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SWINBURNE UNIVERSITY OF TECHNOLOGY

RESEARCH IMPACT

MARCH 2017

NET EQUITY
Empowerment through digital connection

QUANTUM CONDITIONER
Combing through entangled photons

GALACTIC DOPPELGANGERS
Nearby galaxies solve distant mysteries

VOICE OF REASON
Delving into schizophrenia

LEADING LIGHT

Baohua Jia's big-picture science at the nanoscale

RESEARCH IMPACT

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ABOUT THIS MAGAZINE

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ABOUT SWINBURNE RESEARCH

Swinburne University of Technology is an internationally recognised research-intensive university that is focused on delivering research that creates economic and social impact. Our researchers are producing innovative research solutions to real-world problems across a range of disciplines and sectors. In 2016, Swinburne was listed in the world's top 500 universities in the prestigious Academic Ranking of World Universities (ARWU) and we were also named one of the world's top 400 universities by the Times Higher Education University World Rankings 2016. We are committed to delivering world-leading research outcomes and innovations in select areas of science, engineering and technology. In 2016 Swinburne launched a number of exciting initiatives that will drive our future research achievements. Our new 'Innovation Precinct' in Hawthorn, Melbourne, is a hub of world-class research-led innovation activity, and our new Research Institutes will focus on big challenges facing our industries and society. Swinburne's research future is bright.
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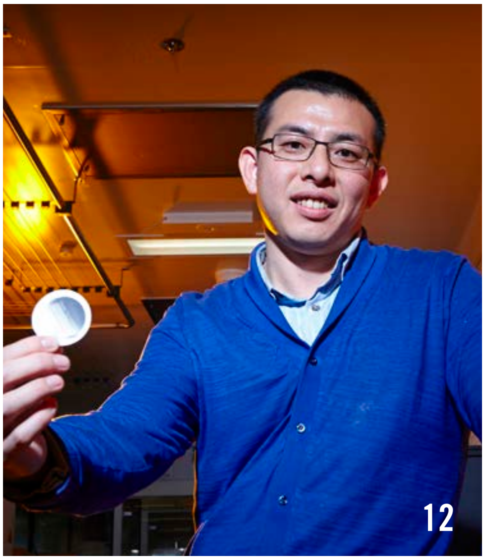
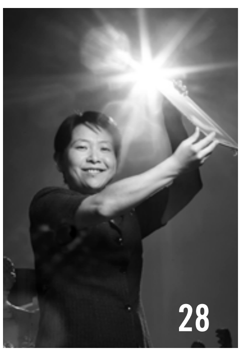




Contents

Swinburne research is world-ranked

SWINBURNE UNIVERSITY OF TECHNOLOGY

Swinburne University of Technology is an internationally recognised research-intensive university that is focused on delivering research that creates economic and social impact.

Swinburne is listed in the world's top 400 universities in the prestigious Academic Ranking of World Universities (ARWU) and we are also named one of the world's top 400 universities by the Times Higher Education University World Rankings.

We are committed to delivering world leading research outcomes and innovations in select areas of science, engineering and technology.

Transforming industries, shaping lives and communities


© Eamon Gallagher

From left to right: Philip Dalidakis, Victorian State Minister for Small Business, Innovation and Trade, Aleksandar Subic, Deputy Vice-Chancellor (Research and Development), and Manoj Nagpaul, Vice President, Asia Pacific and Japan, Wipro.

Ever since Wilhelm von Humboldt appointed distinguished scholars at the University of Berlin to teach and pursue independent research, the creation of pure knowledge has blossomed at research-intensive universities. Two hundred years later research is just as valued, but the drivers of its production are moving well beyond academia to industry, the economy and society. Increasingly new knowledge from universities must lead to the betterment of individuals, organisations and nations — and do so in a pragmatic and timely manner. This is true research impact.

At Swinburne University of Technology, we are taking advantage of our size, agility and industry knowhow to create a research and innovation ecosystem that transforms industries and shapes lives and communities. There are no discipline boundaries for the complexities of the global challenges we all face.

Swinburne has established five new outward-facing research institutes that bring together our expertise in data science, health innovation, smart cities, social innovation and manufacturing futures. These institutes build on the depth and excellence of discipline-specific research undertaken by university research centres. The five institutes — underpinned by the digital innovation capability platform — work coherently as a whole-of-solution shop for our partners, locally and internationally.

Our research is driving innovations across a wide range of important areas. For example, we are developing game-changing technologies for energy storage based on new-generation materials such as graphene; our researchers are helping control infections in medical settings based on new colloid and surface science research; our astronomers and physicists are designing new-generation instrumentation for a range of application areas stemming from discoveries in optical physics and other sciences; our research behind the Australian Digital Inclusion Index is helping to bridge the digital divide and improve communities; the advances we are achieving in digitalisation, and the internet of things in particular, are enabling us to lead Industry 4.0 developments within manufacturing, health and smart cities domains.

I am pleased to report on these and other recent research highlights in this issue of the *Swinburne Research Impact* magazine.

Professor Aleksandar Subic
Deputy Vice-Chancellor (Research and Development)

On the Cover

Baohua Jia at Swinburne's Centre for Micro-Photonics uses the smallest materials to harvest the Sun's power.

Cover image: Eamon Gallagher

Swinburne in numbers

2016 GLOBAL RANKINGS

TIMES HIGHER EDUCATION UNIVERSITY WORLD RANKINGS

Top 400

Top 100 most international universities

QS WORLD UNIVERSITY RANKINGS

Top 450

Top 100 under the age of 50

EXCELLENCE IN RESEARCH FOR AUSTRALIA

5 WELL ABOVE WORLD STANDARD

- Physical sciences
- Astronomical and space sciences
- Atomic, molecular, nuclear, particle and plasma physics
- Optical physics
- Physical chemistry (including structural)
- Maritime engineering
- Materials engineering
- Nanotechnology
- Neurosciences

4 ABOVE WORLD STANDARD

- Quantum physics
- Chemical sciences
- Computer software
- Engineering
- Civil engineering
- Electrical and electronic engineering
- Mechanical engineering
- Technology
- Communications technology
- Psychology
- Language, communication and culture
- Communication and media studies

HIGHER DEGREES BY RESEARCH

1,088 students enrolled in 2016

158 completed degrees in 2016

$8.7m invested stipend scholarships in 2016

555 accredited supervisors

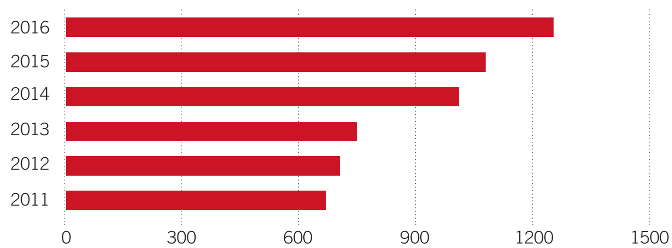
PUBLICATION PERFORMANCE

Top 100 academic institutions in physical sciences

Increase of 30% in article count since 2012 in the Nature Index

*data obtained 25/01/2017 www.natureindex.com

Science Citation Index and Social Science Citation Index publications



RESEARCH WITH IMPACT

Altmetric Attention Score

The host galaxy of a fast radio burst

Journal: *Nature*

Published: February 2016

*data obtained 25/01/2017
www.altmetric.com/details/5988853

ACADEMIC RANKING OF WORLD UNIVERSITIES

Top 500

Top 75 in civil engineering

Top 100 in physics

Top 200 in natural sciences & mathematics

US NEWS

Ranked 65 for space science

RESEARCH INCOME

$25m
2016 total external research income

$175m
2009-2016 total external research income

International campus in Sarawak, Malaysia

22,227
Total student load in 2016
(equivalent full-time student load, EFTSL)

1,088 Higher Degrees by Research students

Female students (EFTSL)
11,244

Male students (EFTSL)
10,983

Approximately
750
Academic staff

34:1
Student/staff ratio

3
Australian Research Council Centres of Excellence (one lead)

5
Dedicated research institutes

11
Research centres

3 campuses in Victoria, Australia

Advanced Technologies Centre
+ Cost $140 million to build
+ 5-star Green Star rating

The Advanced Manufacturing and Design Centre
+ Cost $100 million to build
+ 5-star Green Star rating

News briefs

Digital innovation hub

Swinburne and global IT company Wipro have established a multidisciplinary centre to spur translational research in the areas of health and smart cities. The Digital Innovation Centre will use cognitive computing, predictive analytics and next-generation digital technology to improve the economic, social and environmental dividends of society.

With the goal of taking research out of the lab and into commercialisation, the centre will bid for large-scale projects, with Wipro helping to bring the research to market through its global network of customers.

Making a difference

Swinburne hosted Australia's first Makeathon, a 72-hour marathon to design, code and build assistive technologies for people living with disability. The three-day event was organised by the global community Tikkun Olam Makers at Swinburne's Innovation Precinct in November 2016. Ten teams competed to develop prototypes that could potentially be commercialised, from a lightweight ramp that can be lowered and picked up by a magnetic stick to crutches that convert into a seat.

"It was really exciting to see the incredible things that can be achieved and we were so impressed by the quality of the outcomes that will help not only one person, but potentially thousands," said Innovation Precinct Director, Sally McArthur. "We are excited to see how Swinburne can continue to be involved as these ideas move forward."

Leading by design

Swinburne has established a new centre that brings together researchers, industries and communities to enable user-focused, design-led innovation. The Centre for Design Innovation will investigate and validate the design factors that underpin the uptake of products, services, systems, habitats and symbols. "It's one thing to design, it's another thing to have that design used and valued, and this means more carefully targeted research," said Professor Kurt Seemann, director of the new centre. Current projects include the testing of new materials to increase condom usage and limit the spread of sexually transmitted infections, and smart hats to monitor sports performance.

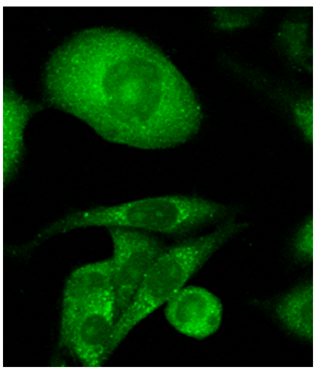
Making waves

In early 2017, Swinburne will lead a $31.3 million Australian Research Council Centre of Excellence for Gravitational Wave Discovery. Named OzGRav, the centre will capitalise on the first detection in 2016 by the Laser Interferometer Gravitational-Wave Observatory (LIGO) of ripples in space-time known as gravitational waves. Many chief investigators at OzGRav supported the breakthrough discovery at LIGO and are keen to expand Australia's role in this nascent field. Led by astrophysicist, Professor Matthew Bailes, OzGRav will help to answer cosmic questions about the death-cries of supermassive black holes and the state of nuclear matter. "It would be fantastic to think that we might discover new sources of gravitational waves right here on campus," says Professor Jarrod Hurley, who will design a $3.5 million supercomputer for OzGRav.

Big-data science

Swinburne and Tel Aviv University have launched a joint research centre for data science. The centre, which will host PhD students co-supervised by academics from both universities, will develop data science methodologies, platforms and analytics, while reinforcing privacy and cyber security. It will encourage facilities-sharing, research collaboration and government and industry engagement in both countries. The partnership builds on the work already underway at Swinburne's Data Science Research Institute, and through its association with the Oceania Cyber Security Centre, which is supported by the Victorian Government, and CSIRO's digital research unit Data61.

New cancer target



The structure of a cell-surface protein implicated in a third of cancers has been solved by an international team of researchers, including members of Swinburne's Centre for Micro-Photonics. First discovered in the 1980s, the epidermal growth factor receptor is fundamental to cell metabolism, growth and differentiation. Mutations in the receptor have been associated with several types of cancer, including lung, breast and brain cancer. The research team combined a powerful microscopy technique with computer simulations of the structure to develop a realistic model of what EGFR looks like and how it functions. "By knowing how it works in greater detail we can design improved drugs," said Swinburne's Associate Professor Andrew Clayton.

Industry 4.0

A partnership between Swinburne and the Australian Manufacturing Growth Centre will spur the adoption of Industry 4.0, the next stage in modern manufacturing in which cyber systems work seamlessly with physical systems. The new TestLab is located in Swinburne's Manufacturing Futures Research Institute (MFI), the first research centre entirely dedicated to Industry 4.0. The MFI will bring in a new era of production efficiency, with enormous gains in quality of life and environmental outcomes. "We will measure our success through delivery of high value-add solutions in collaboration with industry that create impact through innovation, commercialisation, start-ups and new enterprises being formed," said Deputy Vice-Chancellor (Research and Development) Aleksandar Subic.

Life science fellow

Stem cell researcher Peng-Yuan (George) Wang was one of 12 scientists to receive the prestigious 2016 Victoria Fellowship, an $18,000 grant for overseas study.

Wang is currently an Australian Research Council Discovery Early-Career Researcher Award fellow at Swinburne, whose research involves fabricating nanostructures to control the behaviour of stem cells. Wang's tissue engineering techniques could be used in clinical applications, disease modelling and drug screening. As a Victoria Fellow, he will visit two stem cell laboratories in the United States and Canada to learn, share and collaborate with the world's leading bioengineers.

Forging ties in China

A four-party agreement between Australia and China will see the establishment of an advanced manufacturing research centre in Weihei, a city at the tip of a peninsula in northeastern China. The partnership between Swinburne University of Technology and Shandong University, Weihai Economic and Technological Development Zone and the Australian Education Management Group will focus on the areas of automation and mechatronics, biomedical devices, electronics, advanced materials and 3D printing. Leading researchers at Swinburne and Shandong will engage with key industries at a new science and technology park in Weihei, set to launch in early 2017, where Swinburne will be the first international university present.

News flash

A brilliant burst of radiation that travelled a billion light years through space before reaching an Australian radio telescope has given scientists new insights into the fabric of the Universe. The flash, known as a fast radio burst (FRB), was captured in 2015 by CSIRO's Parkes radio telescope and analysed using a system developed by Professor Matthew Bailes and his team at Swinburne's Centre for

Astrophysics and Supercomputing. The FRB contained detailed information about the swirling gases and magnetic fields between galaxies known as the cosmic web.

Vitamin B for brain food

Supplementing the healthy brain

© eyenigelene/E+/Getty

New research from Swinburne University of Technology suggests vitamin supplements may have a positive effect on how healthy adults think and feel.

With support from pharmaceutical company, Bayer, the Swinburne Centre for Human Psychopharmacology has examined the effect of multivitamins and minerals in the brain across different age groups and under varying conditions.

Vitamins are organic compounds required for the body to function healthily, but which the body cannot make. Some, including the B vitamins — thiamine, riboflavin, niacin, and B12 — play a pivotal role in a range of cellular mechanisms, including mitochondrial energy production and neurotransmitter synthesis.

The Swinburne group's most recent work looked at the long-term effects of the multivitamin Berocca, which is made by Bayer, and was based on a randomised, double-blind, placebo-controlled study, involving 71 adults between 18 and 40 years old. Each participant took a Berocca or a placebo with breakfast every morning for four weeks and underwent tests using two techniques for visualising brain activity, functional Magnetic Resonance Imaging (fMRI) and Steady State Visually Evoked Potential (SSVEP), known to cause mental fatigue over relatively short periods.

Participants' brain activity was measured while they performed cognitive tasks, including those using working memory — remembering spatial locations, and marking when odd and even numbers are consecutive in a string of random digits.

The work demonstrated that supplementary vitamins had a discernable effect in healthy adults. "They're getting into the brain and they're having an effect, which I think is a very important first step," said Research Leader and Director of the Centre for Human Psychopharmacology, Professor Andrew Scholey.

There were increased levels of the B vitamins in the blood of those who had been taking the multivitamin and a reduction in the mildly toxic molecule homocysteine. Those taking Berocca also reported improvements in mood over the four-week period.

There was also a significant correlation between fMRI-measured brain activation and cognitive performance in participants fatigued from SSVEP.

Earlier pilot studies at Swinburne had suggested that improvements in attention can be achieved after a single dose of multivitamins and that the effect may be evident as soon as 30 minutes after taking the tablet.

Scholey and his colleagues are now seeing if these effects can be replicated in a larger-scale study to validate the findings. They are also investigating the mechanism by which the benefit of vitamins may be occurring in the brain, which could lead to new treatments for mood and cognition.

Accounting for unchartered waters

An accounting-based method for reporting the amount of available water in a river system has been developed by a Swinburne researcher

The use of water from the huge Murray-Darling River Basin in eastern Australia remains a contentious issue after more than a decade of legal wrangling, policies and plans. But, there is a stronger consensus about how much water the basin actually contains, thanks to an emerging discipline called water accounting, developed by a team including a Swinburne researcher.

Professor Keryn Chalmers, Dean of Swinburne Business School, was part of a team of financial accountants who developed a conceptual framework for general-purpose water accounting.

Every drop, including rainfall, evapotranspiration, surface and ground water is counted. The information will guide the Council of Australian Governments when it meets in 2017 to decide how much water is required to maintain river flows.

"The goal was to create a useful reporting system to inform decision-makers about water resources,

© Hiromi Shiota/EyeEm/Getty

Smart grid to address balance of power

Australia's electricity grid needs maintenance. But rather than patching it up and carrying on, Professor Qing-Long Han says we should prepare for the future.

A Swinburne University of Technology researcher is part of a team that has come up with a plan to upgrade Australia's electricity network and save taxpayers billions of dollars.

The ageing electricity grid is one of the largest pieces of infrastructure in the country. But, it was built in an era when electricity flowed one way — from power stations to the consumer.

