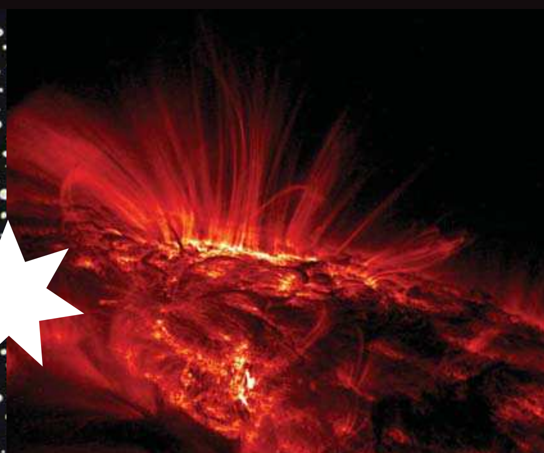
2012 Stories of Australian Astronomy



STORIES OF AUSTRALIAN ASTRONOMY 2012...STORIES OF AUSTRALIAN ASTRONOMY 2012...STORIES OF AUSTRALIAN ASTRONOMY 2012...STORIES OF AUSTRALIAN AST

contents

PHOTOS: (FRONT COVER, LEFT) *HALLEY'S COMET* BY KAREN COMEAGAIN, YAMAJI ART. (FRONT COVER, RIGHT) SUNSPOT LOOPS IN ULTRAVIOLET. CREDIT: TRACE PROJECT/NASA. (BACK COVER, LEFT) ASKAP ANTENNAS AT THE MURCHISON RADIO-ASTRONOMY OBSERVATORY. CREDIT: ANT SCHINCKEL, CSIRO. (BACK COVER, RIGHT) DUNCAN FORBES IS IDENTIFYING ALIEN STARS. CREDIT: PAUL JONES. (INSIDE FRONT COVER) *EMU ON THE SKY* (DETAIL) BY BARBARA COMEAGAIN, YAMAJI ART. (INSIDE BACK COVER) THE SOUTHERN CROSS. CREDIT: AKIRA FUJII/DAVID MALIN IMAGES.

Our thanks to the Australian Department of Innovation, Industry, Science and Research for their financial support. Our thanks to Helen Sim from CSIRO and the Australian Astronomical Observatory (AAO) for her guidance. And special thanks to David Malin for generously providing his remarkable images of the night sky.

welcome

Born from astronomy... Looking to a star-studded future

Welcome to *Stories of Australian Astronomy*. We've put together this publication to give journalists and others with an interest in astronomy a taste of what's happening in Australia.

In 1768 the British Admiralty sent Lieutenant James Cook to the Pacific to monitor the transit of the planet Venus across the Sun. On his way home to England, Cook mapped Australia's east coast, and claimed New South Wales.

For about 40,000 years before that, the Indigenous peoples of Australia had been developing remarkably sophisticated explanations of the workings of the southern sky.

And just 200 years afterwards, an independent Australia was at the forefront of radio astronomy and receiving the first signals from the Moon.

Today Australian astronomers continue to explore the southern sky and research the mysteries of the Universe.

We hope you enjoy *Stories of Australian Astronomy*, our latest collection of stories of Australian science.

Our collection starts big—with the fate of the Universe and Australia's newest Nobel Laureate, Brian Schmidt.

We reveal Aboriginal perspectives on the night sky before turning to the rich history of optical astronomy in Australia. In 1869 Melbourne was home to the largest telescope in the world (though it didn't work very well). Today Australia hosts a rich diversity of powerful instruments that work exceptionally well. We report on some of the more interesting discoveries of the last few years. And we end with CSIRO's pioneering radio astronomy and plans for the Square Kilometre Array telescope which, amongst its many missions will look for the dark energy needed to explain the accelerating expansion of the Universe.

We welcome your feedback on the stories—please email us, comment online at scenceinpublic.com.au/stories or tweet us.

If you'd like to receive occasional bulletins about Australian science please also let me know at niall@scienceinpublic.com.au or sign up online.

I invite you to read these stories and to follow up with any organisation whose work captures your interest.

Niall Byrne
December 2011

SCIENCE IN PUBLIC

Science in Public is based in Melbourne, Australia.
We help scientists present their ideas in public space.

Science in Public Pty Ltd
82 Hudsons Road
(PO Box 2076)
Spotswood Victoria 3015 Australia

Tel: +61 (3) 9398 1416
niall@scienceinpublic.com.au
www.scienceinpublic.com.au

Concept/editor in chief
Niall Byrne

Project coordination/editors
Margie Beilharz
Linda Worland
James Mitchell Crow

Writers
Tim Thwaites
Jonathan Nally
Adrienne Jones

Design
saltcreative.com.au

Print
immij

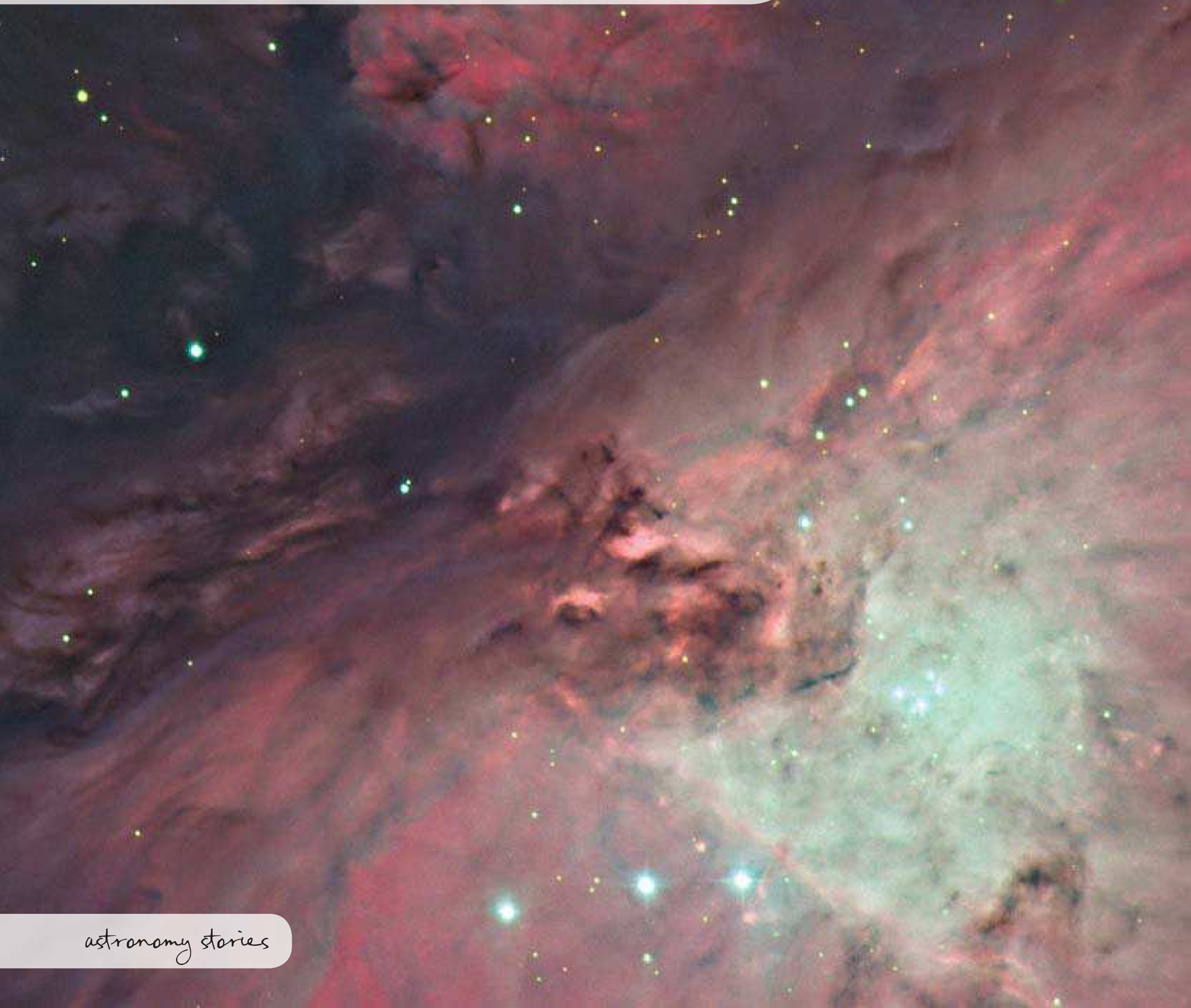
Science in Public

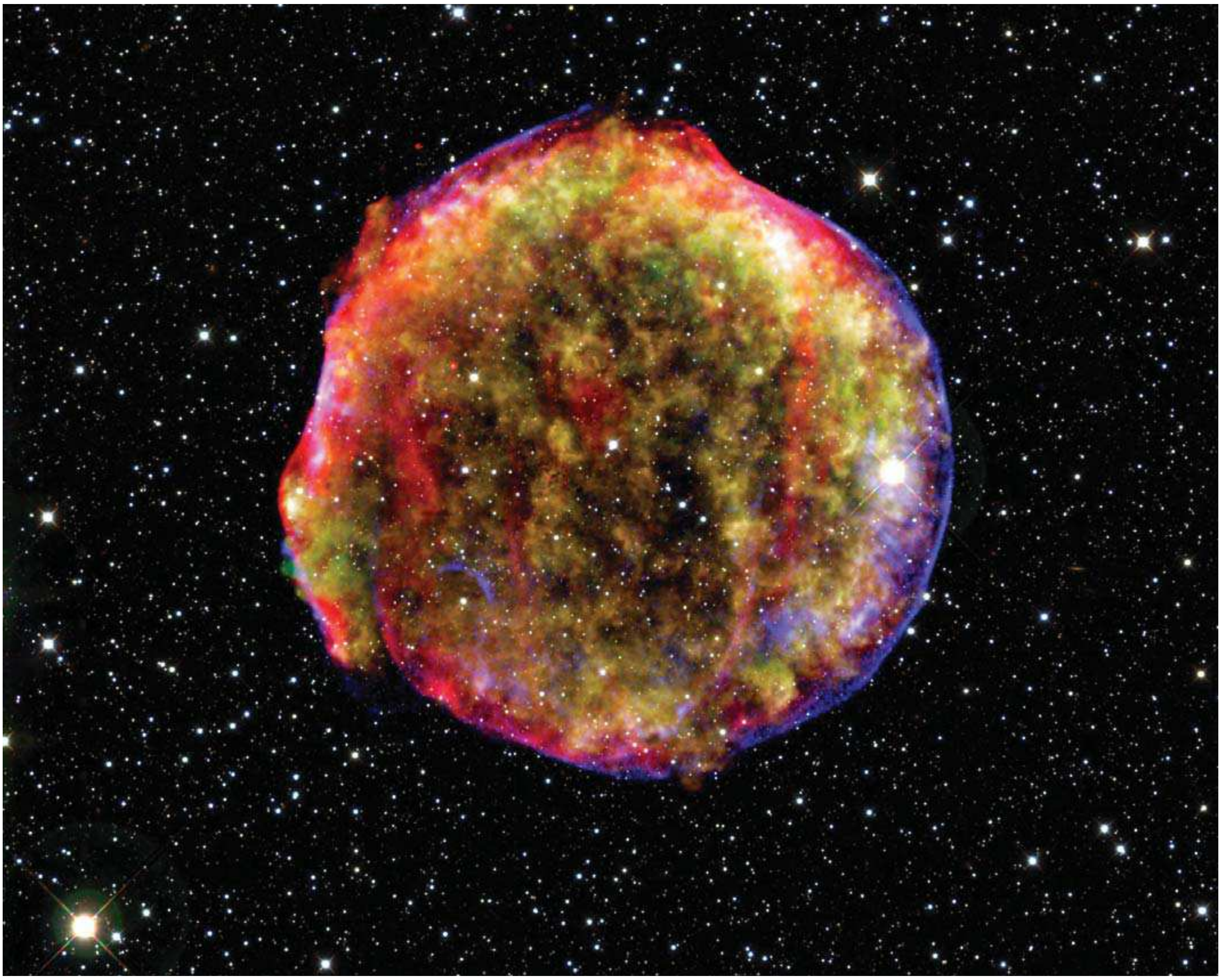
@scienceinpublic, #ozscistories

Our Universe is getting bigger, faster

It was the surprise of the decade. In 1998, two teams of astronomers —one led by the Australian National University's Brian Schmidt— independently reached the same conclusion: the expansion of the Universe is not slowing down or petering out, as most people had assumed, it is accelerating.

