the interstellar medium is higher than expected. When these parameters were fed into two independent computer models of the heliosphere, both suggested that a bow shock does not exist, but rather a gentler 'bow wave' occurs at the interface. The research, to be published in *Science*, was published on-line on 10 May.

'Magnetic Josephson effect' seen for the first time

A fundamental prediction of superconductivity theory has been demonstrated in the lab for the first time. An international team of physicists has observed coherent quantum phase slip, a phenomenon similar to the well-known Josephson effect in which magnetic flux takes the place of electric charge. Its discovery has fundamental implications for our understanding of macroscopic quantum systems and could also lead to intriguing applications.

In 1962 the British physicist Brian Josephson developed a theory of how superconducting electrons tunnel across a thin insulating layer between two superconductors – a structure now called a Josephson junction. This was quickly verified in the lab and Josephson was awarded the 1973 Nobel Prize for Physics. The Josephson junction has become an important technology in its own right. For example, superconducting quantum interference devices (SQUIDs) that, depending on their design, use either one or two Josephson junctions and are among the most sensitive magnetometers to have been invented.

In 2006 Hans Mooji and Yuli Nazarov predicted quantum tunnelling of magnetic flux between two areas of



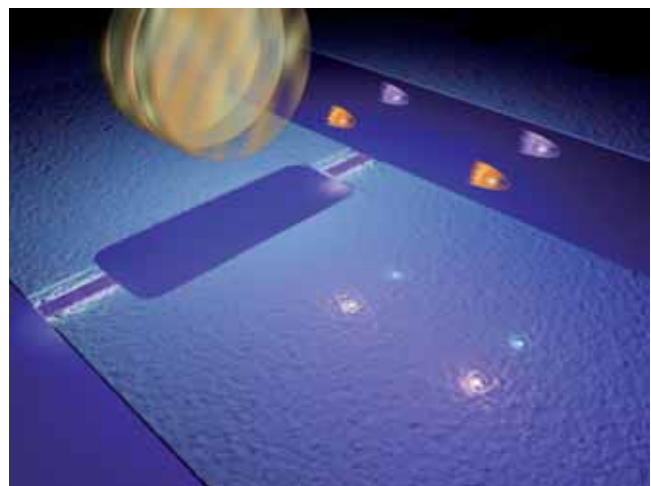
Micrographs showing a loop of superconducting material used to demonstrate coherent quantum phase slip. The magnetic field is applied perpendicular to the loop. [courtesy: RIKEN]

free space through a thin layer of superconductor. This effect is called coherent quantum phase slip, and Mooji and Nazarov argued that it is an exact analogue of the Josephson effect. This is because one of the fundamental properties of a superconductor is the Meissner effect, whereby it expels any magnetic field from its interior. It therefore behaves as the magnetic equivalent of an insulator. Now, Oleg Astafiev and colleagues at the NEC Green Innovation Research Laboratories and the Institute for Physical and Chemical Research in Ibaraki, Japan, are claiming the first experimental observations of coherent quantum phase slip.

The experiment was done on a ring of superconductor that narrows at one point into a very thin nanowire. If coherent quantum phase slip did not occur, magnetic flux inside the ring would be unable to get out, and magnetic flux outside would be unable to get in because of the impermeability of a superconductor to magnetic flux. However, Astafiev's group observed clear evidence of magnetic interaction between the inside and the outside of the ring while the ring remained in the superconducting state – clear evidence that flux was crossing the nanowire by quantum tunnelling. The research was published in *Nature* **484**, 355 (2012).

How to turn darkness into light

Quantum mechanics tells us that the vacuum is not empty but is filled with virtual particles that pop into and out of existence. Normally these particles are hidden from our view, but now a team of physicists has used the electrical equivalent of an ultrafast mirror to convert virtual photons into real electromagnetic radiation.



An illustration of the dynamical-Casimir-effect experiment, where the round mirror at the top of the image symbolises the vibrating mirror that is created in the SQUID below [courtesy: Philip Krantz, Chalmers University].

Known as the dynamical Casimir effect, it was first predicted more than 40 years ago.

The static Casimir effect, proposed by Dutch physicist Hendrik Casimir in 1948, involves two perfectly reflecting parallel mirrors that, when placed in a vacuum, will be attracted to one another. This attractive force results from a mismatch of electromagnetic modes in space, and has been observed in many experiments.

The dynamical effect was proposed by Gerald Moore in 1970 and is caused by a mismatch of modes in time. The phase of an electromagnetic wave goes to zero at the surface of a mirror, if that mirror is a perfect electrical conductor. When the mirror is moved slowly through a vacuum, this zero point can move with the mirror. However, if the mirror is moved at a significant fraction of the speed of light, then the electromagnetic field does not have time to adjust but instead becomes excited and as a result generates real photons. Put another way, the mirror prisms virtual photons (always produced in pairs) apart so that instead of rapidly annihilating, the particles are free to remain as real photons.

Confirmation of the dynamical version has until now proved elusive, partly because of the challenges involved in moving a mechanical object at such high speeds. Christopher Wilson of Chalmers University of Technology in Sweden and colleagues have managed to get around this problem by rapidly varying the electrical properties of a mirror rather than moving it in space. In this case, the mirror was a superconducting quantum interference device (SQUID) at one end of an electrical transmission line.

By switching the effective reflectivity of the SQUID at GHz frequencies, the researchers made the mirror vibrate at up to a quarter of the speed of light. As a result, they were able to detect microwave electromagnetic radiation at the far end of the transmission line. The radiation has the properties expected of photons produced via the dynamic Casimir effect. The research was published in *Nature* **479**, 376 (2011).

Physics of writing derived at last

While humans have been writing for at least 5000 years, we have surprisingly little understanding of the physics underlying how ink moves from pen to paper. Now, physicists in South Korea and the US have worked out a theory – backed by experiment – that suggests the ink's



flow rate depends on a tug-of-war that is played out between the capillary properties of pen and paper.

The team, led by Ho-Young Kim of Seoul National University, considered two scenarios: the blot and the line. With the pen stationary, the researchers identify four main factors that affect the flow of ink: the capillary pull of the pen; the capillary pull of the pores in the paper; the surface tension of the ink; and the viscosity of the ink. When it is moving, the speed of the pen is a fifth factor.