The system is no longer linear, as homes and business-owners increasingly install solar panels and supplement their network supply. Some feed excess electricity back into the grid, creating a two-way flow of electrons.

Distinguished Professor Qing-Long Han, Swinburne's Pro Vice-Chancellor (Research Quality) said the grid sometimes struggles with this intermittent, two-way supply and demand. He said some power companies have restricted new solar connections because they don't feel confident in their capacity to maintain a steady electricity supply with these fluctuating sources.

Professor Han and his colleagues from Griffith University, Central Queensland University and RWTH Aachen University of Technology in Germany have devised a system that would utilize the existing infrastructure, but bolt on 21st-century technology to maximize the value Australians get from the grid.

The system employs the mathematical concept of advanced networked control to manage switching between the various sources of supply — whether that be a large wind farm, a coal-fired power station, an industrial battery, or a lone solar panel on a suburban street.

With advanced networked control, local sources of power and batteries can communicate with each other and work collaboratively to co-ordinate their supply or demand from the larger grid.

Han said moving away from the idea of central control avoided the challenges of communications technologies dropping out at crucial moments.

"We tried to find an evenly distributed way of control, and also co-ordinated control."

He said using a probabilistic approach allowed them to get around the challenges of intermittent supply. They dictated the amount of risk of failure they were willing to tolerate in the system and let the mathematics determine how to manage the supply.

The increasing use of battery systems for

electricity storage will also play a key part in maintaining a steady supply across the whole of eastern Australia and beyond.

"With our methodology we want to use the existing network — that's how we've tried to reduce the cost," he said. Some $36 billion is slated for network upgrades in coming years — just to maintain the status quo. But Han said their system will be more cost-effective and would allow increased use of renewable energy.

This would prevent the need for new power stations, realizing further savings, and help to address climate change.

Peter Wolfs, one of Han's collaborators from Central Queensland University, said even if the system is not adopted by the grid, the system has application on smaller scales.

"Universities have electricity bills in the millions of dollars each year. With advanced networked control and battery storage, they could make better decisions about when to sell their electricity into the grid."

including allocations," said Chalmers. In an audit of existing water reporting processes the researchers found a patchwork of methods in which some water users were not considered.

Chalmer's team established a collaborative process involving hydrologists, engineers, water–users and policy–makers. The outcome was a rigorous method to report water stocks and flows.

"The concept is really similar to general-purpose financial accounts; you have a balance sheet that identifies water assets and liabilities," said Chalmers.

The Bureau of Meteorology now publishes its annual National Water Account for the ten nationally significant water regions in Australia, including the Murray–Darling River Basin using the principles of general-purpose water reporting.

The approach has had an influence globally as well, with the team's ideas contributing to an emerging international discipline of water accounting.

Water accounting methods will be integral as society is forced to manage its water resources more carefully.

Switched-on seniors

Involving end–users in the design of new technology has worked wonders for older Australians

© Anthony Bradshaw/Stockbyte/Getty

A new check-in system for elderly people, designed with their emotional needs in mind, has proved successful in early trials.

Director of Swinburne's Future Self and Design Living Lab, Associate Professor Sonja Pedell, is part of a global movement of designers that believes end-users should be partners in the search for solutions to their problems.

Pedell, along with Emeritus Professor Leon Sterling and other members of the Centre for Design Innovation, turned their attention to emergency alarms for vulnerable Australians, such as the elderly; a research project supported by the Smart Internet Cooperative Research Centre and the Australian Research Council.

They found that older people felt home-based emergency alarms and wellbeing check systems were like "cowbells" forced on them. In response, the research team developed an iPad-based, picture-frame system that allows older people to receive photographs and messages from loved-ones each day.

When the participants responded to these messages, community service providers and carers would be assured that they were OK.

The prototype was embraced by carers such as 'Joe', who felt it helped in sharing the care of an aged relative: "You can build a network of support," Joe said. "It shares the exposure and the responsibility."

Pedell said elderly users were also more engaged with the iPad system because it increased their contact with family and friends. "From an emotional point of view, people were feeling not only cared for, but also cared about, and that is a critical difference," she said.

Pedell said while technology had the potential to improve the lives of the elderly, it often fell short because it did not address their emotional requirements.

She aimed to overcome that through an "emotion-led approach [to design] where we ask the end-users, 'how would you like to feel?'"

"The idea is listening to what people want and taking their desires and needs very seriously to develop technologies that better meet them," she said.

Through the Future Self project in the Centre for Design Innovation and the Living Lab, Pedell and her colleagues were also investigating the use of music and humanoid robots to increase socialisation among dementia sufferers, and refurbishment innovations in older people's homes.

Although fledgling, the work at Swinburne's Living Lab has been recognised with membership to the European Network of Living Labs, a move Pedell said was already fostering global collaborations.

Ageing study considers food for thought

Swinburne researchers want to know whether extracts from ancient natural remedies could slow cognitive ageing

An aquatic herb with a 4,000-year history of improving memory function is one of two plants under the spotlight in a Swinburne-led project on cognitive ageing. The research is exploring the idea that a decline in cognition might be linked to stress at the cellular level.

The project, called ARCLI — the Australian Research Council Longevity Intervention, aims to create a biological map of cognitive decline and determine how plant-based medicines could slow the process. Investigation of the herb, *Bacopa*, will be part of one of the largest trials of its kind conducted in Australia.

As we age, our memory, learning ability and processing deteriorates. Understanding biological mechanisms causing this degeneration in the elderly is incomplete.

ARCLI, led by Professor Con Stough at Swinburne University of Technology's Centre of Human Psychopharmacology aims to address that gap. "The study will provide the richest source of information about the biological mechanisms associated with cognitive ageing in humans. It was one of the reasons why the study was initially funded by the Australian Research Council," said Stough. "This is significant because age is the biggest predictor of cognitive decline, such as dementia."

The ARCLI trial is gathering data on varied factors that could open a window to understanding cognitive ageing. Considerations include genetic markers, cardiovascular health, inflammation, blood markers, neuro-imaging and even gut bacteria populations.

ENVISIONing liveable and sustainable cities

The negative impacts of urban sprawl could be reduced with the help of a new data tool

The harmful environmental impact of Australia's sprawling low-density cities could be reduced with the use of a new tool developed at Swinburne University of Technology.

ENVISION is a geospatial decision-making tool developed by Dr Stephen Glackin and Professor Peter Newton for the Cooperative Research Centre (CRC) for Spatial Information. It identifies large potential redevelopment sites using indicators that identify economically under-utilised urban assets. It looks for areas where the established buildings are ageing, of poor physical and environmental quality, and where the land value represents more than 70 per cent of the total property value.

Such 'greyfields' sites are key to redeveloping more compact and liveable communities at a precinct level, according to Newton, from Swinburne's Centre for Urban Transitions, a partner in the CRC for Low Carbon Living. Redeveloping the built environment at the precinct level brings an economy of scale and the opportunity to design more innovative and sustainable buildings.

When cities become more compact, economic and environmental benefits follow, said Newton. "Compact cities can reduce carbon emissions from transport by around one third compared to a low-density city," he said.

Compact cities increase walkability, reducing air pollution and greenhouse gas emissions, and they use less land, water and energy. They are healthier places to live as well as providing greater accessibility to jobs and services.

Australian cities are renowned for being amongst the most liveable in the world, but they rank poorly when it comes to sustainability. Sprawling and car-centric, the cities have eco-footprints double that of those in Europe, and four times the global average.

State governments have targets to increase densities via urban infill, but are not meeting their goals. "Development is happening on an ad-hoc basis in the form of knock-down-rebuilds," said Newton. "They are not necessarily near public transport or service centres, and private green space is typically lost," he said.

ENVISION identifies clusters of properties in the ageing established middle-ring (greyfield) suburbs, typically located between 10 and 30 kilometres from the city centre. As a multi-criteria analysis tool it also highlights those properties close to public transport, schools and other services. "To catalyse the urban regeneration process governments

should consider using old public housing stock to increase dwelling yield and activate neighbourhoods, because it is easier to assemble redevelopment precincts since there is only one owner," said Newton.

"Another possibility is to offer support to communities of private property owners so they can collectively sell their housing in one parcel to developers, providing owners with a 50-plus per cent higher return on their principal asset."

Newton's affiliation with the CRC for Low Carbon Living is developing other products, in collaboration with Swinburne to regenerate greyfields with quality medium-density housing precincts to slow sprawl and reduce cities' carbon footprint. Dr Stephen Glackin, a Senior Research Fellow in the Centre for Urban Transitions, is involved in the community co-design of these low-carbon precincts in Melbourne and Sydney.

Professor Deo Prasad, Chief Executive Officer of the CRC for Low Carbon Living, said it's indicative of the value created from collaboration between the two organisations. "Not only do they provide social benefits, but they create significant economic impact by reducing carbon."

Early data have identified an increase in a compound linked to oxidative stress, a state where the body has a concentration of unstable molecules that can break apart crucial cell components, such as proteins and even DNA. Anti-oxidants can prevent cell damage from oxidative stress and potentially stave off mental deterioration associated with ageing.

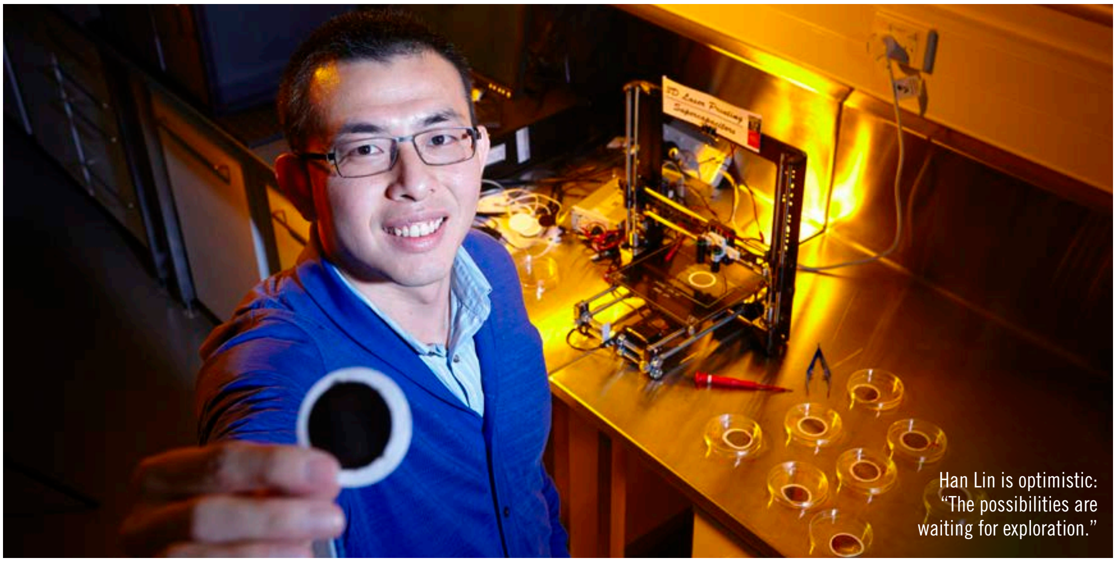
Extracts from the *Bacopa* plant (CDRI08) and another natural compound, pycnogenol, are believed to have antioxidant and anti-inflammatory properties and have been shown to improve mental capacity.

ARCLI will be the first long-term study to chart their impact on brain function. "*Bacopa* has been used for about 4,000 years in Ayuverdic medicine and it is technically the oldest known cognitive enhancer amongst plant-based medicines," said Stough. "Pycnogenol is an extract from French maritime pine bark known for its ability to be a strong anti-oxidant, so this is really testing the hypothesis that cognition might have something to do with oxidative stress. Importantly, anti-oxidant defences decrease considerably as we get older."

The study has a 360-strong cohort and ARCLI is seeking further recruits aged over 65 to help fill a significant gap in cognitive research. "I think the data will provide high-level evidence about whether *Bacopa* and pycnogenol could be used to improve function," said Stough. "That is important because there are no pharmaceuticals for slowing cognitive ageing, the number of older citizens is growing, and there are no proven interventions to stop dementia, so we definitely need some strategies in that space."

Turning current wisdom on its head

Faster, sleeker, more powerful gadgets hit the market daily. The batteries that power them may have struggled to keep up, but an ultra-fast alternative is in sight.



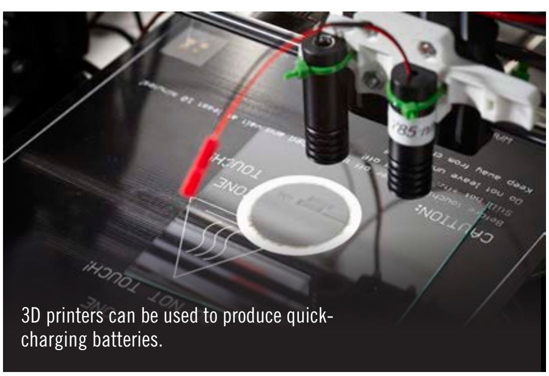
Han Lin is optimistic: "The possibilities are waiting for exploration."

© Eamon Gallagher

Swinburne University of Technology researchers have developed a method for three-dimensional (3D) printing of a powerful battery that charges in seconds, can be recharged millions of times — and would barely be noticeable placed inside your watchband.

The magic ingredient is graphene — a one-atom-thick sheet of carbon with an extremely large surface area that allows a huge amount of charge to attach to its surface. Under a current, charged particles zip between graphene sheets much faster than in the sluggish chemical reactions at the electrodes in normal batteries.

But, to be useful as a battery, in this case called a 'supercapacitor', graphene needs to be stacked as thousands of overlapping sheets, something that until recently was impossible to create with existing laboratory methods.



3D printers can be used to produce quick-charging batteries.

© Eamon Gallagher

Swinburne's Dr Han Lin found a way. First he sprayed flexible plastic with a layer of graphene oxide, a water-soluble graphene precursor. Then, he shone the laser beam from a 3D printer through this thin layer, which broke oxygen molecules from the graphene oxide and fused the precursor film into layers of thousands of graphene sheets in one shot.

Tests revealed Lin's graphene supercapacitor charges thousands of times faster than the lithium-ion batteries that now power devices. "It's much faster because it doesn't involve any chemical reaction, so you can put a high current on it," Lin explained.

The 3D-printed graphene battery is still expensive to produce. But, because there are no chemical reactions during charging and discharging, graphene doesn't suffer the wear-and-tear of normal batteries. "The lifetime is a thousand times longer — so the cost per unit energy is much lower," Lin pointed out.

Lin recently teamed up with a commercial partner to negotiate a large-scale production line, and is hoping to replace batteries which are harmful to the environment, such as the lead acid battery. Graphene batteries require no special disposal and, Lin calculated, have double the energy capacity per kilogram of a lead acid battery.

Thanks to Lin's work, futuristic energy storage is now within reach. Flexible, thin-film batteries in your clothes and trains and buses that flash-charge their super-batteries when they reach a station are all conceivable with this technology.

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All things considered

Harnessing the electronic chatter produced by internet-connected devices is helping solve problems in farms, factories, and society itself

From smartphones to smart electricity meters, electric cars to factory machines, ever more things around us are connecting to the internet. Swinburne University of Technology computer scientist Professor Dimitrios Georgakopoulos has developed ways to gather and distil high-value information from the cacophony of data generated by the internet of things (IoT).

"Just like the internet itself, where we rely on web data provided by other users we typically do not know, the grand challenge of IoT is learning from data produced by billions of machines and devices that are built, owned and maintained by others," Georgakopoulos said. "Our strategy is to create IoT know-how that cuts across and has an impact on many of society's problems."

His cloud-based IoT platforms and real-time data analysis engines have boosted productivity in farming and renewable power generation. Now he is developing IoT solutions for smarter factories and cities.

Take the latest connected cars filling our city streets, for instance. "A Tesla car is a machine with thousands of sensors and cameras, connected to the internet 24-7," Georgakopoulos said. "A connected car could indicate when it needs a mechanic, and then assess service offers from nearby workshops based on price, reputation, *et cetera*."

Socioeconomic issues, such as access to healthcare and the poor availability of affordable housing close to employment centres, may seem a very different beast to connected cars, but Georgakopoulos has used the same data-driven IoT approach to address them.

Real-estate data collected from the internet can identify clusters of existing affordable houses, and data on daily population movements collected via smart devices can identify opportunities for improving transport links for residents.

Georgakopoulos discovered the power of IoT data almost inadvertently. In 2010, while working at the Commonwealth Scientific and Industrial Research Organisation, he was approached by the High Resolution Plant Phenomics Centre and the Grains Research and Development Corporation to develop a large sensor-based system that would take the legwork out of crop trials conducted in approximately two million test plots around the country.

After struggling with logistics and costs of deploying just 150 compatible sensors, "we had the idea to leave the selection, purchase and deployment of the sensors to the growers and plant scientists," Georgakopoulos said. He and his team developed an IoT-based data collection and analysis system that could use data from almost any such sensor. This system quickly grew to include thousands of plots and more than 65,000 sensors.

The lessons learned on the farms are now being applied in unexpected corners of research. Georgakopoulos plans to build strong partnerships with the manufacturing industry to make IoT tools a reality for the next generation of factories.

And, through work with authorities, citizens, and service providers in cities across the world, he hopes to improve transport, energy generation, and disaster response, as well as improve sustainability.

Patterns of creation

Stem cells can be encouraged to sprout by changing the surface of the plastic they grow upon

Controlling the patterning on the surface of plastics may soon enable us to grow bone, fight infections and reproduce stem cells, thanks to research at Swinburne University of Technology.