The discovery has triggered a flurry of activity to understand more about dark energy, the hypothetical driving force pushing the Universe apart counteracting gravity. It has also brought the Nobel Prize for Physics to Schmidt, Adam Riess, and Saul Perlmutter.





Our expanding Universe

"It initially seemed a crazy result," says Brian Schmidt, the leader of one of the two teams who made the discovery that the expansion of the Universe is accelerating. "But we were confident we'd eliminated any errors."

To calculate the Universe's rate of expansion, both teams were studying Type Ia supernovae—distant stellar explosions that all appear to have the same intrinsic brightness—as a means of measuring distances across the cosmos. The further away the star, the fainter the stellar explosion appears to us. By combining those distances with the supernovae's redshifts, where light from receding stars is shifted towards the red end of the spectrum, the astronomers could gauge how fast the Universe was expanding at different stages of its life. Nearby objects, whose light has only been travelling through the Universe for millions of years, were compared to distant objects, the light of which had traversed the Universe for billions of years.

The researchers found that the expansion of the Universe is speeding up. But why? The answer could be 'dark energy', a hypothetical energy that fills space and opposes gravity. But its nature remains a mystery.

"We don't know what it is," says Brian. "And there are still lingering questions of whether it could be that Einstein's general relativity equations are wrong in some weird way. One of the things we will be doing over the next 5-10 years here in Australia is testing how gravity works over long distances. If gravity works a little differently to how we think it does, we should get a different answer."

For their theory-shattering result, Schmidt and his team, along with the second team lead by Saul Perlmutter at the University of California, Berkeley, have not only been recognised by the Nobel committee. They have also won the US$500,000 Gruber Cosmology Prize in 2007 and the US$1 million Shaw Prize in 2006 amongst many honours.

For more information:
Research School of Astronomy and Astrophysics, Australian National University, Canberra
Professor Brian Schmidt, Tel: +61 (2) 6125 8042
brian@mso.anu.edu.au, www.mso.anu.edu.au

PHOTOS: (PREVIOUS PAGE) MESSIER 43 AND THE TRAPEZIUM STARS. CREDIT: DAVID MALIN, AUSTRALIAN ASTRONOMICAL OBSERVATORY. (THIS PAGE, TOP) TYCHO'S SUPERNOVA REMNANT. CREDIT: NASA/MPIA/CALAR ALTO OBSERVATORY, OLIVER KRAUSE ET AL. (THIS PAGE, ABOVE) PRIME MINISTER JULIA GILLARD CONGRATULATES BRIAN SCHMIDT ON HIS 2011 NOBEL PRIZE FOR PHYSICS. CREDIT: PRIME MINISTER'S SCIENCE PRIZES/IRENE DOWDY.

Galaxies point the way to dark energy

A project to produce more than double the number of galaxy distance measurements than all other previous surveys, could lead to an explanation of one of nature's biggest mysteries—whether dark energy, an invisible force that opposes gravity, has remained constant or changed since the beginning of time.

The project, called WiggleZ, is led by scientists at Swinburne University of Technology and the University of Queensland. They're using the advanced AAOmega instrument on the Anglo-Australian Telescope in New South Wales to build up a picture of galaxies stretching halfway across the Universe. There should be a slight pattern in the distribution of those galaxies, seeded by pressure waves in the cosmic fireball shortly after the Big Bang 13.7 billion years ago.

"If dark energy has changed, it will affect the appearance of the galaxy patterns," says team member Michael Drinkwater of the University of Queensland.

WiggleZ has sampled the largest volume of the distant Universe ever surveyed, covering about 200,000 galaxies. Observations were completed in January 2011.

"Until recently we were the only show in town," says Michael. "Our sole international competitor has only just begun, so we have a three-year head start."

For more information:
School of Mathematics and Physics, University of Queensland, Brisbane
Professor Michael Drinkwater, Tel: +61 (7) 3365 3428, m.drinkwater@uq.edu.au, smp.uq.edu.au/content/uq-astrophysics

Spinning galaxies reveal missing matter

Australian astronomers have long been contributing to our understanding of a strange cosmological phenomenon—the Universe's missing matter.

In the early 1970s, Ken Freeman of the Australian National University (ANU) determined that spiral galaxies must contain more matter than we can see. He postulated that dark matter—an invisible material first proposed 40 years earlier—must make up at least half the mass of these galaxies. Now, patches of dark matter are thought to be scattered across the Universe, playing a major role in holding galaxies and groups of galaxies together.

Ken calculated the speed of rotation of disc-shaped galaxies, and found that they were spinning too fast for the amount of matter we could see in them. "They should have flung themselves apart; so something else must be there, something unseen but with lots of mass, holding them together," he says.

Ideas on what the 'something else' could be have ranged from the very large to the very small: such as swarms of black holes, or burned-out stars or planets, to clouds of tiny neutrinos or other exotic particles.

The large candidates have been mostly eliminated, and work is now focused on the sub-atomic end of the scale. Some of this work is being done in particle physics laboratories, such as the Large Hadron Collider in Europe.

But astronomers are on the scent too. If dark matter is made of tiny particles, they might sometimes collide with other particles within galaxies and annihilate themselves, emitting radiation that can be detected by telescopes.

In addition, Australian observatories are scanning galaxies at radio wavelengths to get a better picture of the spread of normal matter. From that, astronomers can infer the extent of the still-unknown dark matter.

For more information:
Research School of Astronomy & Astrophysics, Australian National University, Canberra
Professor Ken Freeman, Tel: +61 (2) 6125 0264, kcf@mso.anu.edu.au, www.mso.anu.edu.au

Ten times more galaxies

A new 'super survey' is producing the largest database of galaxy measurements, spanning the last five billion years of cosmic history. The International Galaxy and Mass Assembly (GAMA) project is combining data from ground- and space-based observatories to measure the 'haloes' of dark matter that surround galaxies.

"The Cold Dark Matter (CDM) model of cosmology makes predictions about how galaxies cluster and, in many cases, collide and merge," says Andrew Hopkins, a GAMA team member. "Our measurements of the speeds of galaxies will reveal the distribution of dark matter, and enable us to test the CDM model."

The Australian-built AAOmega spectrograph on the Anglo-Australian Telescope (AAT) at Siding Spring Observatory near Coonabarabran in northern New South Wales is a vital part of the project, with its ability to capture light from hundreds of galaxies at once. GAMA is revolutionising galaxy evolution studies by measuring galaxy shapes, sizes, masses, star formation rates, chemical abundances, and more.

"We're studying almost as many galaxies [150,000] as the previous largest AAT survey [200,000], but over a smaller patch of sky, so our density is about ten times greater," Andrew explains. "We're getting about 1,000 galaxy spectra per square degree—previous surveys were only getting about 100."

This means that GAMA is picking up fainter and smaller galaxies that were skipped in previous surveys. The project is about half complete. When finished, the huge data set "will be the reference point for galaxy evolution studies worldwide for the next decade," says Andrew.

For more information:
Australian Astronomical Observatory, New South Wales
Associate Professor Andrew Hopkins Tel: +61 (2) 9372 4849, ahopkins@aao.gov.au, www.aao.gov.au/local/www/ahopkins/; http://www.gama-survey.org/

Measuring the Universe from start to finish

Scientific puzzles don't come much bigger than these. How old is the Universe? How big is it? And what is its ultimate fate?

A single number, Hubble's constant, is the key that can unlock all of those questions, but it's a number that has proved notoriously hard to accurately measure. Hubble's constant is the rate at which the Universe is expanding. The first team to accurately make that measurement was co-led by Jeremy Mould, now a professor at Swinburne University of Technology and professorial fellow at the University of Melbourne.

Instrumental to the team's success was the launch in 1990 of the Hubble Space Telescope (HST). Mould and his colleagues used the HST to carefully measure the distances to 800 pulsing stars called Cepheids in 18 distant galaxies, and from this to refine models of cosmic distance measurement. They could then gauge how long the Universe has been expanding since the Big Bang. Their answer, 13 to 14 billion years, tallies well with estimates of the age of the oldest stars.