The team's theory defines a 'minimal pen' as a simple capillary tube, while paper was approximated as an array of cylinders. Rough paper is modelled as narrow, closely packed pillars, while shorter, wider, more generously spaced pillars are used to approximate smoother paper.

The smaller cavities in paper have a greater capillary pull than the wider tube of the pen, but very small pores also restrict the flow of the ink. As long as the pores in the material are not wider than the opening in the minimal pen, rougher materials pull ink more quickly. In contrast, wider pens have less capillary force, so they give up the ink more easily. As for the ink itself, higher surface tension allows it to wet the paper or pillar array more effectively, while higher viscosity slows it down. The team condensed these relationships, plus the time that the pen spends in contact with the paper, into scaling laws.

Kim's group confirmed the models by making the idealised pen and paper in the lab. The team filmed the spread of ink blots and the drawing of lines, finding that the data matched their models. Tests with real pen and paper produced results that were close to those of the models, with small differences attributed to paper swelling. The research was published in *Phys. Rev. Lett.* **107**, 264501 (2011).

Space Weather and the Ionospheric Prediction Service

Dave Neudegg

The Ionospheric Prediction Service (IPS) is the 'Radio and Space Services' branch of the Bureau of Meteorology (see www.ips.gov.au). IPS monitors the solar-terrestrial space environment to predict its variability and effect on technological systems. The space environment ranges from solar surface active regions through the solar wind and interplanetary magnetic field and into the Earth's magnetosphere and upper atmosphere, comprising the ionosphere, partially ionised by solar EUV and X-rays, embedded in the neutral thermosphere above 90 km altitude.

The technologies affected by the space environment include:

- those which transmit radio waves through the environment such as over-the-horizon high-frequency (HF) radio, satellite navigation and satellite communications
- those with a component in the space environment (generally spacecraft), and
- ground-based technologies affected by geomagnetically induced currents (GICs) such as aeromagnetic surveys, long-distance power grids and pipelines.

The effects of space weather span a wide spectrum and are not always catastrophic. Available HF radio frequencies vary with location, time of day, season, phase of the solar cycle and ionospheric disturbance. Strong solar X-ray flares cause blackouts to HF radio lasting several hours. SATNAV accuracy is reduced by strong ionospheric electron density gradients, particularly during large geomagnetic storms. Gradients or tilts in the ionosphere cause ranging problems with HF direction-finding and radar. SATCOM bit error rates increase with ionospheric scintillation.

Aeromagnetic surveys for mining are disturbed by geomagnetic variations in a particular frequency range (22–

100 MHz), even if the overall field is not greatly disturbed and a geomagnetic storm will render surveys inoperable. GICs result from geomagnetic storms mostly caused by solar coronal mass ejections (CMEs) impacting the magnetosphere and the largest storms can cause large induced currents in long distance power lines [1], burning out high-voltage transformers. Pipelines corrode more rapidly due to enhanced currents from GICs flowing across dissimilar metal boundaries.

Spacecraft at geostationary orbits (GEO) or medium earth orbits (MEO) are in, or pass through, the magnetospheric radiation belts. Those in low-Earth orbits (LEO) pass across the auroral oval through down-going energetic particles caused by merging of the geomagnetic and interplanetary fields. Spacecraft effects vary from those on control electronics such as single event upsets from protons and deep di-electric charging by electrons to solar panel degradation.

Some history

IPS was formed in 1947 as a Federal Government body to monitor the ionosphere and the solar activity affecting it



Fig. 1. The IPSNET ground-based multi-sensor array covering about one-eighth of the Earth's surface. The array is grouped by priority region for new sites, maintenance, upgrade and replacement. The highest priority mid-latitude region is further grouped into continental Australia and surrounding islands. Sensor types are indicated in the key.

to enable predictions of HF radio propagation. HF (3–30 MHz) radio is refracted back to Earth from ionospheric layers, predominantly the F2 layer (atomic oxygen ions) around 300 km altitude, but also the daytime F1 layer (molecular oxygen ions) around 200 km and E layer at 100 km, and HF is absorbed by the D-layer near 90 km. Predictions were largely on a statistical basis from historical data. At the time HF radio communications and direction-finding were the only operational technologies known to be affected by the space environment. Over the decades since, a range of new space-based technologies arose that are affected and HF radio technology has become more sophisticated and demanding in performance prediction. Other existing technologies such as geophysical exploration and energy distribution have become large or sensitive enough to be affected.

The wider concept of 'Space Weather' was conceived in the 1980s, extending the environment beyond the ionosphere and the affected technologies beyond HF radio. The information revolution in the 1990s allowed the collection of data and advanced processing to provide real-time services via the internet in addition to existing monthly summaries of solar-geophysical activity and HF radio frequencies, HF system modelling software for customer use [2] and consultancies to model large HF system performance. Major steps were also made in understanding the space environment by the Solar-Terrestrial Physics (STP) community, using traditional ground-based and new space-based sensors.

Further, increasingly complex numerical or theoretical models greatly enhanced the understanding of how the components of the environment were interconnected. Programmatically, IPS existed as a stand-alone branch with its own engineering, IT and administration and the physics based R&D, within several federal departments, until being absorbed into the Bureau of Meteorology in late 2007.

Observations

To make forecasts or 'nowcasts' observations are essential, collected both in real-time and also stored in databases, to allow statistical models of variability in an analogous manner to terrestrial weather. IPS operates a ground-based real-time sensor network, known as IPSNET, as shown in Fig. 1. Its core is on the Australian continent under the mid-latitude ionosphere, but also south and north in the very different polar [3] and equatorial ionospheric environments. IPSNET will be an important component in the proposed 'Spaceship Australis' sensor network for STP research and Space Weather, in the Space Science Decadal Plan by the Australian Academy of Science.

The sensor for ionospheric observations is the ionosonde, a radar that scans the HF band measuring the return times and virtual height of each layer and the frequencies refracted back to Earth. IPS is one of the few organisations that develops its own ionosondes. GPS receivers measure the total electron content (TEC) in the ionosphere and plasmasphere and allow mapping with far greater spatial resolution than the widely spaced large and expensive ionosondes, albeit with much reduced vertical resolution of the layers. IPS uses GPS data from GeoScience Australia in addition to its own.