Variations in the nanoscale structures on the surface of a material can alter the development of cells in the vicinity according to the work of Swinburne's Polymer NanoInterface Engineering Group.

It opens potential for making minute changes to the plastic surface of cell cultures and medical devices in order to control how cells behave both inside and outside the body.

"Depending on the type of pattern and the type of cell, you get different responses. This means you have a starting point for controlling the cell pathway," said group leader, Professor Peter Kingshott. Through their research, Kingshott's team developed a new method to create patterns at the nanoscale, as existing methods were expensive and time-consuming, limiting their industrial application.

In collaboration with the CSIRO's manufacturing unit, Kingshott's group worked on a technique based on the patterns left by crystal particles as a solution evaporates. Their method can be carried out in any laboratory, takes a few hours, rather than months, and is scalable to a practical size.

The Swinburne group also recently collaborated with the Stem Cells Australia network to develop a new, relatively cheap and time-efficient method to regress mature cells to stem cell form.

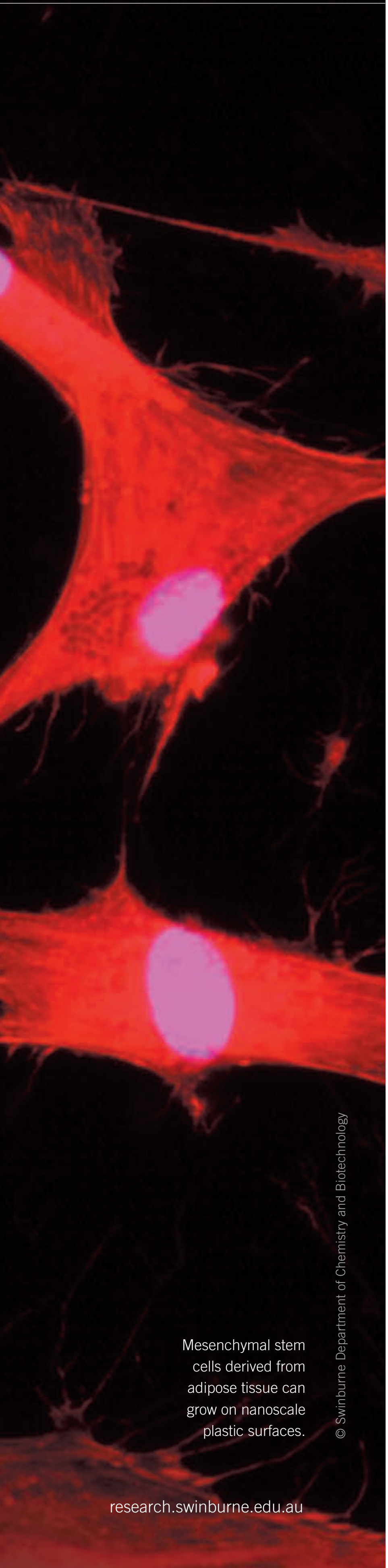
A particular crystal pattern was laid down on the polystyrene surface of cell incubating wells, which were filled with mature cells and a mixture of proteins known to trigger the transformation. In a matter of days, the cells attached to the surface of the well and were converted back to stem-cell form.

Previous methods of inducing this pluripotency have taken weeks and have required the insertion of a layer of a protein called vitronectin to achieve conversion. By speeding up the process and removing a step, the Swinburne–Stem Cells Australia technique could lead to time and cost savings in what is quickly becoming a valuable medical field.

Kingshott said the same approach could determine the behaviour of mature cells. "It doesn't necessarily have to be stem cells. It can be regenerating skin or regenerating bone."

Kingshott's group has also shown that different surface patterns can repel bacteria, pointing to useful applications in medical implants and devices. If catheters and bandages can be manufactured to repel bacteria, the need for antibiotics could be reduced and the growing microbial resistance to antibacterials negated.

Kingshott and his team are now working to determine why the different surface patterns affect cell behaviour.



Mesenchymal stem cells derived from adipose tissue can grow on nanoscale plastic surfaces.

© Swinburne Department of Chemistry and Biotechnology

A healthy debate

Armed with data and evidence, rural communities are getting involved in decisions about their health

© Wendy Hewitt

The Warracknabeal community garden meets many needs.

A Swinburne University of Technology researcher has provided compelling evidence of the value of debate in creating effective health service programs.

Professor Jane Farmer's Remote Service Futures (RSF) co-design framework has engaged groups from Scotland to North Queensland and rural Victoria in grassroots design for solutions to long-term health problems.

"We're moving well beyond consulting with the community. We're evolving into a debate with evidence and data," she said.

Farmer will be Director of Swinburne's new Social Innovation Institute when it launches in 2017. She said with the RSF framework, community members are provided with information about the health of their community along with research findings on potential causes and prevention measures. In workshops, participants are then taken through a decision-making process to devise a workable solution given the available resources. Farmer said the resulting proposals can be unpredictable and innovative.

Community involvement is currently commonly used in developing health services, but Farmer's work has produced early evidence that providing communities with comparative data about local health issues increased engagement in the planning process. Getting access to current research and discovering what other communities have done empowered participants to design creative solutions.

In one example, the framework was used to address oral health in six Victorian and Queensland communities. Combined with other initiatives, it led to the Dental Health Service of Victoria adopting new tooth-brushing guidelines for schools and other centres where hygiene education may be required.

In another case, in 2012, Victoria's Rural Northwest Health (RNH) service collaborated with Farmer to increase community engagement and improve health in the remote region. Outcomes, including a community garden, are thriving, and a wellbeing garden designed through the program is almost completed.

RNH Chief Executive Officer Catherine Morley said the effectiveness of the framework was evident in the results.

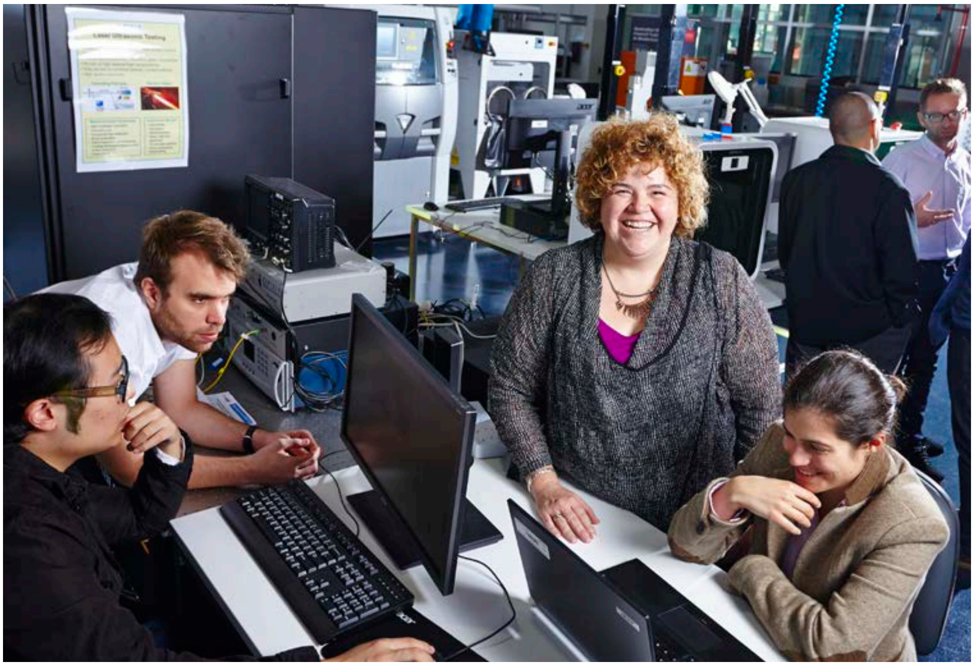
"There is a man who is not involved in any other group, who people would say is a bit of an outcast, but he now goes to the garden every week. He's engaged and people are happy to see him, he's sharing his knowledge, he's adding value and that's what it is about."

The results of Farmer's research will go towards encouraging more health services to adopt the co-design approach, said Morley.

Farmer's work is now going digital with the development of an RSF framework app to enable health-care providers to reach a greater range of community members.

Smashing up the old PhD program

A new approach to doctoral studies will turn out industry-experienced graduates ready to undertake commercial research



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Sally McArthur is rewriting the rules around a doctoral studies program in biomedicine. "When you decide to break something, it's great to really smash the whole thing up."

Swinburne University of Technology has reworked its doctoral studies with a program aiming to create industry-ready graduates, able to undertake commercially applicable fundamental research.

Professor of Biomedical Engineering Sally McArthur, who helped design the new program, said they had completely rewritten the rules around the PhD. Through the Technology Innovation PhD Program, 10 students have taken on the challenge of solving problems within the biomedical field.

"When you decide to break something, it's great to really smash the whole thing up," she laughed.

The unique program is housed in the ARC Training Centre for Biodevices, created through a $1.8 million ARC Industry Transformational Training Centre grant.

Critical to the program's success was the involvement of nine partners, ranging from established figures like St Vincent's Hospital to industry startups such as identification chip manufacturer, bluechiip.

"We needed to recognise that if they were going to invest there had to be outcomes for them. The idea is this helps industry develop new technology," she said.

Professor McArthur said the program, launched in 2015, attracted more than 60 applicants for 10 positions.

She said students started their doctoral studies without a research topic. "The first goal we set for them was to get out in the end-user community and identify 100 needs," she said. At the same time students completed master's-level units in entrepreneurship and innovation.

This helped them convert their top-100 list into "opportunities for research," which were whittled down to possible projects.

These were pitched to the industry partners, who selected the research and researcher they would invest in. There's also room to grow. McArthur said the program can be applied to any field with a cohort of three or more students and with single or multiple industry partners.

Mechanical engineer, Victor Dislakis, 27, left an established career to join the innovative program, to which he was attracted by the strong industry links.

Working with bluechiip, he is investigating ways to enhance the performance and applications of medical sensors used in fields such as stem cell research and IVF.

Dislakis said he was impressed by the "soft skills" he had acquired through the course, in particular how to manage uncertainty and deal with key stakeholders. "The program has provided me with a new perspective on product innovation in med-tech," Dislakis said.

"By immersing myself in clinics and by collaborating with local companies I have been able to connect innovative technologies to healthcare needs."

Why we're designed to move

Clever urban design can make it easier to reap the health benefits of incorporating more physical activity into daily life

Designing urban environments that promote activity and discourage sitting has spurred the development of new cross-disciplinary research at Swinburne.

An estimated 5 million deaths around the world each year are attributable to sedentary lifestyles and in Australia the federal government's physical activity and sedentary behaviour guidelines now recommend limits on 'sitting' time.

The link between increased sitting time and greater risk of heart disease, diabetes and other illnesses was made in part thanks to work by new Swinburne appointment Professor Neville Owen.

Owen's work has shown that the amount of time a person spends sitting can significantly influence their mortality risk. Importantly, evidence increasingly suggests the risk is reduced, but not eliminated, by compensating with extra physical activity.

"Spending long periods of time sitting can be a significant mortality risk," he said. "It is now an urgent priority to better understand how improvements in the built environments of cities, along with initiatives in transport policy and workplace design can help people to be more active."

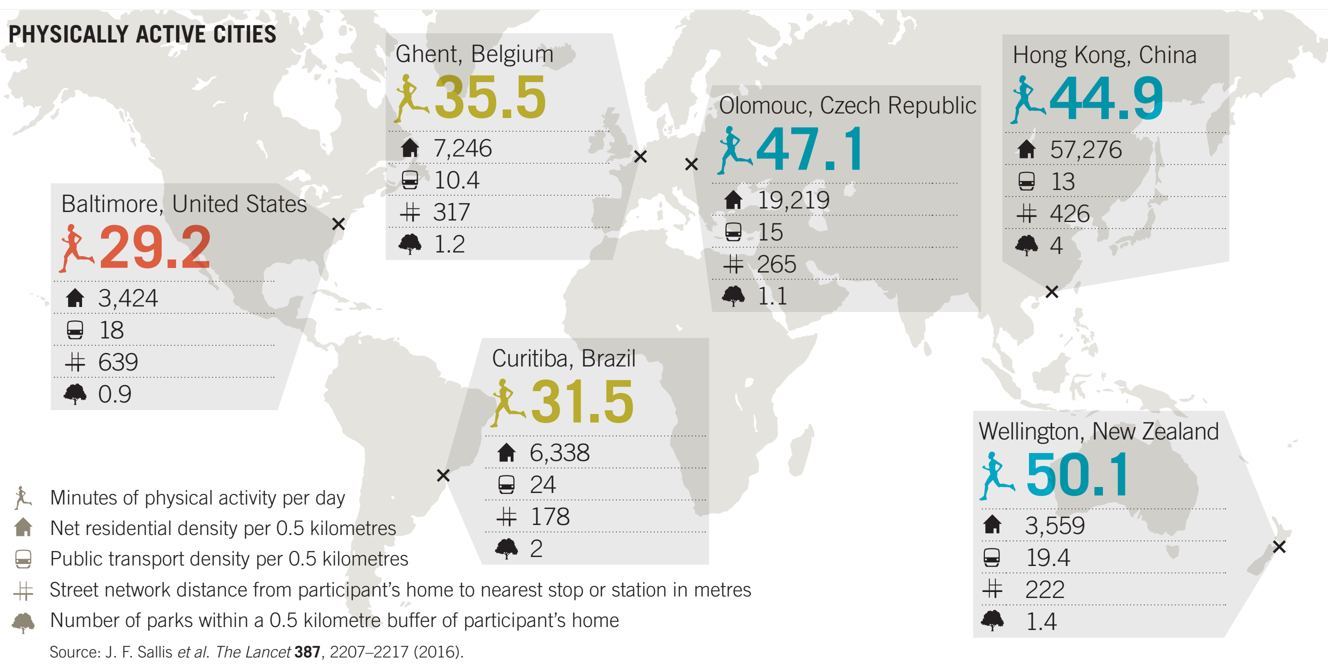
A globally renowned health sciences professor, Owen was appointed Distinguished Professor at Swinburne University of Technology in June 2016. He has worked with the university's Smart Cities Institute to ensure the clinical research identifying the determinants of metabolic disease instruct the formation of policies to shape urban environments for better health.

Research funded by the National Health and Medical Research Council at the Baker Heart and Diabetes Institute in Melbourne, where Owen heads the Behavioural Epidemiology Laboratory, has established that breaking up periods of sitting can significantly reduce blood coagulation, lower blood pressure and lead to healthier blood sugar levels. "Something as simple as very brief interruptions to sitting has major improvements in glucose, insulin, and blood pressure," said Owen.

Separately, in a comparison of lifestyles in cities around the world published in *The Lancet*, Owen was one of an international team of researchers that showed higher density urban areas with good public transport and more green space, meant more active inhabitants (see Physically active cities).

Within Swinburne's new Smart Cities Institute, a multidisciplinary group including social scientists, traffic engineers, urban designers and epidemiologists, such as Owen, work has begun on translating these findings into practical solutions for improving health.

"There is huge potential at Swinburne to build those coalitions," said Owen. The goal is urban design policy that will reduce the risk of diabetes, cardiovascular disease and even breast and colon cancer by helping people to sit less and be more physically active within the normal pattern of their lives.



A study of 6,822 adults aged 18–66 in cities around the world linked four environmental features with physical activity: residential density and public transport density, as well as how close participants lived to a park or station. Residents in Wellington, New Zealand, had the highest physical activity scores, and residents in Baltimore, United States, had the lowest.

Stolen wages analysis sheds light on historic injustice

A Swinburne researcher is working with Indigenous organisations to analyse the history of stolen wages practices in Victoria and their impact on indigenous peoples

Decades of state-sanctioned withholding of wages and social security benefits from Victorian Indigenous people has been documented by researchers at Swinburne University of Technology in collaboration with the Wampan Wages Victorian Stolen Wages Working Group. It is an effort that could lead to Victoria's first scheme to compensate for the discriminatory practices.

"This historical analysis will develop a greater understanding of the past, while also helping to develop appropriate models of reparative justice," said Andrew Gunstone, Professor of Indigenous Studies and Director of Indigenous Strategy at Swinburne. It's more than just an academic exercise: "The project adheres to the principle of reciprocity and aims to benefit both Indigenous peoples and universities."

For much of the 19th and 20th centuries, state governments in Australia implemented a range of practices to control the money received by Indigenous people, from the underpayment or non-payment of salaries, to the redirection of funds to inaccessible trust accounts, and exclusion from social security benefits. The financial cost of these stolen wages to families in the state of Queensland alone amount to an estimated $500 million, with potentially hundreds of millions of dollars more withheld across the country.

Professor Andrew Gunstone pictured with the Wurundjeri acknowledgement plaque at Swinburne's Hawthorn campus.

© Eamon Gallagher

"The fact that so much money has been stolen from Indigenous people over many decades means that there has been far less accumulation of intergenerational wealth, which is reflected in the socio-economic statistics today," said Gunstone. "The policies of the past have a direct impact on the present."

As a result of Indigenous-led legal and political campaigns, several governments have developed stolen wages compensation schemes.

In 2002, the Queensland government announced the first compensation package to former workers, but it was capped at $55.6 million. New South Wales introduced a repayment scheme in 2004 that did not set formal limits and in 2012 Western Australia offered a maximum of $2,000 to those who surrendered their right to any future claims.

Other states and territories, including Victoria, are yet to develop any stolen wages compensation schemes.

The research will be completed in 2017 and presented to the Victorian government, as part of a campaign for a stolen wages compensation scheme.