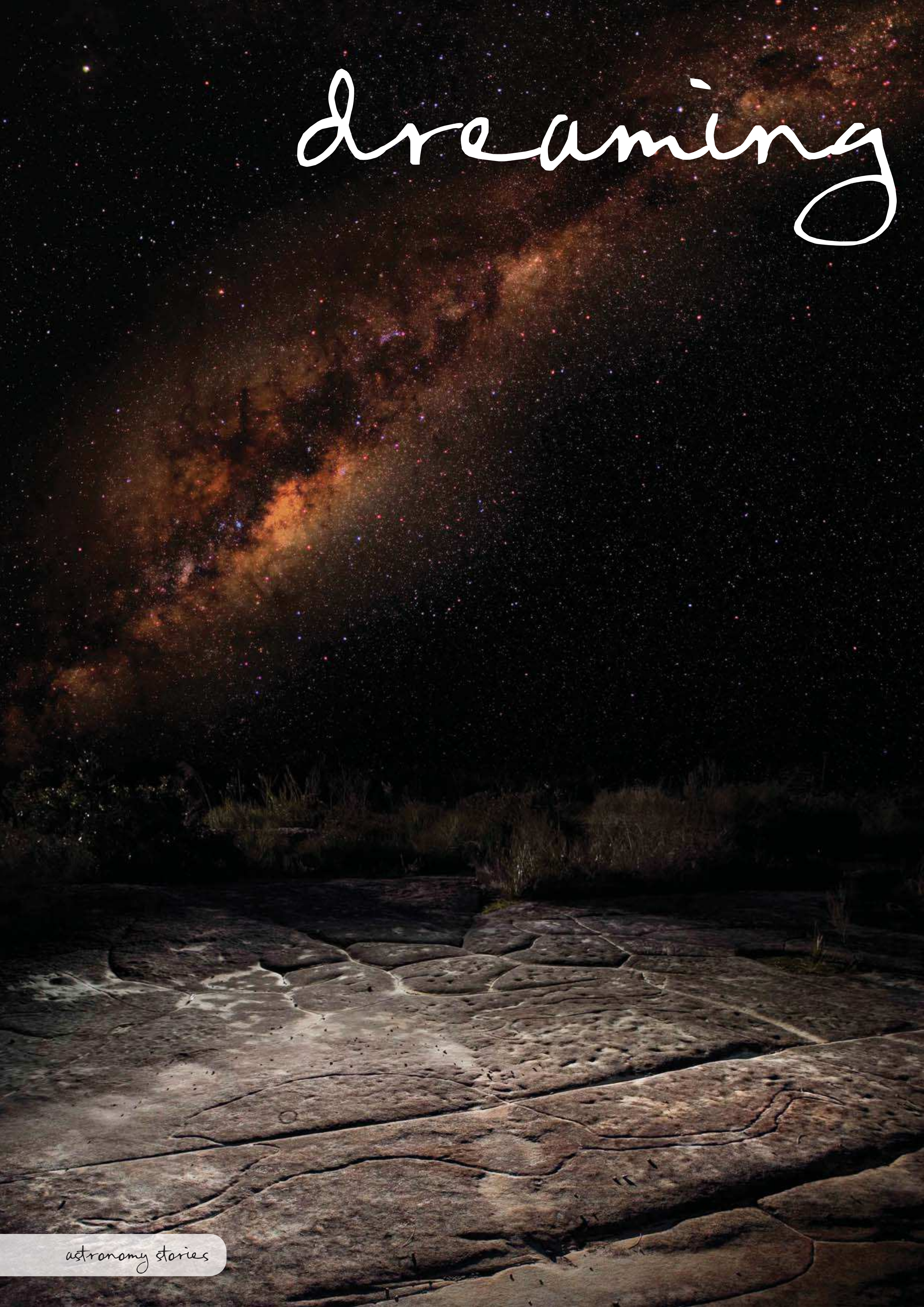
For this trailblazing work, the three team leaders—Jeremy, plus Wendy Freedman from the Carnegie Institution of Washington in Pasadena, US, and Robert Kennicutt from the University of Cambridge, UK—were jointly awarded the Gruber Prize for Cosmology in 2009.

"What the Hubble constant also does is to tell us the expansion rate of the Universe—which is accelerating," says Jeremy. "This controls the future evolution of the Universe."

Mould is not the first Australian winner of the Gruber Prize for Cosmology. In 2007 the Australian National University's Brian Schmidt was jointly awarded the prize for a related discovery that showed that the expansion of the Universe is currently accelerating. Schmidt went on to win the Nobel Prize for Physics in 2011 together with Saul Perlmutter and Adam Riess.

For more information:
Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Melbourne
Professor Jeremy Mould, Tel: +61 (3) 9214 4746, jmould@swin.edu.au, http://astronomy.swin.edu.au/~jmould/

PHOTOS, PREVIOUS PAGE: (TOP LEFT) THE 3.9 METRE ANGLO-AUSTRALIAN TELESCOPE IS COLLECTING OPTICAL GALAXY DATA FOR THE GAMA SURVEY. CREDIT: BARNABY NORRIS. (TOP RIGHT) THE HUBBLE SPACE TELESCOPE CAN BE USED TO TAKE MEASUREMENTS THAT WILL HELP ANSWER SOME OF THE BIGGEST QUESTIONS ABOUT THE UNIVERSE. CREDIT: NASA/STSCI. (BOTTOM) DARK MATTER DOMINATES GALAXIES AND GROUPS OF GALAXIES, YET ITS IDENTITY REMAINS UNKNOWN. CREDIT: DAVID MALIN, AUSTRALIAN ASTRONOMICAL OBSERVATORY.


dreaming
astronomy stories

of the sky

Just as ecologists are increasing their understanding of the Australian environment through studying Aboriginal stories and talking to tribal Elders, so astronomers are beginning to appreciate Indigenous knowledge of the sky.

When Macquarie University PhD student Duane Hamacher encountered Aboriginal Dreamtime myths involving fiery stars falling to Earth, he decided to see if he could track where these objects had landed. Following several leads, Duane surveyed remote areas of Australia using Google Earth—and discovered a meteor impact site at Palm Valley, about 130 kilometres southwest of Alice Springs.

What Duane and colleagues from Macquarie's Department of Earth and Planetary Science found when they visited Palm Valley was a bowl-shaped geological structure that could not have been formed either by erosion or volcanic activity. Rock samples at the site revealed shocked quartz, a direct indicator of meteorite impact. While, as Duane points out, this link between the story and his discovery could be coincidental, evidence that he and several other astronomers are beginning to accumulate suggests Indigenous knowledge of astronomy was considerable.

One of the leaders of this scientific appraisal is Duane's supervisor, Ray Norris of CSIRO. For many years he has had a personal interest in exploring the Aboriginal view of the heavens. He's infected his whole family with his fascination, and has become an adjunct professor in the Department of Indigenous Studies at Macquarie University.

"The picture we are building up is that the Aboriginal peoples across Australia before contact [with Europeans] had a pretty good understanding of the how the sky worked —on their own terms, of course."

Understanding eclipses

Most, if not all, of the 400 Indigenous Australian peoples had their own names and interpretations for celestial and planetary features. Many peoples talked of the Emu in the Sky, a feature marked by the regions of darkness in the Milky Way rather than by stars. And they named many other constellations. The constellation that astronomers know as Lyra, the Boorong people in northern Victoria call Neilloan, the mallee fowl. Orion was seen by Yolngu people of Arnhem Land as a canoe, and they named it Djulpan.

Aboriginal groups used these sky features for navigation and to time events. They clearly understood the link between the movements of the stars and the seasons of the year. When the mallee fowl disappeared from the sky, for instance, the Boorong knew it was time to collect mallee fowl eggs.

Not surprisingly, the heavens also became the source and inspiration for stories, celebrations and artwork (see page 14). The Yolngu people have a special ceremony where they gather after sunset to await the rising of Barnumbirr, or Morning Star (which is the planet Venus).

Two features that crop up in many Aboriginal cultures—the explanation of eclipses, and a linking of the phases of the moon with the tides—have convinced Ray that Indigenous understanding of the workings of the sky was profound.

Aboriginal stories typically talk of a Sun woman and a Moon man. Eclipses are seen in terms of the two coming together and making love—one hiding the body of the other. "Actually, this is a giant intellectual leap," says Ray, "to realise that eclipses of the Sun are not something magic, but a natural process of the Sun and the Moon coming together."

Even more astonishing, he says, is that lunar eclipses are explained in the same way, as a conjunction of bodies. In this case, the Sun and Moon are on opposite sides of the sky and Earth moves in between, casting a shadow on the Moon. "Some Einstein sitting out there in the bush figured this out at some point, and it has become part of Aboriginal tradition," Ray notes.

"And then you've got people discussing how the Moon causes the tides. The idea appears to be pre-contact, and probably goes back a long way. But in 1600, Galileo was saying the Moon doesn't have anything to do with the tides. So the link can't be that obvious. Indigenous people must have made careful observations over time."

For more information:
Department of Indigenous Studies, Macquarie University, Sydney
Adjunct Professor Ray Norris,
Tel: +61 (2) 9372 4416,
ray.norris@csiro.au,
www.warawara.mq.edu.au/aboriginal_astronomy/index.php

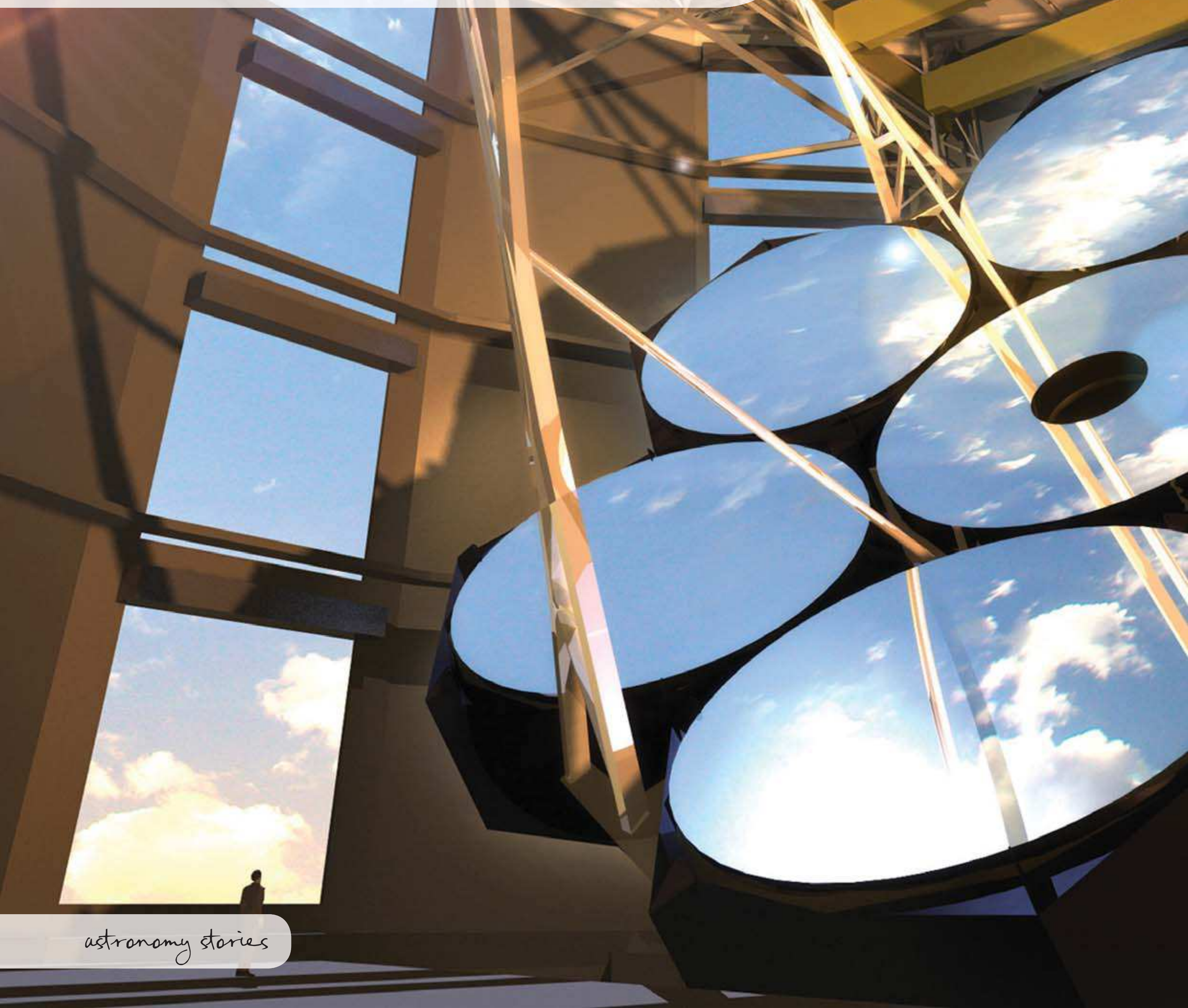
PHOTO: THE ABORIGINAL 'EMU-IN-THE-SKY' CONSTELLATION, WHICH APPEARS ABOVE THE EMU ENGRAVING AT THE ELVINA ENGRAVING SITE, IN KURING-GAI CHASE NATIONAL PARK, NEAR SYDNEY EACH AUTUMN. CREDIT: BARNABY NORRIS

Casting light

Optical astronomy and Australia are inextricably linked. They go right back to the naked-eye sky lore of Indigenous Australians, and Cook's discovery of the continent's east coast during his South Pacific voyage to witness the transit of Venus.