Ionospheric scintillation can affect SATCOM in equatorial and polar latitudes and monitors are deployed. Induction magnetometers are used to measure geomagnetic variations and IPS develops and maintains its own, as well as those from GeoScience Australia, the University of Newcastle and the Space Environment Research Centre in Japan. Solar activity is monitored with a combination of magnetic [4], optical and radio techniques from staffed observatories in Culgoora, NSW, and Learmonth, WA (shared with the USAF). IPS has also been part of the consortium of the TIGER HF research radar operated by La Trobe University and, as well as research into the high-latitude ionosphere, observations have been made of the Southern Ocean sea-state [5].

The ground-based observations are supplemented by international space-based observations of the solar surface, solar wind and interplanetary magnetic field. These are by

dedicated STP platforms such as ACE (Advanced Composition Explorer), SOHO (Solar and Heliospheric Observatory), SDO (Solar Dynamics Observatory) and STEREO (Solar Terrestrial Relations Observatory). Similarly, the ionosphere is observed by the GNSS (Global Navigation Satellite Systems) such as GPS, and soon to be joined by GLONASS (Russia), Compass (China) and Galileo (Europe).

Solar radio observations

Solar radio emissions from sunspots were first discovered in 1942, followed by discoveries clarifying the basic properties of radio emissions from the Sun in both quiet and active states, such as the temperature of the corona, the presence of circular polarisation, the value of interferometry and the classification of radio bursts (largely carried out by CSIRO in Australia). Each of these developments led to more advanced instruments for observing solar radio sources and the solar radio spectrographs are the largest and possibly most complex instrumentation used by IPS. A major step was distinguishing radio emissions in bands of frequencies and how these emissions evolved as function of time in a spectrum.

As part of research funded and supported by CSIRO, a radio spectrograph antenna was constructed at Culgoora, NSW to operate in the frequency region 40–210 MHz [6]. In 1980, a new radio spectrograph antenna with colour display of the spectrum allowed radio burst types to be classified in real-time from their frequency–time characteristics. In 1984, control of the spectrograph was taken over by IPS and, in 1992, the spectrograph was upgraded to operate in the frequency range 18 MHz – 1.8 GHz. A programme of mechanical, tracking and signal processing upgrades has been underway since mid-2010 to prepare for the cycle 24 solar maxima due in 2012–13.

In the band 18 MHz – 1.8 GHz the frequency of solar radio emissions depends on the local plasma density and changes in frequency correspond to motion through the corona. Typical spectra are shown in Fig. 2. The Type II emission is generally associated with passage of a CME through the corona. A comparison of points on the spectra with a simple density model allows a rapid estimation of shock speed and time-of-flight to Earth distance. This is an extremely cost-effective alternative or supplement to space-based speed estimates. A collaborative project with the University of Sydney has produced an automatic solar radio burst detection algorithm (ARBIS) [7]. The CME direction has to be inferred

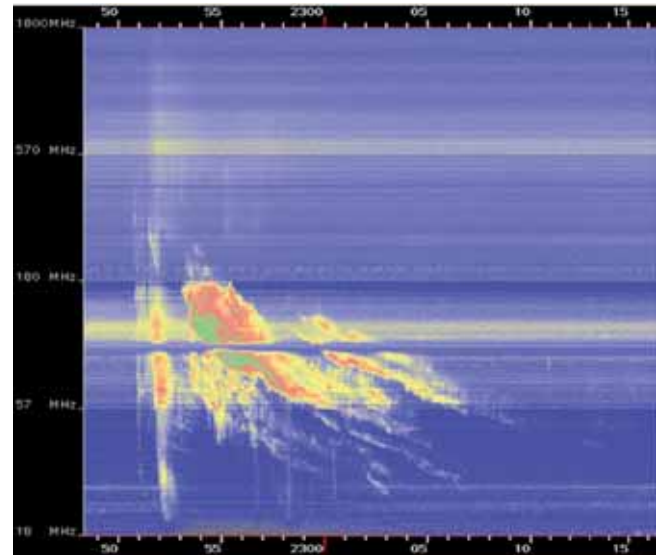


Fig. 2. Display of the Culgoora radio spectrograph for frequencies 18 MHz – 1.8 GHz, showing Type II and Type III radio bursts. Type III bursts drift rapidly from high to low frequencies and generally form due to beams of fast electrons with speeds of the order of $\sim 50,000$ km/s. In contrast, Type II radio bursts drift at ~ 1000 km/s and are caused by shocks moving outwards.

from spacecraft imagery or the location of dominant active regions and possible co-location of optical flares from ground-based instruments.

HF radio systems

The IPS ionospheric HF radio propagation prediction model and related software kernel has been developed over many years. The model is based on statistical analysis of a worldwide network of ionosonde observations of the peak plasma density in the F region, represented by the critical plasma frequency (f_oF_2) which responds to solar, geomagnetic and thermospheric activity in a complicated way. The F2 region is the most important for HF communications as it is at the highest altitude, so that radio waves can travel the furthest distance with a minimum of attenuating hops. F2 also has the greatest plasma density which carries the highest frequencies for less absorption and highest bit rate. The f_oF_2 values from field sites are automatically scaled from ionograms and interpolated to make hourly regional maps, as shown in Fig. 3.

In the mid 20th century the sunspot number (SSN) was used to parameterise f_oF_2 but the relationship is not linear and changes with location. The IPS model parametrises activity using the T-index, derived by empirical iteration, which is an equivalent effective sunspot number giving a linear relationship between ionospheric propagation support represented by f_oF_2 and those solar, geomagnetic and thermospheric factors affecting it.

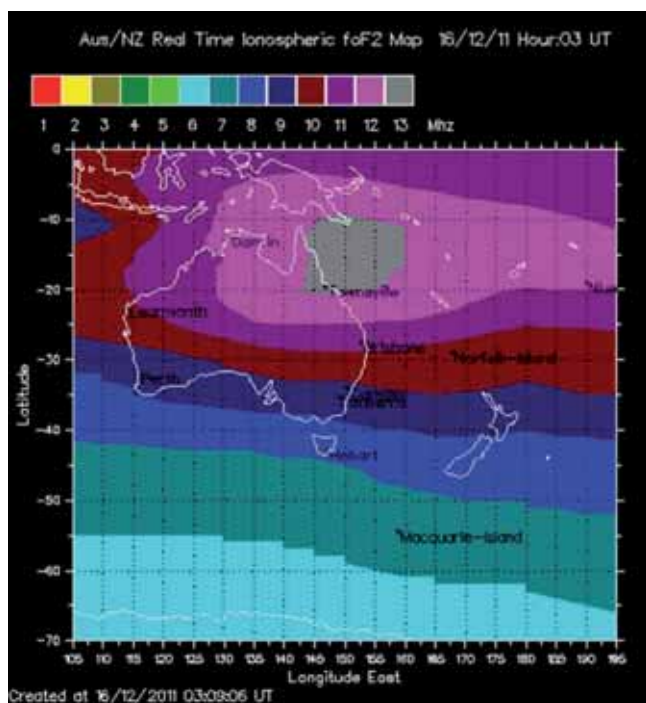


Fig. 3. An hourly ionospheric map of foF2 interpolated from autoscaled real-time ionosonde height versus frequency traces.