"After all, this money used to build Victoria came from the sweat and tears of our ancestors," said Aboriginal elder, Aunty Dot Peters, during an early consultation. "Justice must be given to all families from whom wages were stolen and now is the time."

"Through this research, we are educating the wider Australian community regarding the history and impact of stolen wages policies," said Gunstone. "We call on the Victorian government to develop a genuinely fair stolen wages compensation scheme."

Government stolen wages compensation schemes

For most of the nineteenth and twentieth centuries, Australian state and national governments institutionalised practices to control the wages, savings and benefits owed to Indigenous people, today known as stolen wages practices.

1869
Aborigine Protection Act enacted in colony of Victoria controls almost all aspects of Aboriginal people's lives

2002
Queensland announces first compensation package for former Indigenous workers (capped at $4,000 per individual)

2004
New South Wales government apologises for stolen wages practices and introduces repayment scheme

2006
Australian Senate inquiry into stolen wages "received compelling evidence that governments systematically withheld and mismanaged Indigenous wages and entitlements over decades"

2007
Study estimates that $500 million was stolen from Indigenous people in Queensland alone

2012
Western Australia launches a reparation scheme capped at $2,000 per individual

Return to the fold for super-strong structures

Origami-like composite panels may hold the key to lightweight and explosion-resistant structural components

Light-weight structural panels that can stop bullets or withstand bombs are the goal of a team of researchers working at Swinburne University of Technology.

Since antiquity, engineers have used geometric tricks to improve the performance of load-bearing structures such as trusses and arches. Now, the team led by Professor Guoxing Lu from Swinburne's School of Engineering has put a modern twist on this ancient science by replacing solid metal panels with super-tough and light aluminium 'sandwich' structures inspired by Japanese origami patterns.

A typical sandwich panel inserts a soft, semi-hollow inner core between two thin and strong outer skins. Spacing the skins a small distance apart makes the panels much stiffer than the sheet would otherwise be while dramatically decreasing overall bulk. "The aerospace industry uses sandwich panels because they work so well in reducing weight," said Lu. "But increasingly, we're seeing them in vehicles and civil infrastructure."

Lu and his co-workers are at the forefront of efforts to use sandwich structures to protect against catastrophic events — a terrorist bombing, for example, or the impact of a plane crash. If designed optimally, the soft, crushable cores of these panels can effectively dissipate energy, while the rigid outer skins resist deformation. The team used high-speed cameras to understand how these innovative materials are affected by ballistic collisions by projectiles or pressure waves from explosions.

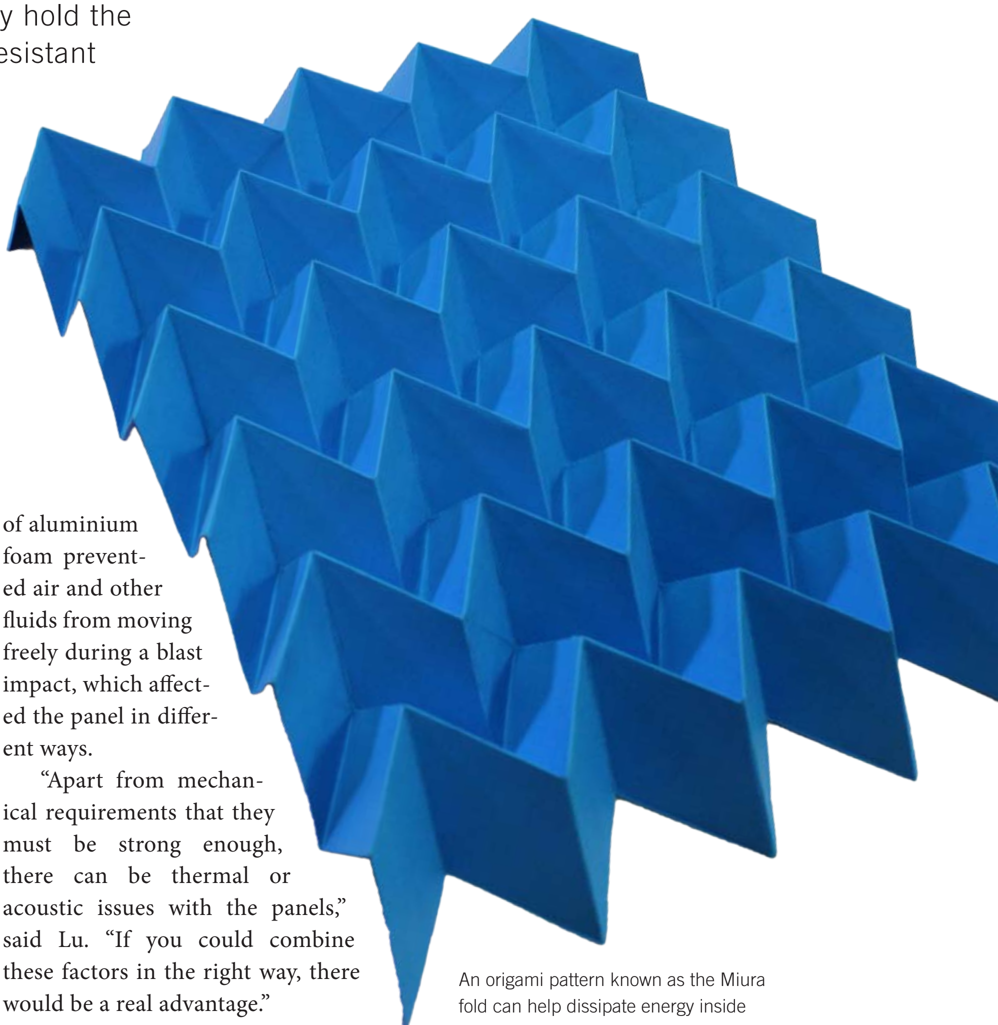
Recently, the researchers have had promising results with aluminium foam, a porous metal tougher than traditional cores with exceptional energy absorption qualities. However, the closed cell structure of aluminium foam prevented air and other fluids from moving freely during a blast impact, which affected the panel in different ways.

"Apart from mechanical requirements that they must be strong enough, there can be thermal or acoustic issues with the panels," said Lu. "If you could combine these factors in the right way, there would be a real advantage."

Lu is embarking on a four-year project to create all-in-one sandwich panels by designing cores with specific geometric folds. Engineers are finding that paper origami models are readily adapted into 'deployable' structures that switch from compact to expanded structures using simple mechanical motion. With help from collaborator Zhong You at Oxford University in the United Kingdom, Lu aims to use shape-shifting origami cores to improve both energy dissipation and fluid movement in blast-resistant panels.

The team's initial investigations involved Miura origami, a means of folding flat sheets into peaks resembling mountains and valleys. "We can control the core by adjusting only the geometry, and it enables air to flow freely," noted Lu. "If we prove it offers better performance for the same mass, it could be very useful."

If successful, the potential applications, for personal safety, building, and aviation, will be significant.



An origami pattern known as the Miura fold can help dissipate energy inside explosive-proof structural panels.

Scanning electron microscope image of the fracture surface of a material made of cocoon silk and biodegradable plastic, which could be used to heal broken bones.

© Alan Lau

A soft touch for mending broken bones

Professor Alan Lau's combination of a little silk with a biodegradable plastic may be the formula to heal broken bones

Silk is an unlikely substitute for steel in any context, but for bone fractures, it may just be the perfect thing. A Swinburne University of Technology researcher has developed a mix of cocoon silk fibres and biodegradable polymers that may one day hold bones together and help heal them from the inside out.

Steel plates and bolts are often a surgeon's only tools for fixing fractured bones. The problem is that steel can block new bone cells from repairing the fracture. Removing the steel through further surgery can leave bones brittle.

Materials scientist, Professor Alan Lau, said this impediment was a real problem and that a replacement for steel was needed.

For 10 years, researchers have investigated a biodegradable polymer called PLA, already used in some food packaging, for medical implants. If PLA could pin bones together and then be gently resorbed by the body over time, bone cells could enter the fracture and heal the bone and eliminate the need for further surgery. But so far, PLA has proved too weak to reinforce bone.

Lau came across part of the solution in 2007. Avian flu had broken out in his native Hong Kong and more than a million chickens were killed to stop the spread. He wondered why the chicken feathers weren't used for something. The idea of mixing animal fibres with other materials was the genesis of his breakthrough, but the fibres from feathers were difficult to purify. Lau's team found an alternative that was easier to work with: the silk from a silkworm's cocoon.

In 2008 Lau's team at Hong Kong Polytechnic University combined cocoon silk fibres with PLA and found the polymer became harder. Adding around six per cent silk fibre made the biodegradable polymer as strong as bone.

The scientists also found cells can grow around the material as it degrades, showing potential for use in patients. "At this stage we have a great accomplishment," said Lau. "But there's still a long way to go."

© Eamon Gallagher

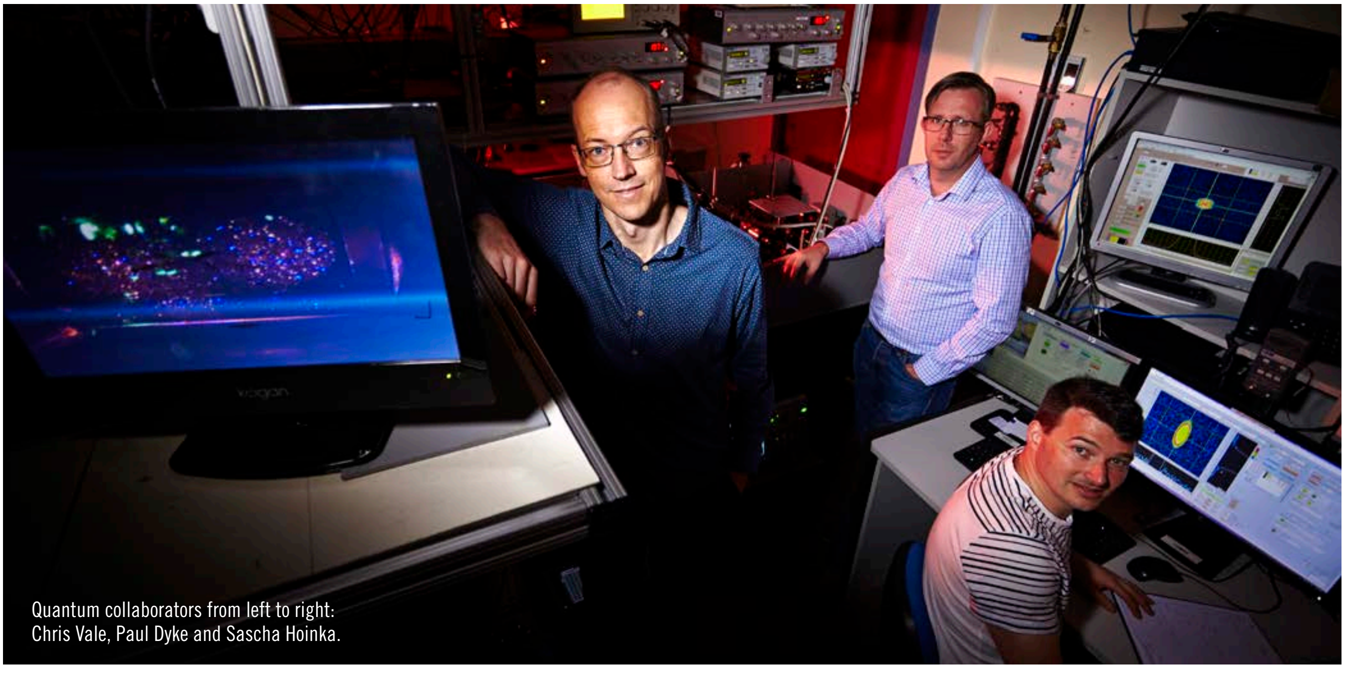
Alan Lau has mixed animal fibres with degradable plastics for better bone recovery.

Lau is now tackling the design of the right pins and screws, speculating that the material could one day be tailored for individual patients by scanning their fracture and 3D printing a shape that fits perfectly.

He is looking for collaborators in Australia to start animal trials and eventually progress the material to patients. He is optimistic: "If we can find a partner here to continue, this material will progress very fast."

Supercool breakthrough brings new quantum benchmark

The first detection of the low-energy 'Goldstone mode' will provide new insights into superconductivity and other quantum phenomena



Quantum collaborators from left to right:
Chris Vale, Paul Dyke and Sascha Hoinka.

By gently prodding a swirling cloud of supercooled lithium atoms with a pair of lasers, and observing the atoms' response, researchers at Swinburne University of Technology have developed a new way to probe the properties of quantum materials.

Quantum materials — a family that includes superfluids, superconductors, exotic magnets, ultracold atoms and recently-discovered 'topological insulators' — display on a large scale some of the remarkable quantum effects usually associated with microscopic and subatomic particles.

But, while quantum mechanics explains the behaviour of microscopic particles, applying quantum theory to larger systems is far more challenging. "While the potential of quantum materials, such as superconductors, is undeniable, we need to fully grasp the underlying quantum physics at play in these systems to establish their true capabilities," said Chris Vale, an Associate Professor at the Centre for Quantum and Optical Science, who led the research. "That's a big part of the motivation for what we do."

Vale and his colleagues, including Sascha Hoinka and Paul Dyke, also at Swinburne, developed a new way to explore the behaviour of this family of materials. They detected when a 'Fermi gas' of lithium atoms, a simple quantum material, entered a quantum 'superfluid' state. Their system allows theories of superconductivity and related quantum effects to be precisely checked against experiment, to see whether the theories are accurate and how they could be refined.

The researchers' advance was based on the fact that quantum materials' special properties emerge when their constituent particles enter a synchronised state. The zero-resistance flow of electrons through superconductors, for example, emerges when electrons can team up to form 'Cooper pairs'.

The team's sophisticated experimental set-up allowed this co-ordinated quantum behaviour to be detected. By fine-tuning the interaction of their lasers with the Fermi gas, Vale and his colleagues were for the first time able to detect the elusive, low energy Goldstone mode, an excitation that only appears in systems that have entered a synchronised quantum state.

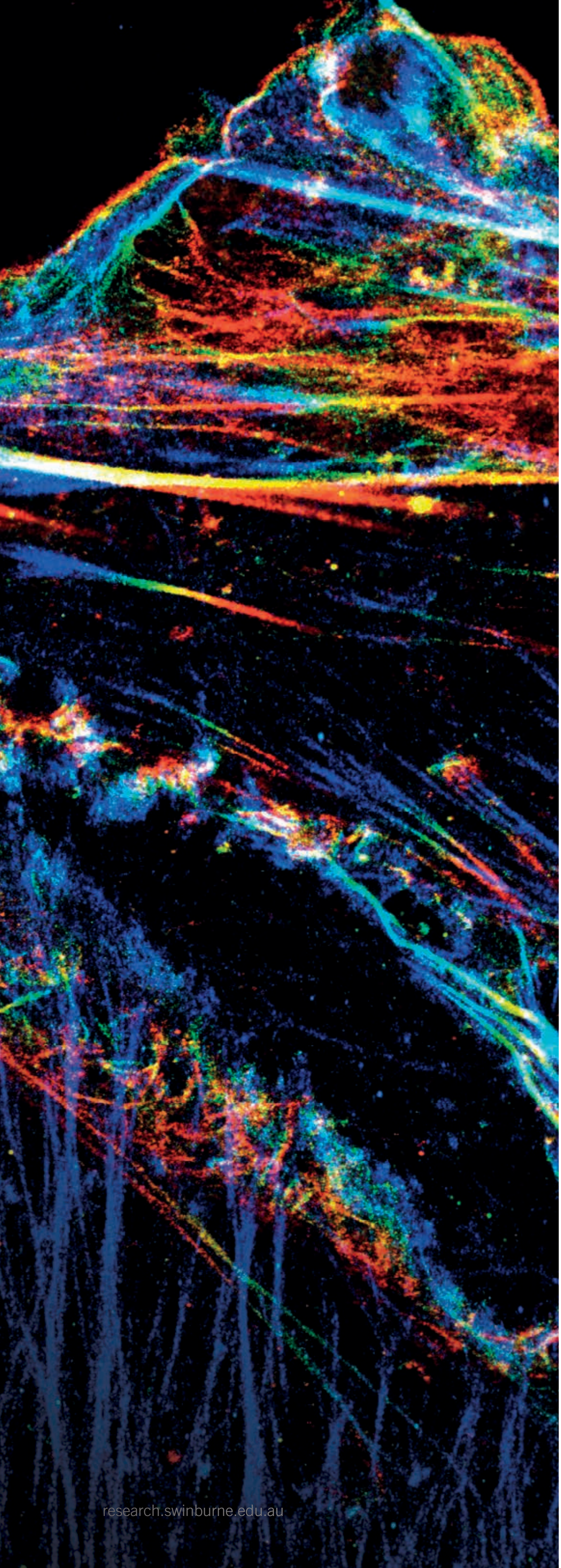
"Because our experiment provides a well controlled environment and the appearance of the Goldstone mode is very clear, our measurements provide a benchmark that quantum theories can be tested against before they're applied to more complex systems like superconductors," Vale said.

"By developing methods to understand large systems that behave quantum mechanically, we're building the knowledge base that will underpin future quantum-enabled technologies."

The structural fibres of a cell showing the level of precise detail made possible by a new imaging method developed at Swinburne.

THE INSIDE OF CELLS AS NEVER SEEN BEFORE

A partnership between biologists and physicists is lighting the way for new imaging techniques providing a never-before glimpse of the inner workings of the cell



© Sarah Russell & Ye Chen

Researchers will have a clearer view of the inner workings of cells using a new method being developed at Swinburne that is bringing image resolution to new levels of clarity.