Today, Australia is home to some of the world's most productive optical telescopes, studying and mapping the southern skies. But the next generation of extremely large telescopes demand high-altitude, mountain-top sites not found locally, so Australian institutions, with the support of the Australian Government, are increasingly investing offshore. Most recently, Australia joined the Giant Magellan Telescope project to construct a 24.5-metre telescope—far larger than any existing instrument—in Chile by about 2018.

Australia contributes more than funding to such projects. The Gemini Observatory—twin 8-metre telescopes located in Hawai'i and Chile—already employs Australian technology for a clearer view through the atmosphere into space. Similar devices, and more, are likely to be fitted to the Giant Magellan Telescope.



From mapping a continent to surveying the Universe

Australia's first observatory was built on the shores of Sydney Harbour by Lieutenant William Dawes of the First Fleet, on the point where the southern pylon of the Sydney Harbour Bridge now stands. Optical astronomy was essential for maritime navigation, and for providing precise location measurements for surveying the new continent.

The country's first major observatory was established in 1821 at Parramatta by Thomas Brisbane, Governor of New South Wales and, later, President of the Royal Society. The observatory was used to discover and record the galaxy NGC 5128—a now much-studied galaxy that radio astronomers know as Centaurus A, within which sits a super-massive black hole (see page 28).

Great Southern Sky

Sydney Observatory took over from Parramatta in the late 1850s. Its main purpose was timekeeping, but it was heavily involved in studying the southern sky. Meanwhile, following the Victorian gold rush in the 1850s, booming Melbourne opened its own observatory in 1863. The Great Melbourne Telescope at Melbourne Observatory was, for a while, the largest fully steerable telescope in the world.

In the 1890s, the Sydney, Melbourne and Perth observatories began mapping the southern skies as part of the international Astrographic Catalogue (Carte du Ciel) project, perhaps one of the first multinational scientific endeavours. The final parts of the vast Catalogue were completed at Sydney Observatory in 1971.

In 1924, the Federal Government established the Commonwealth Solar Observatory at Mount Stromlo outside Canberra, concentrating on solar and atmospheric investigations. During the Second World War it was pressed into service for the production of 'optical munitions', such as gun sights. Post-war, the focus shifted to stellar astronomy in general, and in 1957 it joined the Australian National University (ANU) as the Mount Stromlo Observatory. The Observatory was badly damaged by bushfire in 2003, but has since been revitalised with new facilities for building instruments for its own and other telescopes (see next page).

Although observations were made from Stromlo up until 2003, by the 1960s light pollution from Canberra had become so bad that the ANU decided to establish an observatory at Siding Spring Mountain, near Coonabarabran in northern New South Wales. Since that time, the ANU has opened Siding Spring Observatory to a wide variety of telescopes operated by external groups. Today, a dozen external facilities are operating or planned there, including telescopes operated remotely by researchers in countries such as Poland, Korea, Chile, the US and the UK.

Optical excellence

In 1973, Britain built the UK Schmidt Telescope at Siding Spring, a 1.2-metre telescope specially designed for taking wide-field survey photographs. The Schmidt made several photographic surveys of the whole southern sky, creating an archive that has been hugely valuable to professional astronomers and has now been incorporated into public tools such as Google Sky and Microsoft's Worldwide Telescope. That imaging survey role has now passed to the ANU's new automated telescope at Siding Spring, SkyMapper, which is embarking on the first complete digital survey of the southern sky (see next page). However, the UK Schmidt—now an Australian-run facility—continues to operate, carrying out large-scale spectroscopic surveys, capturing and analysing the light from 150 stars or galaxies at once. One such survey is the international RAdial Velocity Experiment (RAVE), which seeks to trace how our galaxy developed (see page 20).

In 1974, just a year after the UK Schmidt Telescope began operating, a new, large optical telescope opened its doors at Siding Spring: the Anglo-Australian Telescope, a joint UK-Australian project. At the time it was one of the largest telescopes in the world, and one of the first large telescopes to be controlled by computer. Today the AAT is no longer one of the world's largest telescopes, but it is still one of the best. It is the top-ranked 4-metre-class telescope in the world (with more than twice the number of citations than the second-placed). In fact, among all telescopes—including the Hubble Space Telescope and ground-based telescopes twice its size—the AAT is ranked fifth in productivity and impact. It became a wholly Australian facility in July 2010.

Extremely large telescopes

The new cutting-edge for optical astronomy is the current generation of 8-metre-class telescopes, and the coming generation of 'extremely large telescopes'. Australia does not have a suitable mountain-top site for such facilities, so Australian institutions, supported by the Australian Government, are collaborating in projects offshore.

One of those projects is Gemini, the world's largest publicly funded optical/infrared telescopes. The twin telescopes, located in Chile and Hawai'i, can collectively access the whole night sky. Australia has also joined the Giant Magellan Telescope project, to build one of the next generation of extremely large telescopes, an instrument capable of producing images ten times sharper than the Hubble Space Telescope.

For more information:
National Committee for Astronomy, Australian Academy of Science, Canberra
Professor Elaine Sadler, Tel: +61 (2) 9351 2622, ems@physics.usyd.edu.au

PHOTOS: (PREVIOUS PAGE) THE GIANT MAGELLAN TELESCOPE. CREDIT: GIANT MAGELLAN TELESCOPE—GMTO CORPORATION. (THIS PAGE) SIDING SPRING MOUNTAIN' IS HOME TO OVER A DOZEN AUSTRALIAN AND INTERNATIONAL TELESCOPES. CREDIT: FRED KAMPHUES.

Mount Stromlo Observatory rising from the ashes

The Mount Stromlo Observatory of the Australian National University (ANU) is rising from the ashes of Canberra's 2003 bushfires, after an investment of millions of dollars into cutting-edge technologies and facilities.

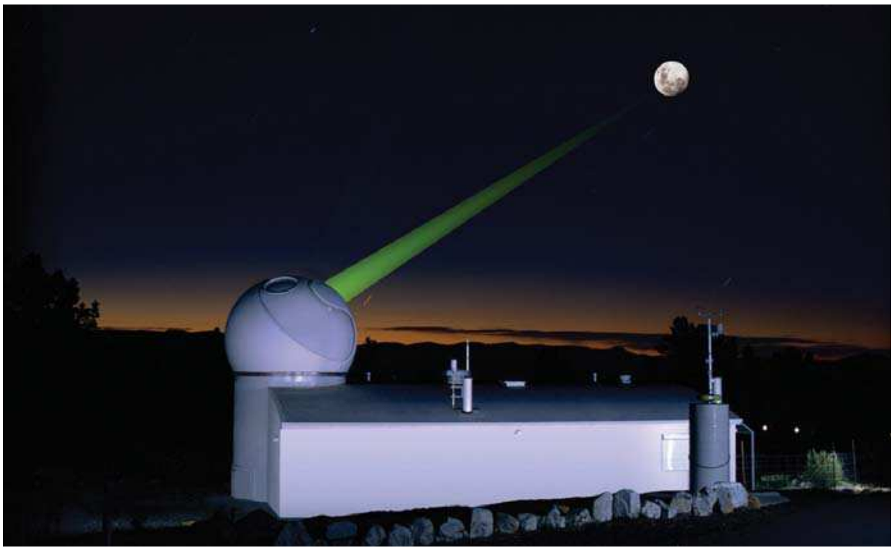
The Mount Stromlo site—home to the ANU's Research School of Astronomy and Astrophysics (RSAA)—no longer acts as a research observatory, but rather as a high-tech hub developing astronomical instruments for the world's most advanced telescopes. Staff at the RSAA's Advanced Instrumentation and Technology Centre have already built multi-million dollar instruments, such as the Near-Infrared Integral-Field Spectrograph (NIFS) for the Gemini North Telescope which provides images in the infrared equivalent to the Hubble Space Telescope in the optical range.

The Gemini South telescope in Chile was fitted recently with an adaptive optics imager built by ANU that takes pictures of the sky corrected for the blurring caused by Earth's turbulent atmosphere. The optics work by continually monitoring atmospheric distortion of three reference stars and five artificial laser guide stars. The resulting images should rival those of the Hubble Space Telescope.

The next generation of the system, to be deployed at the Giant Magellan Telescope (GMT), promises to be even more effective. RSAA is managing Australia's participation in the $650 million international GMT project. "This will allow the next generation of Australian astronomers to remain at the forefront of research," says Harvey Butcher, who directs RSAA.

"New insights often result from the application of technologies that allow new kinds of observations to be made," Harvey adds. "Therefore, we're investing heavily in the capacity to develop innovative instrumentation, both for the GMT and for our own and other facilities."

For more information:
Research School of Astronomy and Astrophysics, Australian National University, Canberra
Professor Harvey Butcher, Tel: +61 (2) 6215 0266, director@mso.anu.edu.au, www.mso.anu.edu.au



Australian company brings the Universe within range

An Australian company, Electro-Optic Systems (EOS), is one of the biggest developers of large, high-precision, optical research telescopes in the world. In fact, EOS has designed, built and installed the SkyMapper telescope and its enclosure at Siding Spring Observatory in New South Wales.

The headquarters of EOS is at the Mt Stromlo Observatory near Canberra, but its reach is international. Equipment the company has installed include the University of Tokyo's two-metre telescope at Mount Haleakala, Hawai'i, a two-metre telescope in the Himalayas for the Indian Institute of Astrophysics, and the 2.4-metre Advanced Planet Finder (APF) at the University of California's Lick Observatory.

The EOS Group made its reputation in space laser ranging and satellite tracking. Its diversification into optical telescopes was stimulated by a contract in 1995 to build six precision laser ranging stations—with telescopes and beam directors—to monitor seismic movement around Tokyo Bay. "The program had a fairly tight deadline," says Chief Executive Officer Craig Smith. "No-one could agree to supply those six telescopes to us within the time we needed them, so we set up our own company to do it ourselves."