The propagation prediction kernel is used by in-house HF prediction programs used for system design consultancies and web tools (see www.ips.gov.au/HF_Systems/7/1), as well as the Advanced Stand Alone Prediction System (ASAPS) utilised by HF radio users worldwide. Observed and predicted frequencies for test circuits across Europe found that ASAPS out-performed other standard international models [2].

The development of new products and services at IPS is guided by specialised consultancy work undertaken for customers usually working in defence and emergency services with large HF communications systems. Diversified capabilities under the radio propagation area include the prediction of terrain attenuation of VHF/UHF line-of-site radio (see www.ips.gov.au/HF_Systems/7/1/12), LF/MF/HF surface wave propagation, digital HF propagation parameters, and VLF waveguide mode prediction (using the Long Wave Prediction Capability model). Fig. 4 is an example of a field strength area prediction for the surface wave propagation.

Ionospheric effects on Global Navigation Satellite Systems (GNSS)

The ionosphere is a significant source of error in SATNAV with free electrons slowing the GPS radio signal causing an additional time delay and hence an error in the distance to each satellite. The greater the total electron content (TEC) on the signal path, the greater the time delay and

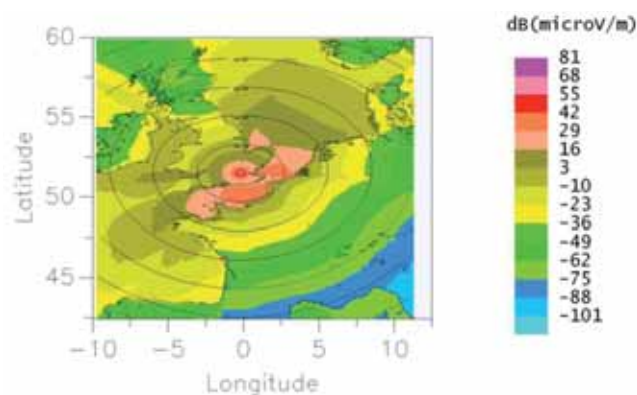


Fig. 4. Field strength area prediction for the ground propagation of medium frequency (MF) radio waves (2 MHz) radiated from a short 10-m monopole located in London. This prediction is based upon a high resolution (2.5 km) model of spatial variations in surface electrical properties.

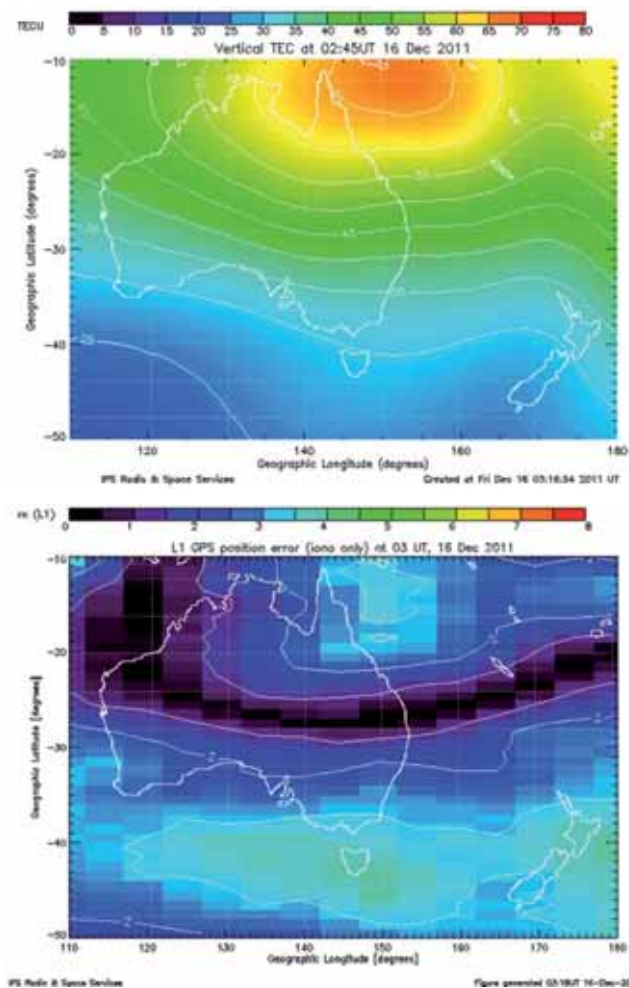


Fig. 5. *above*: An hourly ionospheric map of total electron content (TEC). *below*: The resultant single-frequency GPS position error.

thus the greater the positional error in an uncorrected GPS system. A TEC map, shown in Fig. 5, can be used to correct for the effects of the ionosphere for improved GPS positioning.

The recently developed IPS regional TEC model uses data from a regional network of dual frequency GPS receivers, along with IPS ionosonde data, to model the spatial distribution of TEC over the Australasian region in near real time. The TEC model is composed of a series of spherical cap harmonic (SCH) basis functions. These are related to spherical harmonics, but defined over a discrete region rather than the entire globe. The SCH coefficients are estimated in an optimal sense using the real-time state estimation technique of Kalman filtering.

Real time GNSS observations and data processing

The expansion of GNSS use has lead to a wealth of high quality data becoming available. The free electrons in the ionosphere disperse the two currently used GPS frequencies so that, to first order, the total number of electrons along the line-of-sight is proportional to the differential time delay observed. A single receiver on the ground can probe up to 8–10 different lines-of-sight through the ionosphere to the available GPS satellites. IPS currently uses about 60 stations in the Australasian region, providing several hundred different ionospheric measurements at any given time, greatly improving the density of real-time ionospheric observations. On the other hand, instrumental biases and the fact that each observation is an integrated measure along the entire line-of-site means that careful real-time modelling is required in order to reconstruct the ionospheric state, and Kalman filtering is currently under investigation.