Professor Sarah Russell, an immunologist at Swinburne's Centre of Microphotonics, leads the Cell Biology lab. Her group fine-tuned a super-resolution microscopy method known as STORM, which has allowed researchers to capture clear images to the tens of nanometres.

STORM is dependent on antibodies to 'hold' colour molecules, so that the parts of the cell researchers wanted to see under the microscope can be tagged. But using antibodies brought technical problems that interfered with accuracy and created blurring of the images.

"You're restricted by chemistry. The antibody is a whacking big molecule, and when you are homing in on these very precise locations, the last thing you need during imaging is a great big thing wobbling around, increasing the risk of error," said Russell.

The turning point was when Ye Chen, a Post-Doctoral Fellow in Russell's lab developed some tricks with which to substitute the antibody with a smaller molecule, such as a cell membrane dye. Replacing the usual antibody middleman with smaller molecules led to a method that didn't damage the cell and consistently generated a brighter and stronger signal for the microscope.

The results were images that resembled a finely woven net, showing in crisp detail fibres that make up the structural scaffolding in the cell membrane, in far greater resolution than the original STORM method.

Russell's group discovered the technique also had the potential to show precisely how fibres are arranged. This clearer picture could provide information on the nuances of fibre organisation in different cells and compartments, providing clues on development and function.

Being a biologist embedded in the company of physicists in a 16-year-long collaboration between Peter MacCallum Cancer Centre and Swinburne researchers meant that Russell had access to expertise that allowed her to fast-track ideas.

"There is so much physics and chemistry that can be used to improve imaging. This work is a clear indication why it is so valuable to have physicists who already know how to talk to biologists and vice versa," said Russell. "At Swinburne we can work together and it's a fantastic illustration why this collaboration is such a good set-up."

The results were published in mid-2016 but Russell's group is already closing in on another imaging technique that makes use of the polarisation of light. Together with the fine-tuned STORM technique, she plans to see both methods applied to monitoring and recording how immune cells respond during an infection in real-time.

"The major effort is to keep tweaking until we get to the stage where these technologies are genuinely valuable for learning about biology," said Russell. "At the moment there have not yet been many new biological discoveries made based on super-resolution imaging. But nobody is giving up on it and refining the methods will be critical for biological breakthroughs."

Laying the grounds for greener roads

Coffee grounds, waste bricks and old tyres are some of the discarded materials reducing the environmental impact of road surfaces

Coffee addicts will soon take further pleasure from their morning brew, with the knowledge that the grounds from their drink are contributing to more environment-friendly roads, thanks to researchers at Swinburne University of Technology.

Professor Arul Arulrajah from the Swinburne Centre for Sustainable Infrastructure and his colleagues found a way to treat the unlikely combination of coffee grounds and slag from iron production for use in roads.

"I am an avid coffee drinker and I noticed that baristas throw away a lot of coffee grounds," he said.

He discovered the mixture of coffee grounds and iron slag was strong enough to be used as the foundation material beneath the road surface. But the mixture won't become the dominant road-base anytime soon. "We estimate that Melbourne coffee drinkers only produce enough coffee grounds to build five kilometres of road per year."

Through partnerships with Vic Roads and Sustainability Victoria, Arulrajah also studied the best way to reuse materials such as brick, glass, concrete and rock in road construction. His work has led to recycled content being approved for

© Eamonn Gallagher

Arul Arulrajah could turn your daily brew into sustainable infrastructure.

road-building. Australia generates around 19 million tonnes of waste from demolition and construction each year, including potentially reusable concrete, rock, brick and glass. Only 55 per cent is recovered or recycled.

Brick and glass have been historically considered unsuitable for road base and were limited to small percentages, but Arulrajah and his team tested waste concrete, rock, brick, and glass and found the materials as good or better than quarried material. "We used the same rigorous tests as with quarry material, in the laboratory and the field," said Arulrajah.

Vic Roads has now approved adding 15 per cent recycled glass or brick in high-traffic roads and 100 per cent recycled material for low-volume roads.

VIC ROADS HAS NOW APPROVED ADDING 15 PER CENT RECYCLED GLASS OR BRICK IN HIGH-TRAFFIC ROADS.

The use of landfill waste over virgin quarry materials lowers the carbon dioxide emissions associated with road-building. Sourcing the raw materials and turning them into concrete, plus the chemical reaction that occurs as concrete sets, releases 65 per cent more carbon dioxide than repurposing waste concrete for road-base.

Another research project is looking to improve the lifespan of footpaths by adding rubber from old tyres, through funding from Tyre Stewardship Australia and Vic Roads.

"Australia produces about 52 million passenger tyres annually," said Liam O'Keefe, Market Development Manager, Tyre Stewardship Australia.

"While we send some tyre waste overseas to be burned as fuel, we only recycle 5 to 10 percent in Australia," O'Keefe said.

Professor Arulrajah is researching how to add tyre-derived aggregates to the sub-base layer to reduce cracking and lengthen pavement life.

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Business development programs yield better bang for bucks

Should governments keep their noses out of business development? Swinburne has the answer.

A Victorian government program that helps Australian businesses make connections and improve their international exports resulted in an extra $1.8 million influx to the Australian economy per participant, a Swinburne University of Technology study has found.

"The program more than paid for itself in the cost–benefit analysis and warrants more investment," said Professor Beth Webster, an industrial economist from Swinburne's Centre for Transformative Innovation.

The question of how or if the government should support business has long been debated. Many believe the government should remain separate, while others think it has a duty to help Australian businesses develop international credibility. Despite vociferous rhetoric on both sides, there has been a lack of objective data for officials to base their funding decisions on — until now.

Webster and her colleague, Associate Professor Alfons Palangkaraya, pored over data from more than one million Australian businesses to see if government programs designed to help small to medium-sized businesses provide bang for their buck.

Previous analysis focused on case studies and small sample sizes, which Webster compared unfavourably with drug testing protocols. "Would you be happy using a drug that had only been tested on ten people?"

The limited data on outcomes led to a lot of changing of government policies to see which programs worked and which didn't, until decisions were made almost on a trial and error basis.

In contrast to this haphazard approach, Webster and Palangkaraya used an empirical method characterised by strong scientific elements, including controls, to determine if, on cost–benefit basis, the millions of dollars invested in business development programs were well spent.

Focusing on two programs — trade missions, where a government official takes a delegation to meet trade representatives overseas and VicStart, a Victorian government initiative aimed at assisting innovators and entrepreneurs — the team had the unenviable task of whittling down 40 million data points, gathered between 2002 and 2014, to a more manageable level. By examining more than a decade worth of data, the team were able to reduce political sensitivity and to allow time for the programs to have an effect.

They found that VicStart participants reported an 8 per cent increase in sales and cost the government about $16,000 per company. The trade missions program resulted in an export increase of $1.8 million per participant over the 12 months following the program. The government subsidy per participant was between $2,000 and $3,000. The team noted that these types of studies could help governments establish better criteria for decision-making, "when choosing if they should invest in these types of programs or build a new road instead."

Moving forward, the study could be improved by including data related to repeat attendance in the programs, as Webster noted, "more data, means more nuanced information — at the moment it's more of a headline measure of success." She also noted that this approach could be extended to examine the effectiveness of commonwealth and overseas programs.

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Beth Webster (left) and Alfons Palangkaraya (right) are analyzing government programs using empirical methods.

COVER STORY

BAOHUA JIA
"Life is basically governed by physics and chemistry. If you know the rules, everything is simple."

© Eamon Gallagher

BAOHUA JIA is driven by the desire to change lives, and her work has led to breakthroughs in renewable energy and medical imaging technologies

SEEING THE WORLD THROUGH A DIFFERENT LENS

You never forget a good teacher, says Swinburne researcher Professor Baohua Jia. Especially one who unlocks the world of science, inspiring you to dedicate your life to research.

"As a child I wasn't very good at physics, but in high school there was a physics teacher who really changed my attitude," explains Baohua, recalling the moment her interest in the subject was piqued. "He was able to explain really complicated things in a simple way, and this made me think very differently about physics."

Raised in Tianjin on China's north-eastern coast, from a young age Baohua enjoyed "experimenting and thinking things through," an approach she attributes to her father, an engineer, who she remembers fixing things around their home. Now an Associate Professor at Swinburne University of Technology, she is clearly very good at both. Her work has contributed to the development of speedier telecommunications, cheaper and more efficient solar cells and the application of

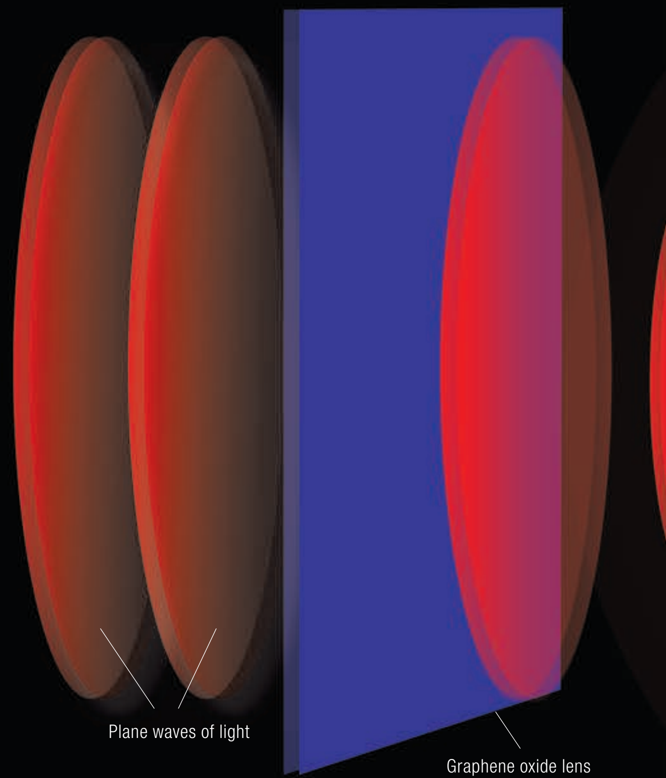
WONDER STUFF

First made in 2004 by researchers in the UK, whose work won them the Nobel Prize in Physics in 2010, graphene is the world's first two-dimensional (2D) material. Its remarkable physical properties have intrigued scientists ever since, and could usher in the next technological revolution.

Made from layers of single carbon atoms arranged in a honeycomb lattice, graphene is around two hundred times stronger than steel of the equivalent thickness, a thousand times more conductive than copper, tougher than diamond, and incredibly flexible and stretchable. It is also completely transparent.

Graphene could open the door for flexible, wearable smartphones and tablets that could be rolled-up like a newspaper. Being transparent, it can be used in applications such as the touchscreens on phones, or electricity-generating window panes.

In the future, graphene could also be used to coat machinery, resulting in almost zero energy loss between moving parts, improving energy efficiency and extending the life of the equipment. It could also be used for coating surgical tools and killing bacteria, reducing the need for antibiotics, leading to lower rates of post-operative infections and improving recovery times.



graphene's amazing properties to streamline lenses and store energy.

"I like to know the rules that govern things, and physics is really the rules behind everything," says Baohua. "Life is basically governed by physics and chemistry. If you know the rules, everything is simple."

WOWED BY SWINBURNE

After completing her university entrance exams, Jia majored in optics for her undergraduate double degree, studying for a Bachelor of Science in Applied Optics and Bachelor of Economics and Management at Nankai University in Tianjin.

"Light seemed really clean and bright to me. I wasn't thinking logically, it just felt right," says Baohua. "I'm also an energetic person who wants to do many things. I enjoyed science, but also studying management turned out to be very important for my career development."

Baohua says she was always interested in finding practical solutions to problems, and, after graduating, continued to pursue her interest in optics by studying for a Master of Science in Optical Communications at Nankai University, focusing on fibre-optic sensors and their use in telecommunications.

After completing her master's degree in 2002, an opportunity to study overseas arose when a meeting with the head of the Centre for Micro-Photonics at Swinburne University of Technology in Melbourne led to the offer of a scholarship to study for a PhD.

"I'd always wanted to go overseas to gain more experiences and further my knowledge, and was considering going to America, but when I saw what Swinburne were doing, I thought 'wow' and moved to Australia instead," Baohua explains.

Despite adapting well to the cultural change, she says the first year was particularly challenging as she battled to find a direction for her research. Having previously worked with fibre-optics, she was now working in a new field in which her knowledge was limited.

Deciding to work in near-field optics — a branch of science that seeks to improve the performance of imaging devices, such as cameras and microscopes — she focused her research on "practical outcomes that could change people's lives".

"My supervisors were very supportive, and once I found a direction for my research, I really enjoyed myself," explains Baohua.

In recognition of the quality of her research she was awarded the Biotechnology Entrepreneur Young Achievement Australia Award in 2005, the first of many accolades.

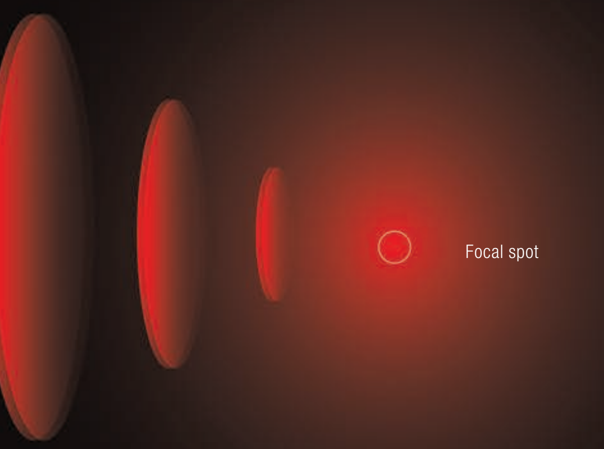
Shortly after giving birth to her first child in 2006, she received her PhD, which she describes as one of the happiest moments of her life: "My daughter was six months old and attended the graduation ceremony with me. I was very proud of that."

"She loves science, and my son, who is now four, is also asking questions. I love explaining things to them. Sometimes I can't answer, so I encourage them to look things up in books."

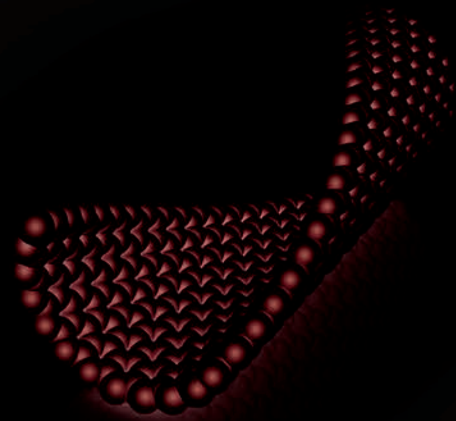
OPTICAL CIRCUITS

With a young family to consider, she initially struggled with the competitive and uncertain nature of academic research, and at one point considered leaving the field to pursue something else. Her persistence, however, was about to pay off.

Soon after receiving her doctorate she was offered a position at the Centre for Ultrahigh-Bandwidth Devices for Optical Systems (CUDOS), an Australian



GRAPHENE LENS
Baohua and co-workers have created an ultrathin graphene oxide lens (blue) that can convert plane waves of light (red) into a focal spot, capable of producing images with the quality and sharpness of much larger glass lenses.



GRAPHENE'S ASTONISHING PROPERTIES PROMISE TO REVOLUTIONIZE MANY OF TODAY'S TECHNOLOGIES.

Research Council (ARC) funded Centre of Excellence.

"I was responsible for coordinating 20 researchers from across five different universities, and our goal was to develop an optical chip to replace the current electronic chips used in telecommunications, which are slow and have limited bandwidth," Baohua explains. "Those two years were very enjoyable and extremely fulfilling."

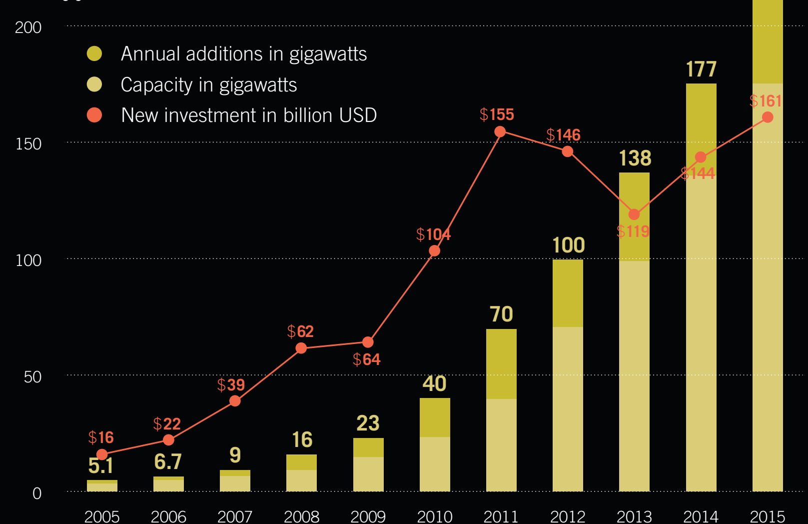
The project led to a breakthrough in optical circuitry, accelerating telecommunications able to transfer much larger amounts of data. The results appeared in the journals *Nature Photonics* and *Advanced Materials*.

In recognition of her work for CUDOS, she was awarded an ARC post-doctoral fellowship (APD) in 2008, which proved to be a turning point in her career.

"The fellowship meant I could develop a long-term goal. Continuity as a researcher allows you to develop an in-depth understanding of a subject," Baohua explains. "Swinburne gave me the freedom and support to focus on my own research and continue along the path I wanted to follow."