EOS has also begun to use its expertise to design, build and test systems to track and record space debris—human-made rubbish in orbit around the Earth—down to a diameter of 10 cm or less. "The next step is to develop high-power laser systems to actually manipulate the debris in space. "If you get enough energy density onto them," Craig explains, "you can actually push them around. You can de-orbit the debris and drag it back into the atmosphere where it will burn up."

For more information:
EOS, Canberra
Dr Craig Smith, Tel: +61 (2) 6222 7900, csmith@eos-aus.com, www.eos-aus.com

SkyMapper's 268-megapixel camera

On a mountaintop in northern New South Wales sits a new telescope equipped with Australia's largest digital camera. The Australian National University's (ANU) SkyMapper facility has been established at Siding Spring Observatory to conduct the most comprehensive optical survey yet of the southern sky.

Fully automated, the telescope is measuring the shape, brightness and spectral type of over a billion stars and galaxies, down to one million times fainter than the eye can see.

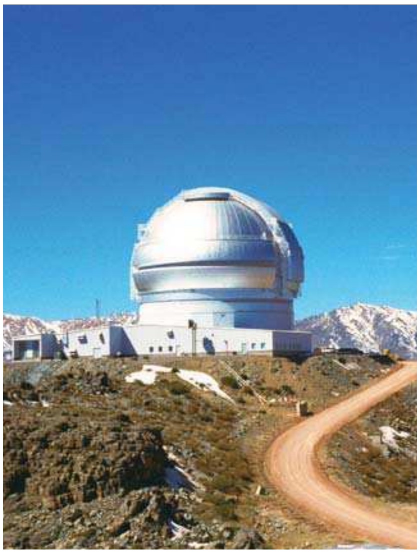
The heart of the system is a $2.5 million, 268-megapixel digital camera that covers an area 40 times greater than the full Moon every minute. It generates 100 megabytes of data each second, and this huge data set is to be shared with the astronomical community and wider public.

In its first five years SkyMapper will cover the entire southern sky 36 times, revealing celestial objects that are changing or moving, such as new planets, asteroids and exploding stars. The ability to discover this activity will give Australian astronomers an edge when bidding for observing time on the world's most important telescopes.

"Access to the new generation of giant telescopes is an extremely precious commodity," says Brian Schmidt of the ANU's Research School of Astronomy and Astrophysics. SkyMapper has the ability to quickly find where we should be looking for the most interesting targets, he explains. "Thus SkyMapper will help us make good bids for access to the big telescopes, and help Australia remain competitive.

"SkyMapper will provide information on all of the objects that will be seen by the next generation radio telescope, ASKAP," he adds, "a synergy that will help Australia to remain at the forefront of both optical and radio astronomy."

For more information:
Research School of Astronomy and Astrophysics, Australian National University, Canberra
Professor Brian Schmidt, Tel: +61 (2) 6125 8042, brian@mso.anu.edu.au, www.mso.anu.edu.au



Keck telescope dons a mask

It seems counterintuitive, but restricting the amount of light that reaches a telescope can sharpen up its output. The technique will be used on NASA's successor to the Hubble Space Telescope: the James Webb Space Telescope. But it is already proving its worth here on Earth.

Images of the binary star known as Wolf-Rayet 104 (WR104), published in 2008 by Peter Tuthill of the University of Sydney, reveal the power of the new technique, which is known as aperture masking. WR104 should be difficult to see because it is in a deep cloud of dust, but Peter and his colleagues used aperture masking when observing the star with the Keck telescope in Hawai'i. The mask leads to sharper images because it cuts down complexity and makes the data easier to process and rid of error.

WR104, which can be described as two stars circling around each other spraying out particles in a spiral like a massive lawn sprinkler in the sky, is about 8,000 light years away from Earth in the constellation of Sagittarius. "WR104 is a beautiful, beautiful thing," says Peter. Wolf-Rayet stars, however, are, by definition, at the end of the line. They have reached the stage where almost all the hydrogen that fuels them has been converted into helium. WR104 will undergo a supernova explosion within the next few hundred thousand years.

"WR104 is a desirable system to study because it displays a lot of physics we couldn't otherwise get at," Peter explains. "It's at the hairy, extreme end of star systems where things are quite unknown, and cause all the stellar fireworks." The images of WR104 show the two circling stars seemingly face-on to the Earth. More recent evidence, however, suggests that the system is angled far enough away from Earth to prevent the remote possibility of a dose of radiation heading our way when the system blows.

For more information:
Sydney Institute for Astronomy, University of Sydney
Dr Peter Tuthill, Tel: +61 (2) 9351 3679, p.tuthill@physics.usyd.edu.au, www.physics.usyd.edu.au/~gekko

Seeing a beach ball on the moon

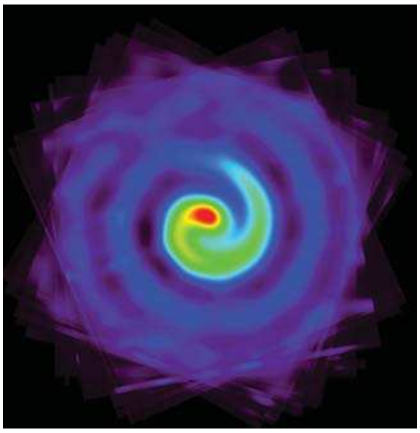
When the present upgrade is complete, the Sydney University Stellar Interferometer (SUSI) will be able to resolve objects the size of a beach ball on the Moon, says Mike Ireland of Macquarie University in Sydney. This large interferometer will be used to determine the dimensions—size, weight and velocity—of pulsating stars, hot stars, and massive stars. SUSI will also be involved in the search for binary stars and their planetary companions.

Built at CSIRO's Paul Wild Observatory near Narrabri in northern New South Wales in the late 1980s, SUSI began operating in 1991. By analysing the interference patterns generated by combining light detected using charge-coupled devices (CCDs—the heart of a digital camera), this interferometer can simulate the performance of an optical telescope with a lens diameter of up to 160 metres. The only drawback is that it can detect only the brightest celestial bodies because it uses such small apertures.

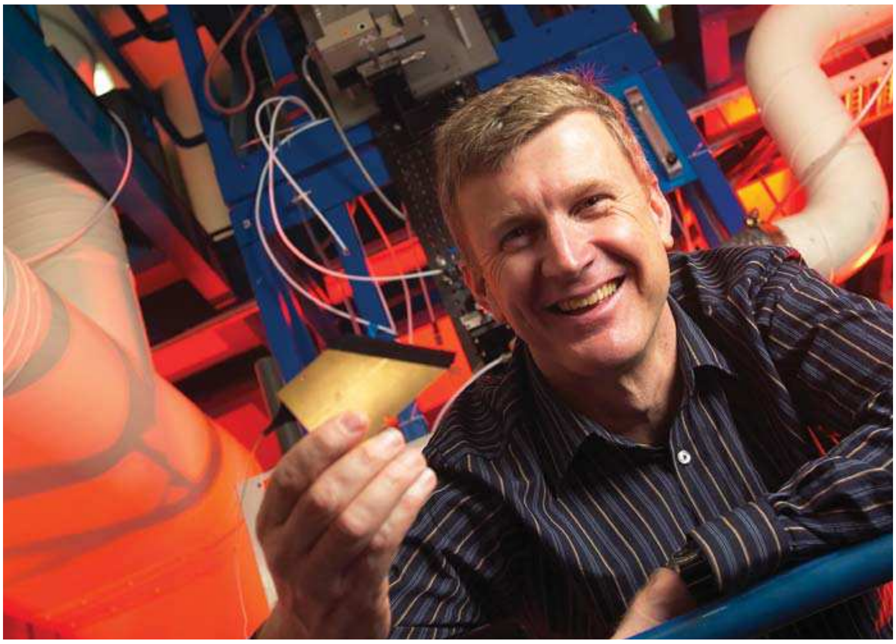
The upgrade involves installing two new devices—PAVO (Precision Astronomical Visible Observations) and MUSCA (Micro-arc second University of Sydney Companion Astrometry)—which combine the beams in different ways to make measurements. The PAVO technology, software and cameras have already been attached to an even bigger interferometer, called CHARA, on Mount Wilson in California. Both instruments can be controlled remotely over the internet from Sydney, and are the highest spatial resolution instruments operating using visible light in the Northern and Southern skies.

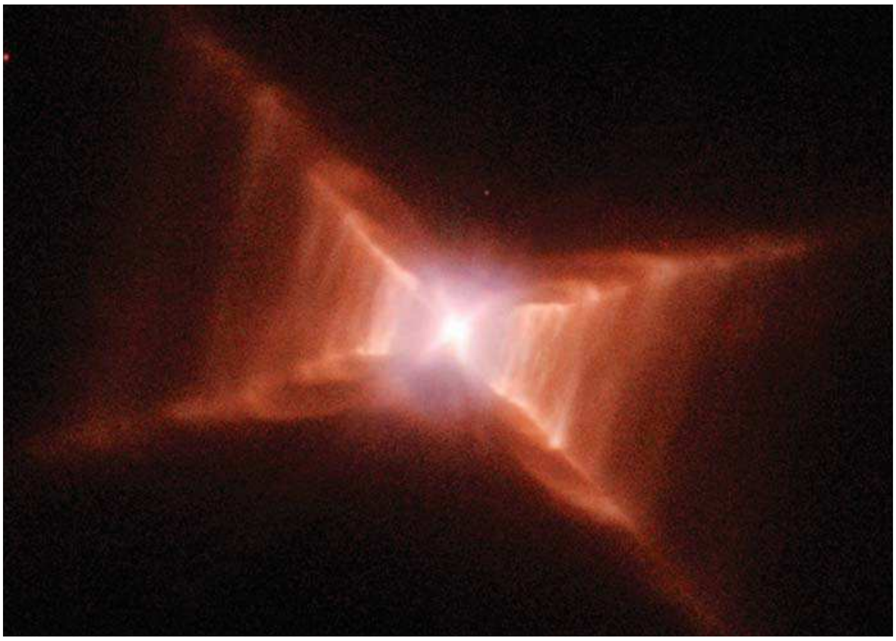
MUSCA can measure the separation between binary stars precisely, and determine if they are moving sideways with respect to one another. In this way, the gravitational tug of an unseen planetary companion can be detected.

For more information:
Department of Physics and Astronomy, Macquarie University, Sydney
Dr Mike Ireland, Tel: +61 (2) 9850 8901, michael.ireland@mq.edu.au, www.mq.edu.au/~mireland



PHOTOS: (PREVIOUS PAGE) THIS SATELLITE LASER RANGING STATION MANAGED BY GEOSCIENCE AUSTRALIA AT MOUNT STROMLO OBSERVATORY NEAR CANBERRA WAS BUILT AND IS OPERATED BY EOS. CREDIT: CRAIG ELLIS. (TOP LEFT) SKYMAPPER AT SIDING SPRING, NORTHERN NEW SOUTH WALES. CREDIT: AUSTRALIAN NATIONAL UNIVERSITY. (TOP RIGHT) THE ENCLOSURE OF THE GIANT 8.1-METRE GEMINI SOUTH TELESCOPE AT CERRO PACHÓN IN THE ANDES MOUNTAINS. CHILE. CREDIT: GEMINI OBSERVATORY. (CENTRE) SUSI AT NARRABRI—ONE OF THE HIGHEST SPATIAL RESOLUTION TELESCOPES USING VISIBLE LIGHT. CREDIT: GORDON ROBERTSON. (ABOVE) A FALSE-COLOUR COMPOSITE IMAGE OF 11 FRAMES SHOWING THE 8-MONTH CIRCULAR ROTATION OF THE BINARY STAR, WOLF-RAYET 104. CREDIT: PETER TUTHILL.