The present GPS network density is sufficient to support a ‘thin shell’ model in which all electrons are assumed to reside at a single fixed altitude, reducing the problem to a two-dimensional map. As the available GNSS networks expand in the next few years, a more complete three-dimensional model is being developed which will assimilate GPS, ionosonde and other data sources such as LEO satellite data into a single self-consistent ionospheric model.

Ionospheric maps using GPS

Maps of regional TEC are derived, using a spherical cap harmonic analysis (SCHA) technique, from GPS data recorded by regional dual-frequency networks such as the Australian Regional GPS Network by GeoScience Australia. SCHA modelling uses data from a discrete region of the Earth, rather than a full global coverage [8]. The SCHA approach yields more detailed maps of Australian regional TEC variation than global models such as the International Reference Ionosphere, a climatological prediction that undergoes performance degrades during solar and geomagnetic storms. The ionospheric model that is broadcast in the navigation data of the GPS signals also has an overall accuracy of just 50%.

SCHA provides reliable ionospheric corrections used for single frequency navigation, surveillance and communication systems. The SCHA and the empirical orthogonal function (EOF) technique also provide an opportunity to understand the natural background variability of the ionosphere required for investigations of the ionospheric response to external perturbations. Decomposition of TEC observations into a set of spatio-temporal structures is employed to extract the main spatial variation, as well as diurnal and climatic variation in TEC which can be used to build empirical models for further study. An Australian regional activity index for the purpose of real-time monitoring of ionospheric conditions over Australia and customer alerts is currently under development. This index is based on the TEC perturbation component resulting from variations in geomagnetic activity.

Acknowledgments

I am especially grateful to physics trained colleagues at IPS, Dr Mike Terkildsen, Dr Murray Parkinson, Dr Zahra Bouya, Dr Matt Francis, Dr Nino Bukilic, Dr Richard Marshall and Dr Phil Wilkinson for their contributions to this article.

[continued p.121]

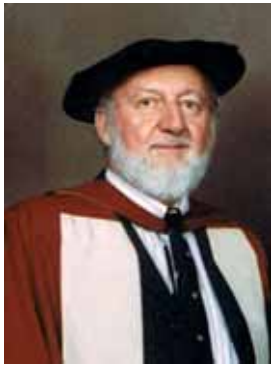


AUTHOR BIO

Dave Neudegg has a BSc(Hons) in radar and atmospheric physics from the University of Adelaide. Ionospheric modelling and HF radio direction finding were then pursued at Andrew Corporation, Adelaide Tech Park. A winter expedition followed with the Australian Antarctic Division at Davis Station. This included vehicle traverses to collect magnetic interferometer data on plasma waves in the ionosphere for a PhD at the University of Newcastle, NSW. He continued with polar space research at the University of Leicester with arctic HF radars and the German Equator-S spacecraft. Next was the Rutherford–Appleton Lab in Oxfordshire working on spacecraft payload operations for the ESA Cluster-II 4-spacecraft and ESA/China Double Star 2-spacecraft missions for space physics, and the Mars Express planetary science mission. He returned to Australia to work at IPS in 2004 and is currently branch executive officer.

Jak Kelly (1928 – 2012)

David Mills



John Charles (Jak) Kelly was born on 14 February 1928 in the tiny hamlet of Borenor, 30 km west of Orange in NSW. The son of a contract wheat harvester, each week he would ride his bicycle back from the town with half a sheep over the handlebars to feed the family. He obtained a scholarship to

the De La Salle school in Armidale and progressed to the University of Sydney, and fell in love with physics. A keen bushwalker, Jak was founding president of Sydney University Speleological Society in 1948 and a local caving icon. Opening the 50th SUSS meeting in 1998, he recalled running out of oxygen: “People were unable to strike matches for their cigarettes. It took 45 minutes to get down and 5 minutes to get out!”

Graduating in 1950, Jak worked at the National Standards Laboratory, publishing his first paper in *Nature* in 1950 on his invention of vibration measurement using multiple beam interferometry. In 1953, he married a pretty, slim girl Irene Traub originally from Vienna, who remained at his side for the next 59 years. He moved to the University of Reading in 1955 to complete a thin film PhD project under O. S. Heavens. To create better quality thin films, he invented Electron Bombardment Deposition using a pendant droplet of melted metal heated by an electron beam. It became a standard method of high temperature metal evaporation. Graduating in 1958, he worked at Harwell on radiation damage in crystals, grown using his single drop method.

Jak returned to Australia in 1961 to a permanent position at the UNSW School of Physics, where he remained for the rest of his salaried career. He wrote more than

150 papers, beginning in 1963 with the first measurement of the surface tension of titanium. He specialised in ion beam deposition, patenting several improvements, co-authoring three books and serving as chair of the Australian Institute of Physics in 1965–66. He became a Fellow of the AIP and the UK IOP, and in 1975 was created a DSc for his body of work. He took sabbaticals at the universities of Sussex, Manchester and Arizona, the Technical Hochschule in Vienna, and the Argonne Labs.

Later, diverse projects with other groups included thermoluminescent dating, using ion implantation to improve the attachment of bone cells to prosthetic surfaces, deposition and improved theoretical modelling of thin film solar energy absorbers, irradiation of wool using ion beams to improve wool properties, and laser fusion improvements.

Jak served as Head of School and Science Faculty Chairman (1985–89), and Chairman of the Australian Academy of Science Section A and other committees. He retired in 1989, remaining a visiting professor, and became Editor of *Australian Physics* magazine (1992–98), Honorary Professor of Physics at Sydney University in (2004), and President of the NSW Royal Society (2005–07).

Jak was an outstanding ambassador for physics. His natural flamboyance and fluency found a ready audience in younger students and his legendary lectures – often off-topic but always entertaining – ushered several into physics as a career. He also supervised many PhD students who became friends and remained so. His sense of humour was never far away. In a 1980 ABC *Science Show* spoof, he played to perfection a scientific sage about the discovery of a 60,000 year-old fossilised beer can left by *Homo micturans*.