SOLAR PHOTOVOLTAICS GLOBAL CAPACITY

The global solar photovoltaics market has seen record growth for the past decade, spurred by annual new investment in the public and private sector. The total capacity in 2015 was estimated at 227 gigawatts.



Source: REN21, Renewables 2016: Global Status Report

SOAKING UP THE SUN

In keeping with Baohua's philosophy that research should lead to practical outcomes that can change lives, she turned her attention to solar cell technologies, and in 2010 was appointed research leader in nanophotonics solar technology at Swinburne.

Taking on the challenge of reducing the cost and improving the efficiency of solar cells — a problem manufacturers have grappled with for decades — she approached the problem from a new angle, using Swinburne's expertise in making nanostructures to find a solution.

> **"I LIKE TO KNOW THE RULES THAT GOVERN THINGS, AND PHYSICS IS REALLY THE RULES BEHIND EVERYTHING."**

"If more light enters the solar cell, a higher efficiency can be achieved," she explains.

"So we approached Suntech Power Holdings, one of the world's largest solar cell manufacturers with our ideas. They were keen to collaborate, but on the condition that we could secure government support."

Solar cells are made of multiple layers of semi-conducting materials that convert light to electricity. To improve efficiency, most research had focused on increasing the purity of the layers. Baohua, working with her team, looked at how extremely small materials interact with light, a field known as nanoplasmonics, and developed a low-cost solar cell that absorbs more light than can be manufactured using current technologies.

The solar cell is a thousand times thinner than current cells. By placing it on a glass pane, it could replace expensive rooftop solar cells with windows capable of powering the whole building (See Solar photovoltaics global capacity, page 31). Supported by their industrial partner and Swinburne University, Baohua's team secured funding from the Victorian government, and the Victoria-Suntech Advanced Solar Facility opened in 2010, with Baohua appointed a senior research fellow for the facility.

"I've known Baohua for more than a decade," says Professor John Wilson. "She's a very good team player and also works well on her own.

"Her work has always been very innovative. She really is quite a star and a real asset to the university." John has been the Executive Dean of the Faculty of Science, Engineering and Technology at Swinburne for the past five years and has great respect for Baohua's research and her approach to working with others.

"She has a very caring nature too, and I had the privilege of meeting her daughter and mother at an award ceremony," says John, referring to the occasion when she was awarded the Australian Institute of Policy and Science's 2013 Young Tall Poppy Science Award. "It was lovely to see the three generations celebrating her success together."

FILM STARS

Baohua continues to work on solar cells, but has recently turned her attention to graphene (see Wonder stuff, page 30), whose astonishing properties promise to revolutionize technologies. "Much of the research has focused on synthesizing graphene, but our starting point was quite different," explains Baohua. "We were interested in looking at its optical properties and their potential use in real-world applications."

Producing graphene can be costly and challenging, so Baohua and her colleagues used a laser to pattern layers of graphene oxide (graphene combined with oxygen), and then by removing the oxygen, produced low-cost, patterned films of graphene, a thousand times thinner than a human hair.

"By patterning the graphene oxide film in this way, its optical and electrical properties can be altered, which allowed us to place them in different devices," says Baohua.

The work has led to the development of a lens a billionth of a metre thick that can be placed on the tip of an optical fibre capable of producing images with the quality and sharpness of much larger glass lenses.

"Compared with current lenses, our graphene lens only needs one film to achieve the same resolution. In the future, mobile phones could be much thinner, without having to sacrifice the quality of their cameras. Our lens also allows infrared light to pass through, which glass lenses don't allow," explains Baohua.

Warm objects give off infrared light, and so mobile phones with graphene lenses could be used to scan for hotspots in the human body and help in the early identification of diseases like breast cancer.

And by attaching the lens to a fibre optic tip, endoscopes — instruments inserted into the human body to confirm diagnosis or deliver treatment, which are currently several millimetres wide — could be made a million times smaller. Baohua's work on graphene lenses was published in 2015 in *Nature Communications*.

Baohua and her colleagues are also investigating graphene's amazing physical and electrical properties for their potential use as supercapacitors, capable of storing very large amounts of energy, which could soon replace conventional batteries (see Turning current wisdom on its head, page 12).

"Baohua has really advanced our knowledge of graphene in the last few years," says Professor David Moss. "We've had a lot of interest in the lens technology, and it's her that is driving this forward. The work is a real strength for the centre."

David joined Swinburne University as Research Director of the Centre of Micro-Photonics six months ago and has already come to respect not only Baohua's expertise, but also to appreciate her assistance in helping him settle into the role. "She's very open and supportive, and it's a huge pleasure to work with her," David says.

"Taking over a new centre isn't easy and we have a number of Chinese students that Baohua has helped with adapting to a new culture, which can often be very challenging."

A positive and open attitude epitomizes Baohua's approach to work and life. "Life should be enjoyed, and doing my science work makes me enjoy life more," she says. In addition to her research, supervisory and teaching responsibilities, she also regularly gives talks to schoolchildren. "A teacher changed my life, and I'd like to do the same thing for the kids I speak to." ■

MAPPING THE DIGITAL DIVIDE

Being connected to the internet is increasingly the key to any chance of wealth, education and status. Identifying unconnected Australians is the first step to improving social equity.

Australia's optic fibre network has arrived in the rural city of Mudgee in central New South Wales, but that doesn't help Carly Hanrahan. Living more than 20 kilometres outside the town, she can't connect to the network. She also lives more than 15 kilometres from available mobile phone reception. Her only options to get online are through dial-up — too slow — or satellite broadband, which is too expensive.

"I knew there was no mobile phone reception when I moved out here, but I thought I would at least be able to get broadband," Carly says. To make matters worse, her workplace just outside town doesn't have an internet connection either. Instead, she has to plan all her online activities, including schoolwork for her young son, around trips to Mudgee.

"It's getting to be a problem with his homework and looking up information, so we just work around that and plan to use the library," Carly says.

This is the digital divide: an invisible, but very real line, between the digital-haves and the digital-have-nots.

On one side of the divide are the majority of Australians, who enjoy fast, affordable access to the internet and know how to get the most out of it. But for another three million or so, access, cost or know-how are a major barrier to taking part in many aspects of modern life.

The gap between those who have access to fast and affordable internet and those who don't is deepening.

> “The costs – financial, social and economic – of being digitally excluded are increasing, while the benefits of being digitally included are growing exponentially.”

The cost is real and significant, says Dr Scott Ewing, senior research fellow at Swinburne University of Technology.

“Digital exclusion exacerbates financial disadvantage, because increasingly firms want to transact with consumers online and you pay a penalty if you want to transact offline,” Ewing says. “It also means you can’t access cheaper goods and services.”

While some people might not see social media as an essential part of life, for those locked out of this world, it is a significant social cost. “Over time, the online–offline binary thing is just going away. People are moving between the two modes and if you’re excluded from one mode, this is a great disadvantage,” Ewing says.

“The digital divide is not new, but its contours are changing as we conduct more of our lives online,” says Professor Jo Barraket, who is Director of the Centre for Social Impact at Swinburne. “The costs — financial, social and economic — of being digitally excluded are increasing, while the benefits of being digitally included are growing exponentially.”

The first step towards overcoming this divide is to understand whom it affects. This is the aim of the Australian Digital Inclusion Index — a collaboration between Swinburne University of Technology; Australian telecommunications company Telstra; collaborative research hub, the Centre for Social Impact; and Roy Morgan market research company.

“The index provides us with clear longitudinal information about the geographic and demographic dimensions of digital inclusion in Australia,” says Barraket. “We wanted to think about what constitutes inclusion and then look at who is and isn’t included and how we are collectively progressing over time.”

The starting point for this is data from Roy Morgan Research’s ongoing, weekly Single Source Surveys, which involve face-to-face interviews with more than 50,000 Australians from across the country, exploring their internet and technology use, attitudes and demographics.

From this enormous dataset, the Swinburne research team identified three critical dimensions of digital inclusion: access, affordability and digital ability. Access describes how, where, how frequently and by what means people access the internet. Affordability describes how much of an individual’s income is spent on accessing the digital world and how affordable that is. Digital ability describes how much people can do online and how confident they are with using the internet for banking, social media, and searching for information.

“Access to infrastructure is important, but it is not the full story,” Barraket says. “The index suggests that affordability is an issue that needs to be monitored as we do more and more online, and that digital ability is a fundamental aspect of digital inclusion around which we can do more to build people’s capacity to participate.”

AGE AND EDUCATION

The first report from the Australian Digital Inclusion Index has examined three years’ of data from 2014–2016, and shows that these three dimensions of digital inclusion vary enormously across age, geography, socioeconomic profile and education level (see Digital inclusion in Australia, page 35).

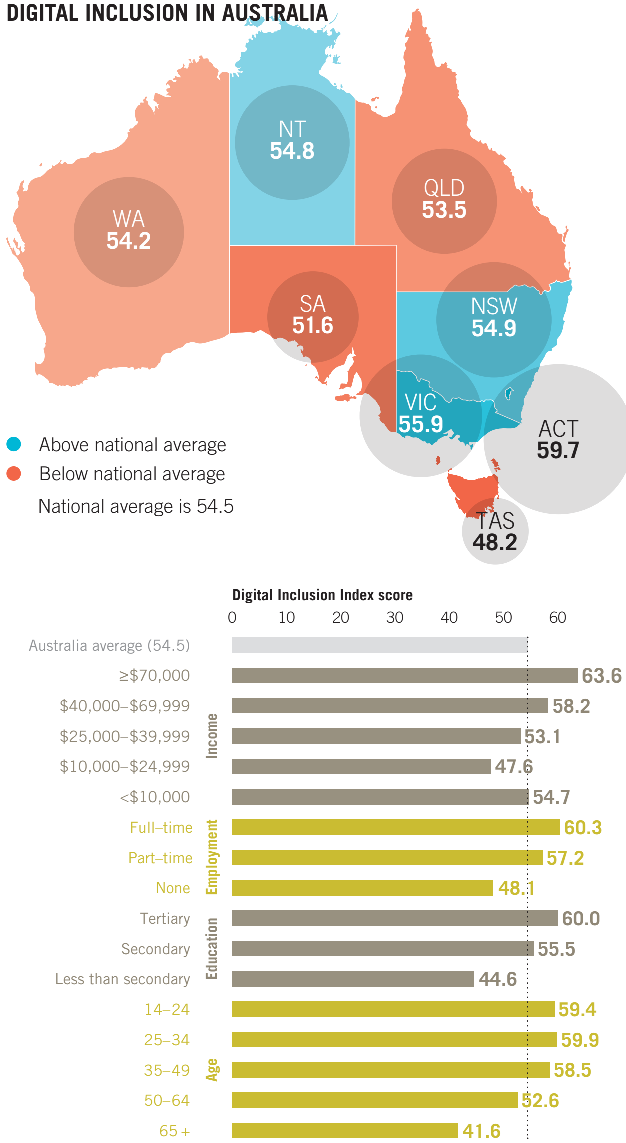
Digital ability in particular is tied to age and education, says Nancie-Lee Robinson, General Manager of Digital Inclusion at Telstra. While anyone born in the last 20 years has grown up in the digital age, there are millions of Australians aged over 65 who haven’t, and they are more vulnerable to digital exclusion.

“This is where education comes into play. Large portions of the workforce — because of the kinds of work they’ve been doing these past 20 years, are not as skilled as others in terms of digital use,” Robinson says. “Even though they have the access, what they’re doing online is not the same as what an 18-year-old is doing.”

As technology evolves, older generations face a greater challenge in keeping up-to-date. “Even though we might have people who know how to email or search on the internet, do they know how to use social media, pay their bills, purchase something or create content?”

In Australia, where you live also has a big impact on your ability to access digital services, and this is an issue that other countries don’t necessarily face, says Julian Thomas, former Professor of Media and Communications at Swinburne. “It’s a striking fact that the people who, in a way, have the most to gain from these

DIGITAL INCLUSION IN AUSTRALIA



Source: Roy Morgan Research, April 2015 - March 2016.

The Digital Inclusion Index score assesses several variables related to access, affordability and digital ability on a scale of 0 (low inclusion) to 100 (perfectly digitally included).

technologies because of their remoteness and isolation, are often the people who have least access and opportunity to use them," he says.

The third dimension of digital inclusion — affordability — revealed some surprises. While the cost of data has gone down, affordability of digital access has actually declined across Australia, particularly in Tasmania.

"Household incomes have been pretty static for three years, but people are spending more money on data," Thomas says. Some of this increased cost may come about as more Australians sign on to live streaming entertainment services, such as Netflix, which could be being offset as they spend less money on satellite-based services. But it is a concern, particularly for people on fixed lower incomes, he says.

"When governments are moving services online, and we're seeing health and education going online as well, then we really need to make sure affordability is not a serious impediment."

Overall, Australia is doing pretty well. Access scores have increased steadily, digital ability scores have also increased at a national level, and while affordability itself may have declined, the value of expenditure — the cost of data — has fallen.

But the index showed that digital exclusion follows similar patterns to other forms of social and economic exclusion, says Robinson. "Where there is existing disadvantage, these people are also not enjoying great online life and in a digital age it means there is a big risk of those people falling further behind," she says.

"This has an impact on their education, health and wellbeing, and social connections. You could argue that's the very group that could benefit the most from being online."

Wealth played a big part in digital inclusion, as did full-time employment and education level. Indigenous Australians had a relatively low level of digital inclusion, which may even have been underestimated, due to the low numbers of remote indigenous communities surveyed.

The first Australian Digital Inclusion Index report revealed hotspots of exclusion: Tasmania, the Hunter Valley, northwestern Queensland, Eyre in South Australia, and much of regional Western Australia.

There were also hotspots of inclusion: Wollongong earned a digital inclusion score higher than that of some capital cities.

So how can this data be used? As the first of at least two more annual reports, it will provide a regular snapshot of the changing face of digital inclusion in Australia, which could be especially useful in monitoring the impact of interventions designed to increase inclusion, Robinson says.

"The first report has provided us with a benchmark, but it helps policy-makers, it helps practitioners, it helps the people in libraries that are becoming digital hubs, it helps businesses like Telstra that have support programs, it helps us to better target our efforts," she says.

"There are three million people not online in Australia — that's three million people who are behind the eight-ball, so it's a significant social justice challenge." ■

FINDING A VOICE OF REASON

Research has shown the voices heard by people with schizophrenia may be thoughts perceived as sound. A new Swinburne study is trying to track down exactly where in the brain the signal goes awry.

Have you ever heard someone call your name, then turned to find no-one there? Maybe it's happened once or twice, but you've dismissed it and life has gone on as usual.

Imagine that this wasn't an isolated occurrence. Imagine that voice talks to you all the time, not just calling your name, but insulting you and telling you to do unspeakable things. And, when you turn around, there is no-one there.

This is life for many people with schizophrenia. As many as 80 per cent of sufferers hear voices; sometimes sporadically, sometimes chronically.

Auditory hallucinations also affect people with bipolar disorder, depression, borderline personality disorder, and even people with no other manifestations of mental illness.

The causes of auditory hallucinations have occupied Professor Susan Rossell for more than two decades. A cognitive neuropsychologist at Swinburne University of Technology, she's using powerful new imaging technology to study why some people hear voices and what can be done to help them manage it.

One insight from Rossell's work is that voice-hearing appears to be an abnormal experience of a very normal human phenomenon — internal self-talk. "We all have internal dialogue but we can choose to listen to our thoughts or not to listen to our thoughts," Rossell says.

Her previous work has shown that this internal dialogue activates the same regions of the brain — the language processing centres — as when someone real is talking to us. Most people are able to tune out this internal voice, along with all the other extraneous auditory stimuli we are constantly exposed to, such as traffic noise, birds, and other conversations.

But, this 'attention inhibition' switch is what Rossell thinks might be malfunctioning in conditions such as schizophrenia.

"We think people who hear voices are not able to correctly filter out the noise in the world around them and included in that noise is their own internal dialogue."

This discovery was profound for Rossell and her patients. "When we worked out that hearing voices was just a normal linguistic experience, it was incredibly relieving for the sufferers because we were able to tell our patients that this is part of normal language," she says. "They really like it, because they've been told for years that their brain is wrong."

This discovery raised the question of why people with schizophrenia and other conditions aren't able to tune out the voices.

To explore this, Rossell and her colleagues are combining conventional magnetic resonance imaging (MRI) and magnetoencephalography (MEG), a new imaging technique. MEG shows the magnetic patterns produced by the brain's electrical activity, in very fine detail and in real-time, while the MRI will enable researchers to look at the brain structures activated when people hear voices.

Patients sit in the MEG scanner and are given a button to push whenever they hear a voice. It's the first ▶

Susan Rossell has spent more than two decades using powerful brain imaging technology to study why some people hear voices and how to help them.

Often the voice is that of the perpetrator of prior emotional, physical or sexual trauma.

time voice-hearing has been studied like this, and is made possible by Swinburne's world-class neuroimaging facility.

"What we're doing for the first time is looking at the 20 seconds before the voice-hearing experience to explore what brain mechanisms are involved in the trigger and causing the voice," Rossell says. "This experiment is trying to study these attention inhibition networks just before the voice experience to see if there is an area of the brain that is activated incorrectly, because nobody's been able to look at that before."

Data analysis will begin when the study finishes early in 2017.

At the same time, Rossell and colleagues are conducting other studies to better understand who is affected by voice-hearing and what some of the triggers might be for the phenomenon.