Bringing dark corners of the Universe to light

Using the Gemini South telescope in Chile, a team of astronomers led by Joss Bland-Hawthorn of the University of Sydney revealed the faint, outer regions of the galaxy called NGC 300, showing that the galaxy is at least twice the size as thought previously. The findings suggest that our own Milky Way galaxy could also be bigger than the textbooks say.

But Joss's telescope observations are just a part of his contribution to astronomy. He is also helping to pioneer a new technology known as astrophotonics, which uses optical systems to improve our understanding of the Universe.

According to Joss, Australia is leading some 25 per cent of the major developments in the astrophotonics field. The invention of the photonic lantern, a device some believed could never exist, was Australia's first major success, Joss explains. The lantern splits light gathered by a multi-wavelength optical fibre into numerous outgoing single wavelengths, which can then be fed into a spectrograph to analyse the light. The lantern also has major potential in telecommunications and sensing applications.

Development of fibres that act as the most complex optical filters ever conceived are another success, says Joss. "They're used to block the faint glow of the Earth's atmosphere, which drowns out weak astronomical sources. We can now render the sky very dark indeed, as if we were in space."

Instruments based on this technology are in the pipeline for the next generation of extremely large optical telescopes, such as the Giant Magellan Telescope. But they're not the only potential use of astrophotonics in telescopes.

For more information:
Sydney Institute for Astronomy, University of Sydney
Professor Joss Bland-Hawthorn, Tel: +61 (2) 9351 2621, jbh@physics.usyd.edu.au, www.physics.usyd.edu.au/~jbh

PHOTOS: (TOP) JOSS BLAND-HAWTHORN HOLDING A PHOTONIC LANTERN, A REVOLUTIONARY DEVICE TO ANALYSE THE LIGHT OF DISTANT STARS, INVENTED IN AUSTRALIA. CREDIT: CHRIS WALSH. (CENTRE) THE RED RECTANGLE IS A PECULIAR NEBULA WITH SOME STRANGE CHEMICAL PROPERTIES. CREDIT: NASA/ESA/ HANS VAN WINCKEL (CATHOLIC UNIVERSITY OF LEUVEN) /MARTIN COHEN (UCB). (BOTTOM LEFT) LAUNCHING THE KEPLER SPACE TELESCOPE. CREDIT: BALL AEROSPACE AND TECHNOLOGIES CORP. (BOTTOM RIGHT) THE ZADKO TELESCOPE MAKING OBSERVATIONS NEAR GINGIN, 70 KILOMETRES NORTH OF PERTH. CREDIT: JOHN GOLDSMITH/CELESTIAL VISIONS.

Sifting sky data

Imagine an extremely large optical telescope fitted with detectors that can selectively collect light from a particular section of the telescope's focal plane. Using revolutionary robotic technology called Starbugs, the detector will reconfigure itself in real time to collect from any particular area of the image, and will feed the data into any analytical instrument.

That's exactly what Matthew Colless and his team at the Australian Astronomical Observatory have in mind with the development of MANIFEST (the many-instrument fibre system)—which make use of the special photonic technologies developed by Joss Bland-Hawthorn and his team at the University of Sydney.

"MANIFEST will allow you to look at the whole of the focal plane, but only collect information from the bits you care about, and not all the boring bits of sky in between," says Matthew. Matthew and his co-workers hope that the robotic fibre optic system will be fitted to one of the world's most advanced optical telescopes, the Giant Magellan Telescope in Chile.

The Starbugs technology literally drives the optical fibre detectors to the right part of the focal plane, Matthew explains. "Every optical fibre will have a little robot attached to it that can walk around the focal plane in real time." Each fibre can move independently of all the others, and the fibres can adjust to track an object as it moves across the sky.

Matthew says the team is planning to use optical fibres that filter out unwanted light emitted by the Earth's atmosphere, and also hexabundles—clusters of small fibres that can be used to break images down into many bits so they can be spatially resolved.

"This isn't just talk," says Matthew. "We've built some prototypes already."

For more information:
Australian Astronomical Observatory, New South Wales
Professor Matthew Colless,
Tel: +61 (2) 9372 4812,
director@aao.gov.au, www.aao.gov.au

Starquakes reveal family secrets

Stars forming in clusters from a single galactic dust cloud are not as similar to one another as previously thought, according to an international team of astronomers who analysed 'starquakes' from just three months of data from NASA's Kepler space telescope. And there is at least another four years' data to come.

"In the past, it was assumed that the only difference [between stars in the same cluster] would be their mass," says Dennis Stello of the University of Sydney. "But the seismology [data] tells us that might not be correct. There's probably a spread in age or in composition because the original cloud of gas was not homogeneous."

Launched in March 2009, the Kepler observatory monitors the brightness of some 145,000 stars in its field of view every half-hour. Among other things, this data can be used to measure starquakes, which can provide information on size, temperature and internal composition of stars.

Starquakes occur when hot gas boils to the surface and releases energy, thus cooling and sinking in the process. "The star becomes like a big gong in a sand storm," says Dennis, who leads two groups of about 60 scientists working on cluster stars. "Every such convection event is like a sand grain hitting it. The whole star sets up many internal standing waves each vibrating at different frequencies." This leads to slight changes in temperature at the surface, which in turn leads to the small changes in the luminosity or amount of light emitted—and that is what is detected by the Kepler telescope.

For more information:
Sydney Institute for Astronomy, University of Sydney
Dr Dennis Stello, Tel: +61 (2) 9036 5108,
stello@physics.usyd.edu.au,
physics.usyd.edu.au/~stello/astronomy.html

Is the Red Rectangle a cosmic Rosetta Stone?

Cracking the puzzle of unusual molecules in deep space that absorb some wavelengths of starlight is like unlocking the secrets of the Rosetta Stone, according to Rob Sharp of the Australian National University's Research School of Astronomy and Astrophysics. "It's the longest-standing problem in astronomical spectroscopy," he says.

The identity of the molecules has been a mystery for 80 years, but Rob has now joined forces with chemists at the University of Sydney to try to crack the molecular code.

The best clues could lie in a bizarre object called the Red Rectangle, a tightly shaped gas cloud surrounding what is probably a dying binary star system. This nebula is an unusual red colour, which is probably caused by the mystery molecules.

The key suspects are polycyclic aromatic hydrocarbons (PAHs), giant constructs of carbon and other elements. But "we can't get some key information from our wavelength absorption observations," says Rob, "so my chemistry colleagues are testing gas mixtures under controlled conditions in the laser laboratory to give us the missing information about these important molecules."

Rob and his team then use that data to investigate what they see in the light spectrum.

"These PAHs are basically combustion by-products of stellar evolution," says Rob. "They're complex molecules and we don't yet understand their formation mechanisms in space. And if we want to understand the evolution of stars and galaxies, we need to comprehend the overall chemical picture."

For more information:
Research School of Astronomy and Astrophysics, Australian National University, Canberra
Dr Rob Sharp, Tel: +61 (2) 6125 0233,
rgs@mso.anu.edu.au, www.mso.anu.edu.au

The destruction of a star

You have to be well prepared, quick and lucky to take a picture of an explosion, especially if that explosion occurred 11 billion years ago in a remote part of the Universe. Having the right equipment, plus friends in high places, certainly helps. And that's exactly what the Zadko Telescope—managed by the University of Western Australia at the Gingin Observatory about 70 kilometres north of Perth—does have.

In December 2008, just after it was installed, the telescope was first on the scene to record for future analysis the afterglow of a momentous event—a huge explosion as a star collapsed into a black hole releasing a massive gamma-ray burst. It's the kind of happening the one-metre Zadko Telescope, currently the largest optical telescope in Western Australia, was built to observe. And it performed flawlessly, outpacing the world's most powerful telescopes at the European Southern Observatory in Chile.

But it had a little help from its friends. The robotic Zadko Telescope is part of a network of ground stations linked to NASA's Swift space telescope, which was launched to detect and observe just such gamma-ray bursts. Swift is equipped with three instruments, one of which, the Burst Alert Telescope, can locate and calculate the coordinates of a burst within 15 seconds. The position is then passed on to ground-based telescopes such as the Zadko.

The Zadko Telescope was established particularly with high school and university students in mind. They will participate fully in its research program. The telescope was made possible by a generous philanthropic donation by James Zadko to the University of Western Australia (UWA). The research facility is jointly managed by the International Centre for Radio Astronomy Research (ICRAR), the Australian International Gravitational Research Centre, and the UWA School of Physics.

For more information:
Zadko Telescope
Associate Professor David Coward,
Tel: +61 (8) 6488 4563,
coward@physics.uwa.edu.au,
zt.science.uwa.edu.au

the art astrono

The fact that we are a tiny part of an awe-inspiring universe is all too apparent at night in the rural and remote parts of Australia. Skies crammed with glittering stars, planets, galaxies, comets, meteorites and cosmic dust surround us. That's why, from the earliest times, astronomy has been a formative element in Australian culture. It calls forth—demands—a response, and has been a significant source of inspiration to artists.