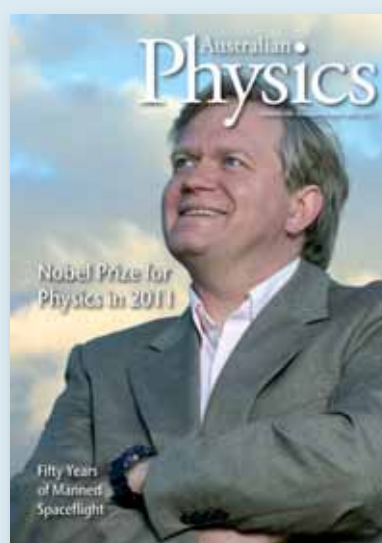
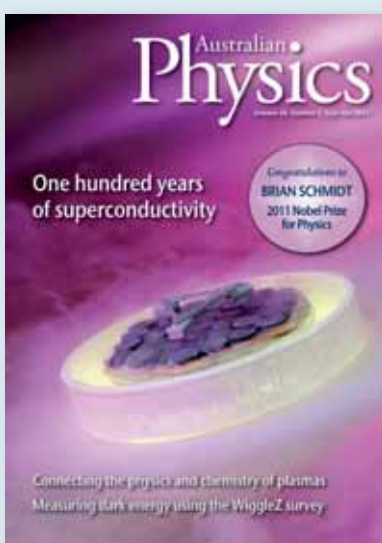
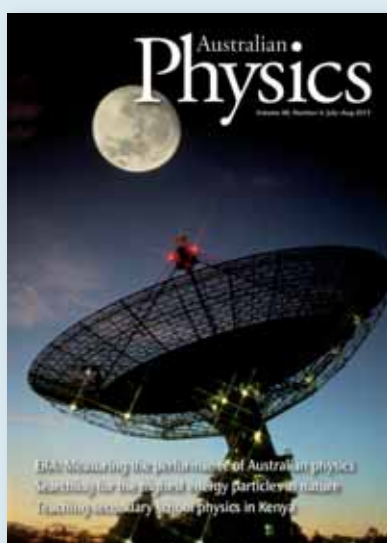
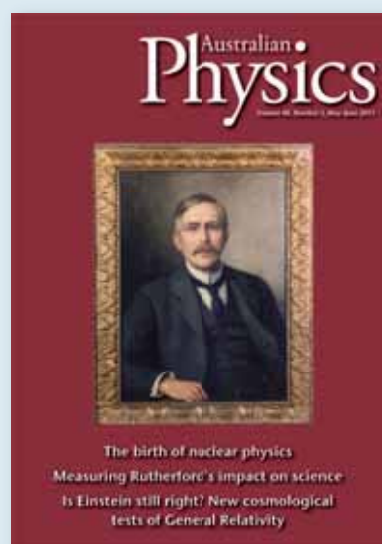
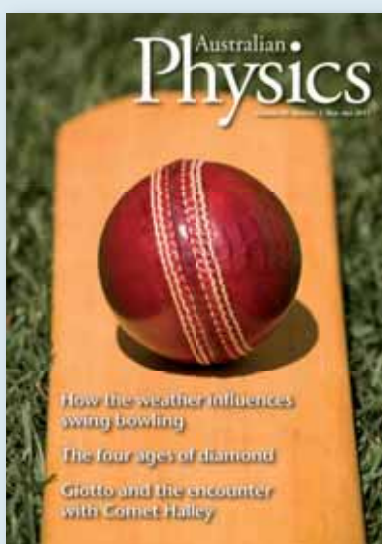
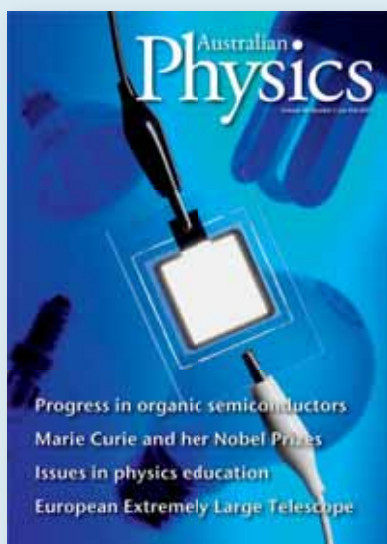
Jak Kelly is survived by Irene, sons Michael and Julian, and daughter Karina. He died with his family around him, three days before his 84th birthday. When asked what he would like people to say at the funeral, his reply was characteristic: “Look, he’s moving!”

David Mills is Jak Kelly’s son-in-law.

References

- [1] R. Marshall *et al.*, *Space Weather* **9**, S10004 (2011).
- [2] M. Pietrella *et al.*, *Adv. Space Res.* **43**, 1611–20 (2009).
- [3] P. Wilkinson *et al.*, Proc. 11th Conf. on Ionospheric Radio Systems and Techniques (IRST-11), 2009.
- [4] G. Steward *et al.*, *Space Weather* **9**, S11004 (2011).
- [5] R. Greenwood *et al.*, *J. Atmos. Solar-Terrestrial Phys.* **73**, 2379 (2011).
- [6] J. P. Wild, *Proc. Inst. Radio Electron. Eng.* **28**, 277–384 (1967).
- [7] V. Lobzin *et al.*, *Space Weather* **7**, S04002 (2009).
- [8] Z. Bouya *et al.*, 38th COSPAR Scientific Assembly, Bremen, July 2010.

We know you receive *Australian Physics* magazine
—but does your Department?
Here are six good reasons why it should...

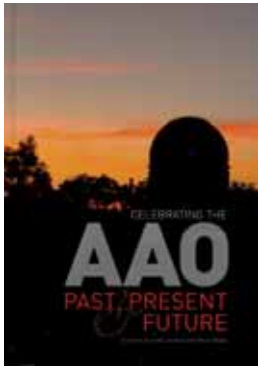


As a special introductory offer, new subscribers in 2012 will receive complimentary copies of our 2011 volume.

Ask your Librarian or Head of Department to subscribe now. For information on the magazine and subscription rates, contact our Subscription Manager at aip@aip.org.au

Australian
Physics

Support Physics in Australia



Celebrating the AAO: Past, Present and Future

By Russell Cannon and David Malin (eds)
Department of Innovation, Industry,
Science and Research, Canberra, 2011, 353
pp. (hardback)
ISBN 978-1-92-191604-5

Reviewed by Joss Bland-Hawthorn,
University of Sydney

The Australian Astronomical Observatory (formerly the Anglo–Australian Observatory) continues to be an astonishing success story in modern astronomy. Founded in 1975 as a bi-national facility, the Anglo–Australian Telescope (AAT) at Siding Spring in NSW was the largest southern hemisphere facility until the establishment of the Very Large Telescope by the European Southern Observatory two decades later. For a while, it seemed that the rise of the new generation of 8–10 metre behemoths perched on distant volcanoes would relegate the AAT into a lower division. But a succession of outstanding directors, supported by a dedicated Board and outstanding telescope staff, had other ideas. If all else fails, innovate.