"We've got a good idea of some of the triggers of voice-hearing experience; things like previous stressors, developmental issues, problems with auditory processing, problems with a type of memory, referred to as source memory," she says. "It's quite a comprehensive picture but it's no way near complete."

For many people who experience voice-hearing, it's an intensely persecutory experience, which seems to stem from prior emotional, physical or sexual trauma, and often the voice is that of a perpetrator. The involvement of past trauma and association with stress may explain why the phenomenon is significantly more common among immigrants and refugees.

Clinical psychologist, Associate Professor Neil Thomas from Swinburne, says he is often astounded at how well people who hear voices are able to function, given how distracting the experience must be.

"Not only is it hearing someone talking which seems as real and as loud as I'm talking now, but also the voices are talking directly to the person or about them, so it's got this other layer in which it can really capture the person's attention," says Thomas. He and colleagues have been working on ways to help people who experience voice-hearing to better understand the triggers for the experience.

While Rossell is using neuroimaging to look at what happens inside the brain just before the onset of voices, Thomas is working with PhD student, Imogen Bell, using smartphones to look at what might be happening outside the brain at that same moment.

Individuals who experience voice-hearing can use an app on their smartphone to record the noise around them when the internal voices get more intense so that researchers can gather clues about what else might be going on around them at the same time.

"There are usually patterns identifiable when voices occur," says Thomas. "It might be when people are experiencing more stress, it might be when things are really noisy, it might be when people are particularly fatigued, so the first thing we're doing is helping people to track patterns." Alcohol and substance abuse are also known triggers for voice-hearing.

They're also using smartphones to find more effective coping strategies for voice-hearing. One approach being studied is based on the principles of mindfulness; a practice derived from Buddhist meditation, which encourages a focus of awareness and consciousness on the present state.

"The person who experiences the voices can program coping advice for themselves into the phone," Thomas says. "So when they're in the situation where they are hearing voices, they can look at the phone and it can give them advice and prompt them with reminders throughout the day to do things that might be helpful in reducing the intensity of voices."

This approach has the advantage of providing help to people who might not be able to access the kind of specialist services provided by Thomas and Rossell's clinic, which is one of the few in the world specifically focusing on auditory hallucinations. Thomas has also found that peer support from others who experience hearing voices can help people cope with these episodes.

UNDERSTANDING THE EXPERIENCE

Drug treatment is available for disorders such as schizophrenia, and for some patients, it can make the voices go away. But, Rossell and Thomas's work is unique in helping patients to understand their own experiences. "Many of the people that we work with don't understand what's causing the voices or are very confused by the experience," Thomas says. "For them it can be helpful to work out that the voices aren't actually able to harm them."

It is also revealing that these voices are an experience common to the human condition. Rossell's work has identified a group of people with no other signs of mental illness, but who also experience voices at a similar intensity to people who do. have other manifestations.

> "For many people it can be helpful to work out that the voices aren't actually able to harm them."

What's striking about the former group is that their voice-hearing is often a positive experience.

"Some people describe them as like their guardian angel," Rossell says. "It's a voice that helps them make decisions, guides them, or gives them good advice."

Historically, voice-hearing has not necessarily been viewed as a negative phenomenon, but perhaps a sign of divinity — as for Joan of Arc — or inspiration — as for Charles Dickens and Socrates.

These past perceptions reinforce the notion that this is not the manifestation of a broken mind, but variations on a wide spectrum of experiences, Thomas says.

"We're shifting our understanding of this from being a symptom of illness to something which is a human phenomenon," he adds.

As their research advances, the voices are likely to be better understood, and more manageable than ever before. ■

The quest for commercial quantum computing has taken a leap forward with the advent of a quantum chip that can generate many entangled photons and is compatible with existing semiconductor fabrication processes

HIGH-STAKES CHIPS

Quantum physics is unlike anything in our everyday experience. It allows an object to somehow exist in all of its possible states at the same time, and 'quantum-entangled' objects seemingly communicate instantly at any distance. It is a relief that we don't need to contemplate such contortions of predictable reality in our daily lives, but we are fast approaching an era in which these exotic quantum effects could be driving everyday activities such as secure online communications, as well as their much touted use in the supercomputers of the future.

Professor David Moss, Director of Swinburne University of Technology's Centre for Micro-Photonics in Melbourne, has been using light for more than a decade to develop better devices for data communications and processing, and his research has now taken him to the leading edge of quantum technology. In collaboration with colleagues from around the world, including Roberto Morandotti from the INRS (Institut national de la recherche scientifique) in Canada, Moss and his team at Swinburne have demonstrated a computer chip that overcomes two of the most challenging obstacles to commercial realisation of quantum technology — generating a continuous high-volume supply of quantum particles, and producing the device using conventional mass-fabrication techniques.

"Our device represents an unprecedented leap in the quality, sophistication and sheer

DAVID MOSS
"We have a whole bag of tricks that we are planning to use to tame and enhance these microcombs."

> "The race is on to devise and construct a quantum device that can out-compute today's solid-state silicon supercomputers."

ENTANGLEMENT VS SUPERPOSITION

Wave-like particles of light, known as photons, can behave in a peculiar manner known as 'entanglement'. By running them through crystals and laser equipment, the photons' properties become correlated or entangled. If they are then despatched in different directions, quantum physics dictates that when we measure a property on one of the entangled photons, we can be sure that the same property of the other is correlated.

The paradox that flustered even Einstein is that the result differs depending on which property is measured, and the measurement of one photon appears to change the properties of the other. Physicists believe that this arises because once entangled, the pair of photons becomes governed by a single quantum equation, with both existing in a linked but fuzzy, unresolved quantum state of all possible properties — quantum superposition — until one is measured and the uncertain state collapses into two separate but correlated states. Entangled states are the basis of many protocols and algorithms for both quantum communications and computation. Superposition, without entanglement, can also be used on its own for quantum computing, where the fuzzy superposition of quantum states is used to perform many calculations simultaneously — akin to reading all pages of a book at once. Rather than the binary on-or-off bits in conventional computing, the 'qubits' of quantum computers can be in the on and off states. Theoretically, an array of many qubits could greatly accelerate simulations, allowing rapid calculation of problems that take years using supercomputers.

number of quantum entangled photon pairs that can be generated on an integrated chip," says Moss, "and we did it using a chip that is compatible with conventional integrated circuit fabrication methods."

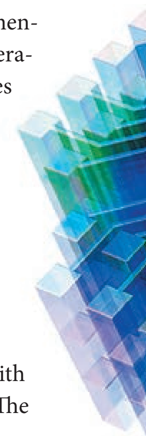
DIFFERENT QUANTUM STROKES

In quantum physics, objects are described not by classical properties, such as where they are and how fast they're moving, but by a quantum equation full of uncertainties with profound metaphysical connotations. These uncertainties resolve themselves at the macroscopic scale, giving rise to classical, predictable physical behaviour. At the subatomic scale, however, seemingly bizarre phenomena become apparent. Two such exotic quantum manifestations are entanglement and superposition (see Entanglement vs superposition), and both have their potential uses in quantum technologies.

These effects can now be reliably generated in atoms, electrons (particles of electric charge) and photons (wave-like particles of light), so researchers have a rich choice for the quantum effect they want to harness, and the platform with which to do so.

"The details of quantum entanglement for example — generating it and using it — differ depending on whether one uses electrons or photons," explains Moss. He says they focused on photons because recent advances have enabled the generation of entangled and single photons on a chip. This gives rise to the possibility of transmitting quantum states encoded in photons that will act as the ones and zeros of conventional computing through fibre optic networks and even free space.

"Photonic systems are also much less sensitive to environmental noise — even at room temperature — compared with strategies based on electrons or atoms that require ultra-low temperatures. This has been an extreme challenge for the solid state folks," says Moss.



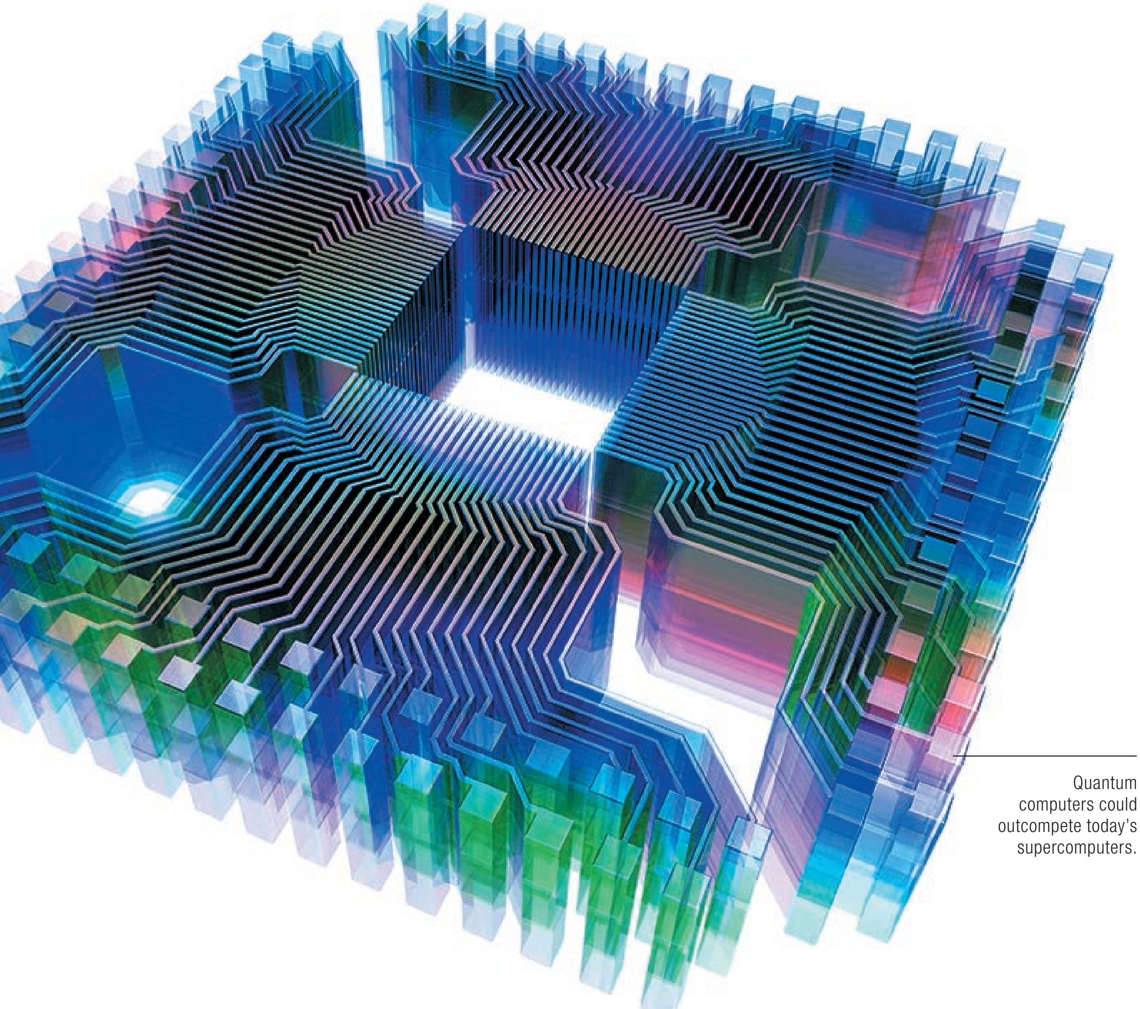
Another key advantage of using light is that it can be applied in ways that mirror conventional electronics, but with the promise of so much more. The study of light is a research area that has expanded phenomenally this century and has given rise to some remarkable new technologies including lasers, better optical fibre systems and photovoltaics, night vision, and even 'invisibility cloaks'.

FROM PHOTONICS TO QUANTUM SUPREMACY

The idea behind quantum computing has been around for almost half a century, but getting to a point where quantum effects can actually be created experimentally has taken a long time.

Now that materials physics and photonics have caught up, the race is on to devise and construct a quantum device that can out-compute today's solid-state silicon supercomputers (see Quantum computers).

"Many researchers believe that the goal of quantum supremacy — performing a function that is beyond the capability of classical computers — will be achieved using photonics rather than solid-state approaches," says Moss. "Realising quantum functions on photonic integrated chips or circuits will be critical to mov-



Quantum computers could outcompete today's supercomputers.

QUANTUM COMPUTERS

A conventional computer works by registering which of the millions of transistors in its central processing unit are switched on or off at any one time. These two simple states — on or off — are the ones and zeros of digital computing. Your computer seamlessly and instantly processes millions of these instructions every second to recreate images, download text and perform calculations. But imagine if your computer understood on, off and an untold number of combinations of those states. This is the goal of quantum computing: using the mind-bending world of quantum physics to process masses of information instantly.

ing quantum technologies out of the laboratory and into the real world."

Recreating the mirrors, beam splitters, phase shifters and other complicated laboratory equipment used to create even a single entangled pair of photons, however, is far from straightforward.

"This project began more than ten years ago when I started a collaboration with Brent Little and Morandotti on nonlinear devices for optical signal processing," says Moss. He says they started to move away from silicon but they still wanted to focus on devices that were compatible with silicon computing chips.

They were pioneers in the field of nonlinear integrated optical devices that are compatible with electronic chips. These are considered to be essential components if the promise of quantum computing is to be realised. "At that time, it had become apparent that silicon itself had fundamental limitations for classical nonlinear optics. This motivated us to explore a new platform for integrated nonlinear optics, and we focused on one that was being developed by Little for linear applications, and the rest is history.

"It has been a tremendously successful collaboration, and a truly international one with many people being critical to its success, including some very brilliant students and post-docs, many of whom have remained part of the collaboration after becoming professors in their own right."

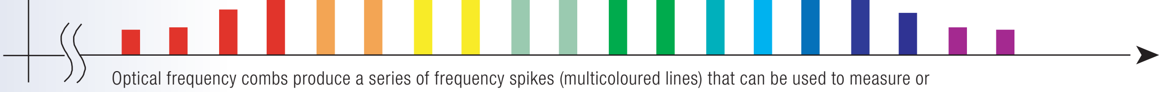
THE SECRET: OPTICAL COMBS

Moss's device utilises what is known as an optical frequency comb — an optical configuration that produces a regular series of extremely precise and equally spaced 'colours' or optical lines, like the notes on a piano (see Optical frequency combs, page 44). Optical combs are ideal photon sources for quantum applications because the comb naturally produces photon pairs at precise frequencies or colours on an optical grid. Creating an optical comb, though, is much harder than it sounds, and up until recently could only be achieved using very expensive and elaborate laboratory-scale laser systems.

"In 2007, however, a new mechanism for generating optical frequency combs using exotic micro-resonators was reported, and with my collaborators in Canada we developed an integrated version of the device," says Moss. "Since

OPTICAL FREQUENCY COMBS

If you wanted to measure the frequency of light with precision, you'd need a very good measuring device. That's what optical frequency combs do. Like their quotidian namesakes, optical frequency combs consist of equally spaced 'teeth'. But in these combs, the teeth are beams of light that span a visible or infrared optical spectrum, each tooth a slightly different colour — or frequency — from its neighbour. Generated by extremely stable, ultrafast lasers, optical frequency combs typically have hundreds or even thousands of teeth. The spacing between the teeth is exact so the combs can be used for measuring the frequency of light emitted by things like lasers, atoms or stars with extreme precision. They are also the core technology behind ultraprecise optical atomic clocks. John L. Hall and Theodor W. Hänsch were awarded the Nobel Prize in Physics in 2005 for their contributions to the development of the optical frequency combs.



Optical frequency combs produce a series of frequency spikes (multicoloured lines) that can be used to measure or synthesize any optical frequency with extreme precision.

"The level of sophistication of quantum computing increases dramatically with the level of entanglement one can achieve."

Optical frequency combs, which are an ideal source of photons for quantum computing, could be fabricated in devices as small as a one-dollar coin.

then, the field of microcombs has exploded, and we are on the cusp of being able to create optical frequency comb sources in devices the size of a postage stamp."

Not only is Moss's device a natural quantum entangler, but they believe it can entangle more than one pair of photons at once. Also known as cluster states, multiple entanglement is one of the grand goals of quantum technology as it would make it possible to harness a much larger slice of the enormous potential of quantum computing.

"The level of sophistication of quantum computing increases dramatically with the level of entanglement one can achieve," says Moss. "This platform is capable of generating four-photon correlated states and this represents an important step in this direction as a possible source of photons for a quantum supremacy demonstration."

A PLATFORM FOR BIGGER THINGS

"There are many top research groups around the world that are now working on integrated microcomb sources for classical applications, but I believe we are leading the world in applications of microresonators to quantum optics," Moss says.

"We have achieved some of the best results in the world with our platform and our goal is to remain in the lead by increasing the performance of our devices. We believe they are capable of much more than what we've achieved with them so far."

With his team at Swinburne, Moss is developing an in-house fabrication facility for producing very high-performance nonlinear optical microresonators, and in the future for fabricating complex photonic circuits with many additional optical elements including switches and modulators.

"We have a whole bag of tricks to use to tame and enhance these microcombs," says Moss. "We are really only just beginning." ■

YOUTHFUL ANCIENTS

The study of ancient galaxies and star formation suddenly became a whole lot easier when Swinburne astronomer Professor Karl Glazebrook stumbled across some local lookalikes

The spiral galaxy Messier 104, known as the Sombrero and located 50 million light years away, is a subject of interest for astronomical palaeontologists.

"The living fossil galaxies are lumpy and full of gas, and are forming stars at a high rate, not like most of the massive galaxies today that are quiescent."

Karl Glazebrook collaborates with a global network of the best radio telescopes in space and on the ground.