of

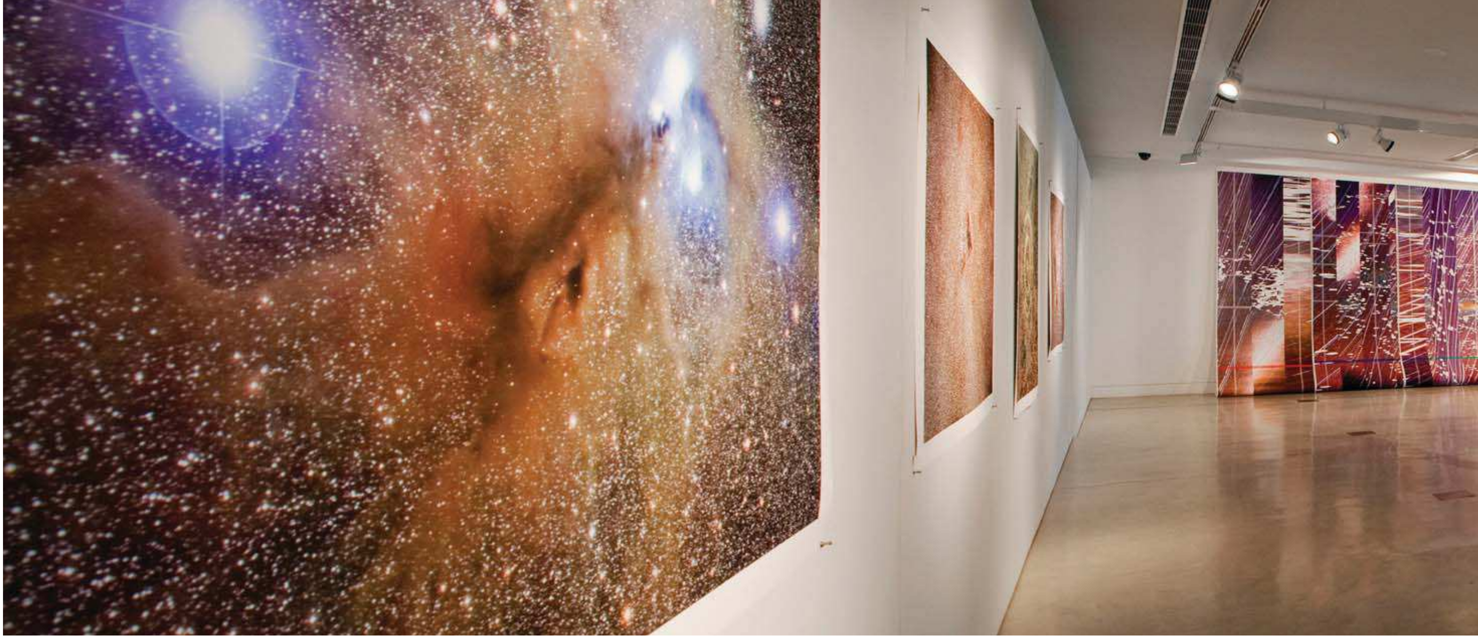
my

The Aboriginal peoples were among the world's first astronomers, naming constellations and tracking them across the sky. They recorded and used their observations for navigation, and they timed and followed the seasons using the positions of the stars and planets (see page 7). Not surprisingly, the night sky figures large in their visual arts.

An exhibition of paintings by artists from the Yamaji Art group entitled *'Ilgarijiri—things belonging to the sky'* was put together for the 2009 International Year of Astronomy. The project is a collaboration between the artists, who are based in Geraldton, Western Australia, and astronomers from the International Centre for Radio Astronomy Research led by Curtin University's Professor of Radio Astronomy and Premier's Fellow, Steven Tingay. Geraldton is the nearest city to Australia's proposed site for the Square Kilometre Array at the Murchison Radio-astronomy Observatory on Boolardy Station (see page 33). Besides Perth and Geraldton, the Ilgarijiri exhibition has travelled to Canberra, and to an international meeting in Cape Town in South Africa. In October 2011, it was exhibited at the Australian Embassy in Washington, D.C.

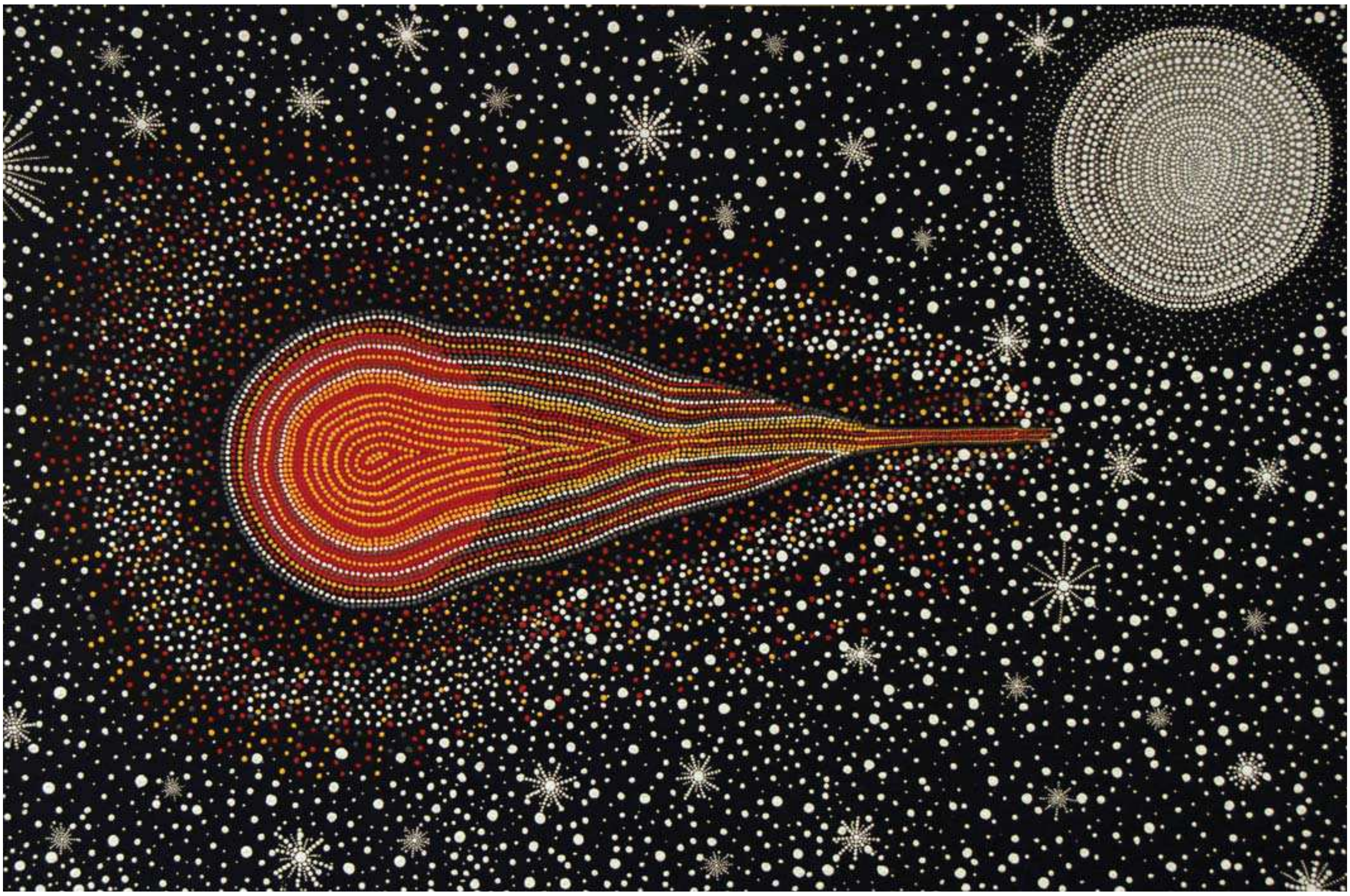
Links between ancient and modern, the Arts and the latest technology, are not unusual in astronomy. They demonstrate an aesthetic heart to the science. In 2009 another exhibition entitled *Beyond visibility: light and dust*—held at the art galleries of Monash University in Melbourne and the University of Technology in Sydney—explored the same rich vein. It was designed to draw attention to the history of human efforts to make two-dimensional pictures of the three-dimensional universe.

ARTWORK: GALACTIC ENERGY(DETAIL) BY GEMMA MERRIT, YAMAJI ART.



“I was walking through a park in Sydney one night, and I looked up... This is the universe we live in. It contains enough awe and amazement to more than fill a lifetime.”

Frances D’Ath



Beyond visibility: light and dust included large-scale prints of the work of famed astrophotographer David Malin, whose pioneering photographs taken at the Australian Astronomical Observatory (then known as the Anglo-Australian Observatory) were the first true-colour images of deep space. The Indigenous Yirrkala artist Gulumbu Yunupingu exhibited her bark paintings and hollow log memorial poles known as larrakitj encrusted with painted patterns representing the endless depths of the night sky and her vision of the universe. Felicity Spear contributed a seven-panel mural-sized work which gently curved from the wall out on to the floor of the Gallery like a large wave or curve in space.

The International Year of Astronomy stimulated many other arts events, including two exhibitions at the National Gallery of Victoria. *Light years: photographs and space* was a compendium of images from the glory years of NASA celebrating the 40th anniversary of the first Moon walk, while *Shared sky* included prints, paintings, photographs and Indigenous works celebrating the response to the sky through the ages.

Two works created for the International Year combined images and live music. One, *Harmonious Revolutions*, took the life and work of Galileo as its theme. It blended modern astronomical photographs with historical images, setting them against a narrative derived from Galileo's writings and the music of his period played by some of Australia's finest musicians. Another work, *Music and the Cosmos*, was presented by the University of Sydney in its Great Hall. It interleaved discussion of the latest research findings by three astronomy professors with music from *The Planets* by Gustav Holst, and an original composition, *Four Suns*, by Cliff Kerr, a PhD student in physics who also studied at the Sydney Conservatorium of Music.

Perhaps one of the most unusual artistic responses to astronomy emerged from a residency of choreographer Frances D'Ath at the Swinburne Centre for Astrophysics and Supercomputing. Frances and her dancer collaborators used different parts of their bodies to trace, mimic, outline, inscribe or otherwise respond to or reproduce the shapes and movements they encountered in simulations of galactic movement and interactions.

D'Ath's inspiration? "I was walking through a park in Sydney one night, and I looked up," she says. "The sky was so clear. I just thought, 'This is the universe we live in. It contains enough awe and amazement to more than fill a lifetime.'"

For more information:
Australian Astronomical Observatory
(The Australian node for IYA 2009)
Helen Sim, Tel: +61 (2) 9372 4251,
hsim@aao.gov.au

PHOTO: THE BEYOND VISIBILITY: LIGHT AND DUST EXHIBITION AT THE UNIVERSITY OF TECHNOLOGY, SYDNEY GALLERY. CREDIT: PAUL PAVLOU AND UTS GALLERY. ARTWORK FROM THE *ILGARIJIRI—THINGS BELONGING TO THE SKY EXHIBITION*: (PREVIOUS PAGE) *HALLEY'S COMET* (DETAIL) BY KAREN COMEAGAIN, YAMAJI ART. (THIS PAGE) *EMU ON THE SKY* (DETAIL) BY BARBARA COMEAGAIN, YAMAJI ART.

Australian astronomers take on the Universe

The nature of dark energy and dark matter, the processes of star formation, the creation and evolution of galaxies, the origin of cosmic magnetism, the formation of planetary systems, the prospects for extra-terrestrial life—these are just some of the areas of astronomy in which expatriate Australians are playing a significant role.

Travel to just about any country with an active astronomy program, and there you will find Australian astronomers plying their trade. Over the past several decades, the 24 Australian universities with astronomy programs—in collaboration with the nation's sophisticated telescope facilities—have consistently graduated about 20 astronomers with PhDs each year. With their specialist skills and hands-on training, half of them are quickly snapped up overseas—not a large contingent, but a vital shot-in-the-arm for international collaboration.

Astrobiologist and planetary astronomer Victoria (Vikki) Meadows, for instance, is an associate professor in the University of Washington's Astronomy Department in the US, and also a Principal Investigator at the NASA Astrobiology Institute's Virtual Planetary Laboratory. Vikki trained at the University of Sydney.