Australian astronomy has a long tradition of brilliant innovation: Bernie Mills with the cross beam telescope, Hanbury Brown with his stellar interferometer, John O’Sullivan and the invention of WiFi, and so forth. The AAO is no different. As the new text ‘Celebrating the AAO: Past, Present and Future’ lays bare, the AAO has built its towering reputation on a string of outstanding innovations since the early years, which have been copied the world over. For its day, the telescope project was a major undertaking. The story of the construction, design and commissioning of the telescope makes for riveting reading (Frater, Wehner, Gillingham, Gascoigne). The remarkable dedication of the telescope support staff is made clear in an understated article by Chris McCowage.

Arguably the greatest single innovation of the AAO has been the use of photonic components, in particular, optical fibres in wide-field astronomical spectrographs (Gray, Watson). Before optical fibres, celestial sources were observed one at a time. The AAO pioneered the use of robotic positioners that could rapidly and accurately align many fibres with stars or galaxies over the telescope focal plane (Taylor, Lewis). This gave the AAT and the UK Schmidt Telescope a huge strategic advantage over other observatories. These surveys were supported by wide-field photometric campaigns by the UK Schmidt telescope and Australian radio telescopes (Hartley, Sadler).

In time, it became possible to obtain spectra of a

million galaxies and stars, providing astonishing new insights into the Galaxy and the Universe beyond. About a quarter of the contributed papers are devoted to the history and outcomes of fibre-based astronomy (Steinmetz, Colless, Croom). Particular standouts are the historical reviews by Fred Watson, Keith Taylor and Richard Ellis, all of whom were heavily involved in the historical development of fibre-based instrumentation.

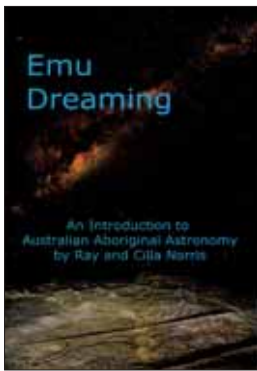
One of the key successes of the AAO has been to encourage scientists to explore. During the 1970s, David Malin, one of the book’s editors and the world’s leading astrophotographer, pioneered techniques to extract faint signals from photographic plates. From these, he made some of the first wide-field photographs to delight audiences worldwide. But Malin made important discoveries that were years ahead of their time, including the dust rings around SN 1987A, stellar shells and faint stellar streams around galaxies. Much of this history is colourfully described here.

This tradition continues with several articles showing the way forward (Colless, Freeman, Lawrence, Goodwin). In particular, Jon Lawrence paints an extraordinary vision for the future of instrumentation. This involves using photonic technologies that have barely left the laboratory but already show signs of changing the way we think about instrumentation.

This extraordinary culture of AAO innovation shows no signs of decline. In 2010, the UK withdrew from the Anglo–Australian agreement after 35 years of scientific success. For the past two years, the AAO has been operated skilfully by the Australian government, which has succeeded in keeping the golden goose in rude health. The AAO’s security appears to be assured well into the next decade.

Ongoing scientific surveys are producing superb results, including WiggleZ, RAVE, GAMA, the AAT Planet Search survey (Drinkwater, Steinmetz, Tinney, Hopkins). The next generation of instrumentation includes the forward-looking HERMES project (Freeman) to obtain the most detailed chemical information on a million stars, a project that is now being shadowed by similar efforts worldwide.

Witnessing the unfolding success story of the AAO (and by inference the AAT) is rather like watching the Rolling Stones in concert. Can they really keep this up? Who knows what the next decade has in store. My bet is the consistent excellence and creativity of the AAO will ensure that it survives in some form or other in perpetuity.



Emu Dreaming: An Introduction to Australian Aboriginal Astronomy

By Ray and Cilla Norris
Emu Dreaming, North Rocks, NSW, 2010,
30 pp. (paperback)
www.EmuDreaming.com
ISBN 978-0-98-065700-5
Reviewed by Ben Watson, Melbourne

Australian Aboriginal astronomy is a fascinating subject. I was fortunate enough to see CSIRO astrophysicist Ray Norris present a paper at a recent Australian Rock Art Research Association conference, and was completely absorbed by his findings. It was with much pleasure that I received this little book, in which he and his wife Cilla present the preliminary results of five years of research with the Aboriginal Astronomy Project based at Macquarie University. The research presented in it is largely ethnographic-based, including oral histories recorded in Arnhem Land in northern Australia, but also archaeological, including a consideration of stone arrangements and astronomical symbolism in prehistoric rock art in various parts of the country.

The book focuses on six main topics. The first, ‘The Milky Way and the Emu’ outlines known Aboriginal interpretations of the Milky Way, its constellations and its dark patches. The second, ‘The Magellanic Clouds’, details stories associated with two of the three galaxies that can be seen outside the Milky Way with the naked eye.

The third section, ‘Sun, Moon, and Eclipses’, focuses largely on Yolngu stories about the Sun and the Moon, including the relationship between the Moon and the tides, and Aboriginal explanations for both solar and lunar eclipses. The next section, ‘Calendars and Constellations’, explains some of the complexities of Aboriginal calendrics, and tells the fascinating Aboriginal story as-

sociated with the constellations of Orion and Pleiades and its remarkable similarity with the Greek myth known in European culture.

In the section entitled ‘Morning and Evening Stars’, the authors describe their encounter with Mathulu Munyarryun, a Yolngu elder and custodian of ancient stories of the sky, who recounted a story to them about the evening star. The final section, ‘Astronomical Measurements’, looks at the petroglyphs at Ngaut Ngaut on the Murray River north of Adelaide in South Australia, and the possibility that they depict the cycles of the Moon. This section also presents the hypothesis that the Wurdi Youang stone arrangement in Victoria marks the positions of the Sun on the horizon at the solstices and equinoxes.