Professor Karl Glazebrook is a kind of cosmic palaeontologist. He searches for ancient galaxies that offer clues about how our galaxy ended up the way it is.

His quest changed suddenly in 2008 when he, and his student Andy Green, stumbled across the galactic equivalent of living fossils — galaxies that looked identical to ancient ones, but were alive and flourishing. Best of all, they were relatively nearby, making studying them quite easy.

"We set out to make a control sample of local galaxies to compare with the ancient ones, and discovered local ones that looked like the ancient ones," says Glazebrook, from the Swinburne Centre for Astrophysics and Supercomputing.

"The living fossil galaxies are lumpy and full of gas, and are forming stars at a high rate, not like most of the massive galaxies today that are quiescent."

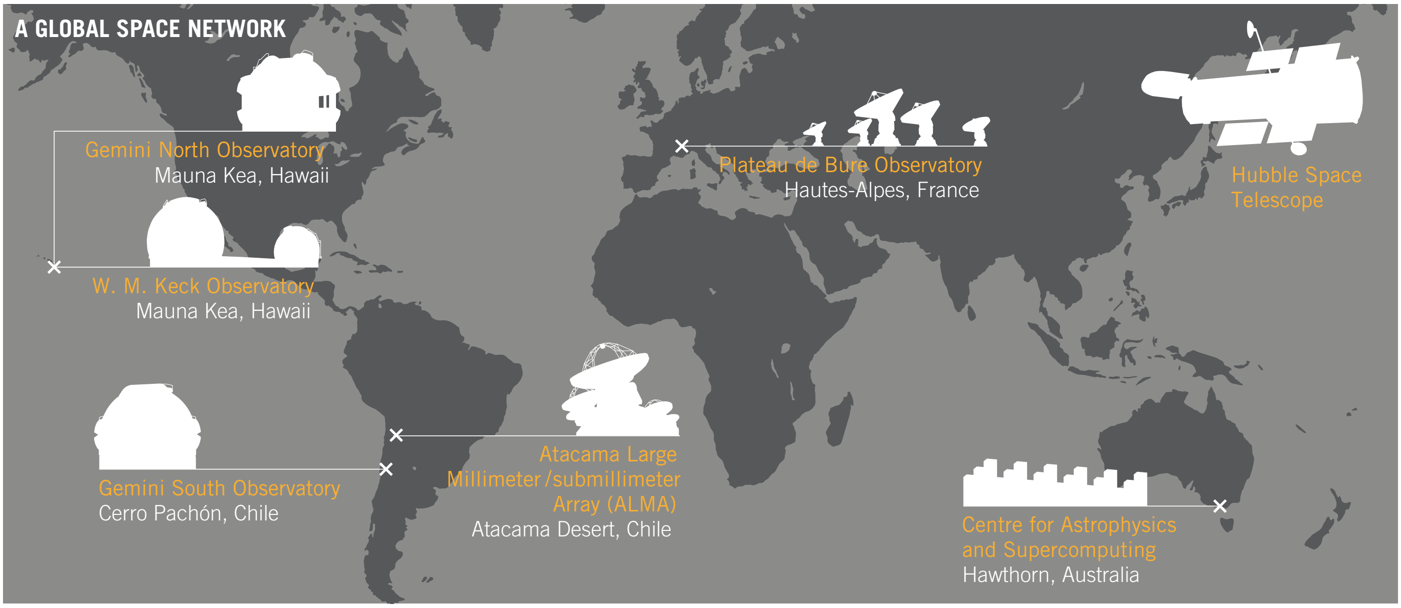
Nearly a decade later Glazebrook has built up a research powerhouse that is transforming our understanding of the early Universe with a swathe of studies using the best telescopes from around the world and, of course, the Hubble telescope in space.

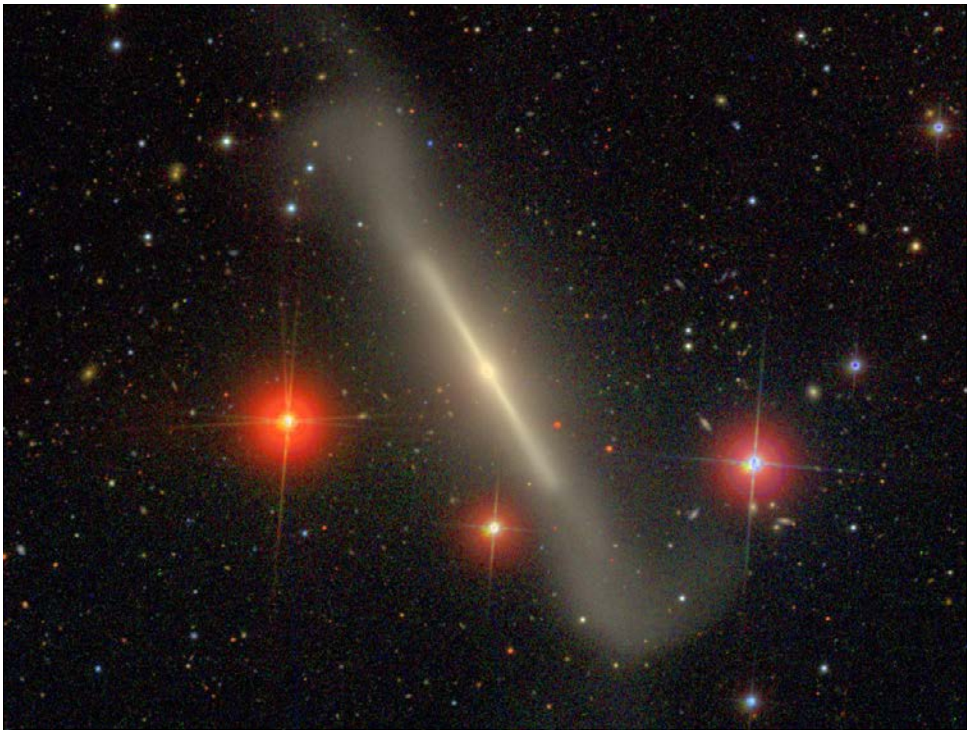
The challenge for astronomers is that they can't run experiments, they are only able to observe what the Universe presents them, try to connect the dots and come up with a coherent story of how ancient fossil galaxies evolved into what we see today.

But astronomical palaeontologists have numbers on their side. Unlike their terrestrial counterparts who have to piece together evolutionary family trees from a couple of teeth and a hipbone, Glazebrook's data set is all the visible galaxies in the Universe, numbering in the billions. The astronomer's challenge is selecting the set of matching galaxies that go together to tell a story.

Sifting through all the nearby galaxies, Green and Glazebrook came up with a set of 96 that look like they belonged in a very different time, when the Universe was expanding rapidly and many stars-to-be were still clouds of swirling hydrogen gas.

Astronomers had seen many of these swirling, irregular-shaped





The disc-shaped galaxy NGC 4762 in the constellation Virgo about 65 million light years away. Ancient clumpy galaxies could have evolved into similar thick disk components of modern galaxies.

galaxies as they peered into the furthest reaches of the Universe. Travelling a distance of ten billion light years, the light from these galaxies had been en route to Earth for three quarters of the life of the Universe. At that distance even the largest of these galaxies appears as a tiny blur, only a couple of pixels across, making it almost impossible to get much detail about their gas swirls and star formation processes.

Imagine Glazebrook's delight when he found nearby galaxies with swirling gas and glittering young stars.

"They're rare," he says. "But we can resolve them ten times better and do tests you just can't do with the distant galaxies."

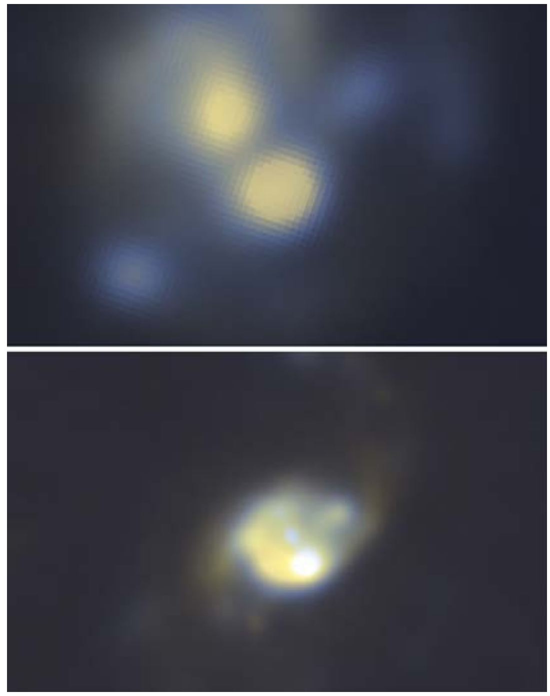
This was the birth of the DYNAMO study, (DYnamics of Newly-Assembled Massive Objects), which combines images from the Hubble Space Telescope with optical spectra from the best telescopes on the ground, Keck in Hawaii, and the twin Gemini telescopes in Hawaii and Chile. The DYNAMO team has also used a radio telescope array in France's Plateau de Bure and is rounding out the picture with the most powerful radio telescope array, ALMA in South America (see A global space network, and Tinkered twinkle, page 49). "In DYNAMO most of the things we do are new, trying different sorts of observations," says one of the newest recruits to the Swinburne team, Dr Paola Oliva-Altamirano. "Karl has new ideas every second," she says.

Leaving her native Honduras for a research internship in California, Oliva-Altamirano developed a fascination for the life and death of galaxies. A spirit of adventure drew her to Australia and, ultimately, Glazebrook's quest for galactic fossils. "The DYNAMO galaxies are such

SEEING RED

Just as sound from a plane moving towards us seems higher, then drops to a lower frequency as the aircraft passes and moves away, H-alpha radiation from hydrogen gas moving towards us appears shifted to the blue. Gas moving away from us gives a spectral line shifted to the red. And, if the gas is a turbulent mixture swirling in all directions, the spectral line is also a mixture of frequencies shifted in both directions from the original — in other words the range of observed frequencies is broader.

> "We don't know what sustains the turbulence in the galaxies, it should die out in about 10 to 20 million years."



Clumpy galaxies observed by the DYNAMO study (DYnamics of Newly-Assembled Massive Objects), which could be what galaxies looked like 10 billion years ago.

interesting galaxies. We get scenes we would never see, and make presumptions about the past."

The DYNAMO study began with measurements of red light emitted by hot hydrogen gas, a giveaway that stars are forming. Known as H-alpha, this spectral line's frequency changes if the gas emitting it is moving, as a result of the Doppler effect (see Seeing red, page 47).

A strong H-alpha line is exactly what had been found in the ancient galaxies that so intrigued Glazebrook. In the old galaxies the line was broad, too, showing that the gas clouds were moving at up to 100 kilometres per second, around five times the typical value for current galaxies.

Inside these turbulent galaxies, stars are forming ten times faster than they are in the Milky Way, but from the faint images of galaxies, more than ten billion light years away, it was impossible to tell how the star-formation rate was related to the turbulence.

But, as Glazebrook assembled his collection of nearby fossil galaxies, and realised they had similar star formation rates and turbulent gases to their ancient counterparts, as well as unusually low spin for a modern galaxy, suddenly it seemed a more detailed picture of galactic dynamics in the early Universe might be within reach.

LUMPY GALAXIES

The living fossils passed another test too. The images of the ancient galaxies beamed down from the Hubble Space Telescope showed clumpy structure, rather than the typical smooth, rotund galaxies close by. Sure enough, DYNAMO's selection of nearby galaxies also had clumpy structure. Now the work could begin analysing these weird galaxies for insights into the Universe 10 billion years ago.

Glazebrook and his team analysed the gas speeds in the nearby galaxies in detail and were able to solve the mystery of the clumpiness. Astronomers had speculated that the high gas content of the galaxies contributed to the clumpy structure, but the DYNAMO surveys were able to rule that out, instead finding that the cause was more likely to be the low spin of the whole galaxy.

"Ten years ago we had no idea why galaxies were the lumpy shapes they are," he says. "We now have a beautiful picture connecting galactic dynamics, the temperature of the gas and the gas content; it's a very simple equation."

DYNAMO's insights could provide answers to some of the biggest puzzles facing galactic astronomers at the moment about how young swirling galaxies become the stagnant, burnt-out galaxies that are common today, says Richard Ellis, Professor of Astrophysics at University College London.

"The physical processes are complex and require detailed information of the motions and chemical composition of gas clouds — the fuel for forming stars.

"DYNAMO is addressing this fundamental problem by studying the internal properties of a wide range of star-forming galaxies. Such a comprehensive approach involving several international observing facilities promises major progress in addressing how galaxies grew in the expanding Universe," Ellis says.

Behind it all, Glazebrook believes they have gleaned a broader insight into the evolution of the cosmos, which comes from the rotation of the galaxies. The ancient galaxies are rotating more slowly — they have lower angular momentum — than typical local galaxies.

This poses a question: how could local galaxies have gained angular momentum? Unlike a ballet dancer who speeds up a pirouette by pushing off the floor, galaxies floating in space have nothing to push against.

Some theories had proposed the reason current galaxies like the Milky Way have higher angular momentum was linked to their lower gas turbulence than is found in ancient galaxies.

But Glazebrook believes the answer is simpler and stems from cosmic expansion. As the Universe expands, its angular momentum increases. Younger galaxies formed at a time of higher angular momentum and carry that angular momentum for the rest of their lives.

"This result suggests that spin is fundamental to explaining why early galaxies are gas-rich and lumpy while modern galaxies display beautiful symmetric patterns," says Glazebrook.

That such deep insights into the history of the Universe could have come from the accidental discovery of nearby clumpy galaxies still amazes Glazebrook.

"It's been an unexpected journey down a rabbit-hole, this last eight years," Glazebrook says.

He and his team are delving deeper into the DYNAMO treasure chest. They have been awarded valuable time on the Atacama Largest Millimetre Array (ALMA) in Chile, an array of 66 radio telescopes that make up the world's prime sub-millimetre wave radio astronomy facility. Their target is another piece of the galactic gas jigsaw puzzle — cold molecular gas in the DYNAMO fossil galaxies, the fuel for intense star formation.

As with the Doppler shifting of the hot hydrogen gas, turbulence in the cold gas will be detectable as shifts in the frequency of the molecules, which naturally emit at 115 GHz.

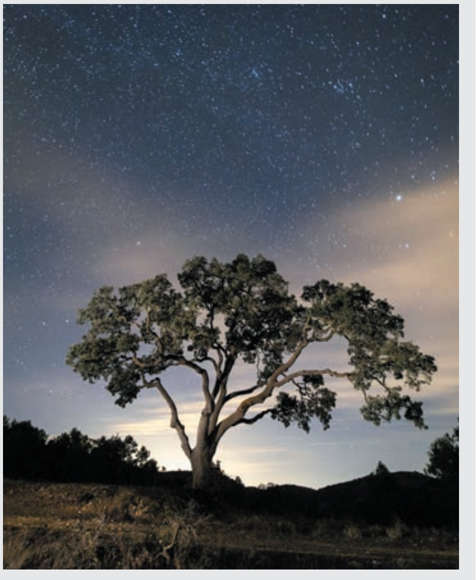
The ALMA study should see results early in 2017, and Glazebrook hopes to secure a better understanding of what drives the turbulence.

"We don't know what sustains the turbulence in the galaxies, it should die out in about 10 to 20 million years," he says.

"We don't know why they still exist nearby. My speculation — unproven — is that they arise via an unusual process, and they live in rare environments, similar to the early Universe."

Proving it, perhaps, will be Glazebrook's next rabbit hole. ■

TINKERED TWINKLE



The romantic twinkle of stars in the night sky is the bane of an astronomer's life. Like the heat haze above the toaster, it is caused by turbulence in the Earth's atmosphere as hot and cold air mixes together. Astronomers build telescopes in places where there is less turbulence — on the mountaintops of Hawaii, the high Chilean desert, Antarctica — but the best spot of all is above the atmosphere, in space. The Hubble Space telescope has shown that by providing 20 years of stunning images of distant objects, including clumpy galaxies ten billion light years away.

The best telescopes on the ground, the 10-metre Keck in Hawaii, and the twin 8.9-metre Gemini telescopes in Hawaii and Chile have the advantage of being much bigger than Hubble's modest 2.4 metres, so they can detect fainter objects. They also have mirrors that constantly bend slightly to compensate for atmospheric turbulence, effectively de-twinkling stars, a technology called adaptive optics.

The other advantage they have over Hubble is they have the ability to break each pixel in the telescope images up into a readout of its wavelength, a technique called integral field spectroscopy.

These detailed spectral maps of galaxies give astronomers like Karl Glazebrook the ability to trace where hot hydrogen is forming stars, and through the Doppler effect, how turbulent the stars are.

Swinburne Innovation Precinct

Research-led innovation delivers social and economic impact

Launched in 2016, Swinburne Innovation Precinct is our front door to research-led innovation and entrepreneurship. It brings together people of all backgrounds to collaborate, solve problems and create real-world outcomes. Focusing on connecting students, staff, business and industry, it provides a platform for ideas at any stage to be scaled up into commercial technology and services.

Its core strength, along with its people, is a combination of cutting-edge design, manufacturing and digital technology and knowhow. Incorporating Design Factory Melbourne, Factory of the Future and the Digital Innovation Lab, Swinburne Innovation Precinct is the centre of a rich innovation ecosystem.

“Our aim is to connect innovation capabilities across the university, working with industry to solve problems and reach outcomes that have real and lasting impact.”
Swinburne Innovation Precinct Director, Professor Sally McArthur

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