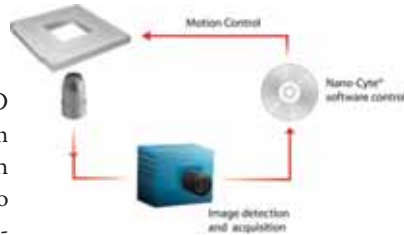
Suited for the non-specialist, the book is highly readable and also inexpensive, making accessible to the lay person a subject that few would otherwise be exposed to. For those who wish to delve further into the subject, the accompanying website, www.emudreaming.com, provides a wealth of further reading, including links to several published articles.

The book is illustrated with 22 colour photographs, including Barnaby Norris’ award winning image ‘Emu in the Sky’, which shows the emu-shaped dark clouds of the Milky Way above the similarly-shaped rock engraving of an emu at Ku-Ring-Gai Chase National Park, north of Sydney, New South Wales (see www.emuinthesky.com).

What I find most enjoyable about the book is not only the insights it gives into the astronomical knowledge of Aboriginal culture, but that it invites you to *experience* Aboriginal astronomy – to venture outside to view the night skies for yourself and understand the cosmos in a new way. With all proceeds going towards further research and promoting a greater appreciation of Aboriginal people and culture, I cannot recommend the publication more highly.

LASTEK – TOPTICA PHOTONICS

Join the Mad City Labs Nano-Cyte® Revolution!



Nano-Cyte® LC is a 3D image stabilisation system for microscopy. With Nano-Cyte® LC you no longer need to be concerned with temperature gradients, sample drift, and microscope drift. Unprecedented stability in the nanometre regime allows the extension of single molecule techniques into the realm of cell biology.

Nano-Cyte® LC is the complete image acquisition and stabilisation instrument for live cell imaging. Factors such as system instability, environmental temperature drift and sample-to-microscope temperature gradients are no longer a factor with Nano-Cyte® LC. Our integrated approach to image stabilisation yields image stability within ± 10 nm in X and Y, and ± 20 nm in Z. Nano-Cyte® LC has proven stability over days and is a unique offering that promises to revolutionise live cell imaging. Advantages:

- Active stabilisation for days
- 3D stabilisation at the nanometre scale
- Eliminates drift
- Simultaneous image acquisition & stabilisation
- Integrated hardware & automated software control
- Microscope platform independent
- Stability of ± 10 nm (XY), ± 20 nm (Z)
- Experiment intrinsic method, directly stabilises the detected image.

Venteon CEP Stabilised Femtosecond Ti:Sapphire Laser System



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.

Due to the octave-spanning output spectrum the CEP-lock can be done directly without any additional spectral broadening or the need for difference frequency generation in a nonlinear crystal. An accurate filtering of the spectral wings, needed for the f-to-2f self-referencing technique, allows for more than 90% of the original output power remaining with unchanged beam quality for subsequent experiments.

The VENTEON | PULSE : ONE CP can be ordered with an option to stabilise the carrier-envelope-offset frequency to zero

generating a pulse train with constant CEP. It is the first commercial system of this kind with unique specifications. This system allows for field sensitive experiments at full oscillator power and repetition rate without the need for pulse picking.

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.

The CP Edition includes an extended water-cooled breadboard with reserved space for a pump laser installation within the laser enclosure and a direct location of the interferometer next to the oscillator.

Specifications:

- Repetition rate: 80 MHz
- Average output power (stabilised) > 150 mW
- Pulse duration < 6 fs and pulse energy > 1.5 nJ
- CEP-lock without additional spectral broadening
- SNR for fCEO-beat > 30 dB (@ 100 kHz RBW).

Introducing Energetiq Laser-Driven Light Sources (LDLS™)



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
- Very high brightness across complete spectrum
 - UV-Vis-NIR (170–2100 nm)

- Eliminates need for multiple lamps (replaces D2/Tungsten/Xenon Arc)
 - Simplified optical system
- SMA fibre-coupled output model available
- Excellent spatial stability
 - Repeatable measurements
- Superior short and long term power stability
 - Repeatable measurements
- Electrode-less operation for long life
 - Reduced consumable costs
 - Minimal recalibration of instrument.

The available LDLS™ models are:

- LDLS™ EQ-99: Compact, economical, high brightness, broadband light source
- LDLS™ EQ-99FC: Compact, long-life, high brightness; broadband light source with fibre-coupled output
- LDLS™ EQ-1500: Extreme high brightness, broadband light source.

For more information please contact Lastek at sales@lastek.com.au

Lastek Pty Ltd

10 Reid St, Thebarton, SA 5031

Toll free: Australia 1800 882 215; NZ 0800 441 005

Tel: +61 8 8443 8668; Fax: +61 8 8443 8427;

Web: www.lastek.com.au

WARSASH SCIENTIFIC

Sintering with Adjustable Pulse Width Capability

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
Warsash Scientific Pty Ltd
Tel: +61 2 9319 0122; Fax: +61 2 9318 2192;
Web: www.warsash.com.au

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.



For applications requiring higher power Fianium's existing range of supercontinuum lasers produces total power up to 8 W and visible power greater than 1200 mW.

Fluorescence Lifetime

Edinburgh Photonics has appointed Coherent Scientific as its distributor for Australia and New Zealand.



Edinburgh designs and manufactures steady-state fluorescence spectrometers, dedicated fluorescence lifetime spectrometers and laser flash photolysis spectrometers, covering the vacuum UV to the near infrared with outstanding sensitivity. They have pioneered the technique of Time Correlated Single Photon Counting (TCSPC), permitting lifetime measurements down to 5 ps to be made quickly and easily. Edinburgh's spectrometers are highly modular, allowing systems to be configured for a wide variety of applications or to be upgraded as research priorities change.

Edinburgh's products are used across a wide range of applications including photophysics, photochemistry, semiconductor physics and biophysics.

For further information please contact Paul Wardill or Dale Otten on sales@coherent.com.au
Coherent Scientific
116 Sir Donald Bradman Drive, Hilton, SA 5033
Tel: +61 8 8150 5200; Fax: +61 8 8352 2020;
Web: www.coherent.com.au

AGILENT TECHNOLOGIES

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
- the ability to build realistic scenarios with 2 GSa of waveform memory
- 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.

More information is available at www.agilent.com.au/find/M8190.

Agilent PCIe High-Speed Digitiser

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.

The U1084A's digitiser technology combines fast analog-to-digital converters with on-board field programmable

gate array technology allowing original equipment manufacturers to easily design-in high-speed signal acquisition and analysis.



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