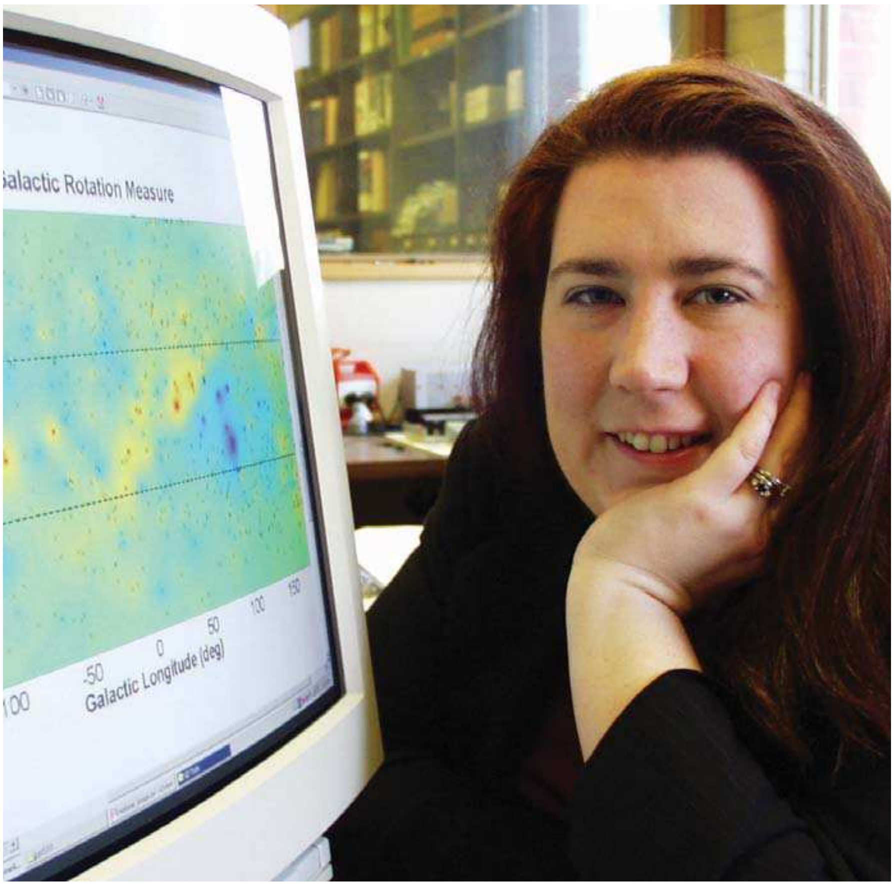
She leads an international team of scientists using the world's most advanced supercomputers to determine the likely characteristics of habitable planets orbiting other stars. Their work has helped NASA to plan space-based observatories that will search for life on other worlds and planets similar to Earth.

Medium-sized black holes

Expatriate X-ray astronomer Sean Farrell, a PhD graduate of the Australian Defence Force Academy in Canberra, specialises in black holes. He led the international team which used the European Space Agency's XMM Newton X-Ray space telescope to discover in 2008 the first medium-sized black hole ever found. More than 500 times the mass of the sun, it bridged the gap between small black holes and those of the super-massive variety.

Lisa Kewley, until recently a Hubble Fellow at the Institute of Astronomy of the University of Hawai'i, studies the evolution of galaxies from a billion years after the Big Bang. Still in her 30s, she has already won two top American Astronomical Society Awards—the 2005 Annie Jump Canon Award and the 2008 Newton Lacy Pierce Prize—for discovering the links between oxygen and the evolution of galaxies. As a by-product, she calculated that most of the oxygen atoms we breathe today were created five to 12 billion years ago.

Closer to home, Melanie Johnston-Hollitt, an Australian radio astronomer at the Victoria University of Wellington, New Zealand, chairs the New Zealand Square Kilometre Array (SKA) Research and Development Consortium, linking New Zealand astronomers, engineers, physicists and other research scientists, industry and government in a conjoint effort with Australia to win and participate in the project.



EMU survey

In her day job, Melanie leads a research group studying the physics of galaxy clusters, the largest gravitationally bound structures in the Universe. Her group is using some of the world's most powerful radio, optical and X-ray telescopes to establish how these clusters have evolved.

And she also heads one of ten working groups of scientists involved in the Evolutionary Map of the Universe (EMU) projects. This is an all-sky radio survey of the southern sky to commence in 2013 using Australia's powerful new Australian Square Kilometre Array Pathfinder (ASKAP) telescope, now under construction at the site of the proposed SKA in Western Australia (see page 33).

Harvey Butcher, Director of the Research School of Astronomy and Astrophysics and the Mount Stromlo and Siding Spring Observatories at the Australian National University, Canberra, says the limited number of funded positions in Australia contributes to the expatriate exodus, but also that the facilities of modern astronomy are so expensive astronomers around the world necessarily work in teams, and successful astronomers need to follow the work.

Foundation Director of CSIRO's Australia Telescope National Facility, CSIRO Research Fellow and past president of the International Astronomical Union Ron Ekers urges Australian astronomers to recognise the competitive advantage of their distinctiveness.

"Australians are so successful overseas not because we're so clever but because we're different. The value of internationalism is that we've grown up in a different system with a different education and a style of research, where we've learned to do things as well as teach them."

PHOTOS: (PREVIOUS PAGE) MELANIE JOHNSTON-HOLLITT CHAIRS THE NEW ZEALAND SQUARE KILOMETRE ARRAY RESEARCH AND DEVELOPMENT CONSORTIUM. CREDIT: UNIVERSITY OF ADELAIDE. (THIS PAGE) SUPER SCIENCE FELLOW DR JAMES ALLISON AT NARRABRI DURING AN OBSERVING RUN AT THE AUSTRALIA TELESCOPE COMPACT ARRAY. CREDIT: ANANT TANNA.

Nurturing super astronomers at home

Advanced telescopes need advanced astronomers to run them. Australia is matching the millions of dollars it is investing in new telescope technology with funds to help train the rising stars of Australian astronomy.

"We've had big investments in infrastructure, and now we need young scientists with the expertise to use them," says Elaine Sadler, professor of Astrophysics at the University of Sydney and chair of the National Committee for Astronomy.

One new tranche of research funding for early career astronomers comes in the form of three-year Super Science Fellowships from the Commonwealth Government. In 2011, 14 young astronomers became Super Science Fellows, joining the 17 who started work in 2010. All up, astronomy will receive one-third of the Federal Government's $27 million commitment to the Fellowships program.

Four of the fellowship winners will join the Galaxy Genome Project, which builds on the Galaxy and Mass Assembly (GAMA) survey (see page 5) at the Australian Astronomical Observatory. The project will characterise galaxies by the spectrum of light they emit—just as genomes characterise individuals—to create a definitive source for studying galaxy evolution, cosmology and the large-scale structure of the Universe.

One Super Science Fellow, James Allison, has joined Elaine in her hunt for faint galaxies. Elaine is leading one of the major surveys to be carried out by CSIRO's ASKAP radio telescope, FLASH, which will study galaxy evolution by looking for the faint signal of hydrogen gas. Another Fellow will join Bryan Gaensler on his POSSUM sky survey of the Universe's magnetic fields (see page 33).

Bryan is also directing another new initiative that will help to train young astronomers—the ARC Centre of Excellence for All-sky Astrophysics (CAASTRO). Launching in 2011, the Centre will use Australia's new generation of advanced telescopes to help answer unsolved questions about the Universe, from galaxy evolution to the nature of dark energy and dark matter. "The focus is on research, but also on training the next generation of Australian astronomers," adds Elaine, who is also a CAASTRO chief investigator.

CAASTRO, which is set to receive more than $28 million in funding over the next seven years, is led by the University of Sydney, in conjunction with the Australian National University, the University of Melbourne, the University of Western Australia, Curtin University, Swinburne University of Technology, CSIRO, and the Australian Astronomical Observatory. Institutions from Germany, France, the US, Britain and Canada are also partners.

For more information:
Sydney Institute for Astronomy, University of Sydney
Professor Elaine Sadler, Tel: +61 (2) 9351 2622, ems@physics.usyd.edu.au, www.caastro.org

Understanding our home: the Milky Way

The far reaches of the Universe hold many mysteries—but there's a lot we still don't understand about our own backyard, the Milky Way galaxy within which our Solar System sits. How did it form, and how has it grown? How are new stars born within our galaxy, and how do old ones die? These are some of the questions about our galaxy that Australian astronomers are working to answer.

Our gas-guzzling galaxy

"There's a lot we still don't know about our Milky Way galaxy," says Naomi McClure-Griffiths of the CSIRO Astronomy and Space Science. "It's the old can't-see-the-forest-for-the-trees problem—we have a hard time seeing its structure from the inside."

Since 2004, Naomi has headed the Galactic All Sky Survey (GASS), the most sensitive survey of the galaxy's hydrogen gas visible from the Southern Hemisphere. Using CSIRO's Parkes radio telescope, GASS is investigating how different parts of the galaxy interact, where stars are being formed, what happens when they die, and how they cause new stars to be born.

"Our galaxy is basically a big machine that's producing stars from gas," says Naomi. "How that works is a question that dominates not just galactic astronomy, but astronomy in general."

The survey half of the project is complete and now the analysis has begun, with six papers already published. One thing the team is hoping to determine is whether the bits and pieces of gas floating around the galaxy are the fresh 'food' the galaxy needs to make new stars. Does this gas come from outside or inside? "We're finding that it's both," says Naomi. "But the galaxy particularly needs fresh stuff from outside, and we think that comes partly from small galaxies it has consumed."

The Parkes telescope, which is now fitted with a receiver to observe multiple parts of the sky at once, is vital to this study, says Naomi. "The multibeam instrument has made Parkes seven times better and completely revolutionised the field," she says. "If the multibeam didn't exist, work I finished years ago would still be incomplete today."

For more information:
CSIRO Astronomy and Space Science
Dr Naomi McClure-Griffiths,
Tel: +61 (2) 9372 4321,
naomi.mcclure-griffiths@csiro.au,
atnf.csiro.au/research/GASS/

Galactic archaeology—digging into the Milky Way's past

Ken Freeman is hunting for fossils. But he's not looking for old bones—he's exploring the very origin and history of our Milky Way galaxy.

Conventional theory says that our galaxy grew big by engulfing smaller ones. If this is correct, stars from the original galaxies should be still identifiable within the main mass of stars via several tell-tale signs, from unusual velocities to spectral types. These stellar fossils would point to the galaxy's birth and growth.

Ken, an astronomy professor at the Australian National University (ANU), along with Joss Bland-Hawthorn of the University of Sydney, pioneered the field of galactic archaeology. "Galactic archaeologists are aiming to discover and interpret the stellar fossil record, so that we can get a strong observational basis for our ideas about how galaxies like the Milky Way formed," says Ken. Doubts linger, however, about whether or not the big-from-small theory is fully correct.

"The theoretical models have great trouble in generating a galaxy shaped like ours," Ken says.

Observations using Australian facilities and instruments could settle the question. The ANU's new SkyMapper telescope will help select stars for study, and the Australian Astronomical Observatory's (AAO's) AAOmega instrument will provide spectral information on these target stars.

The main work, though, will come from the AAO's High Resolution Multi-Object Spectrometer (HERMES) which, when commissioned in late 2012, will make detailed measurements of the velocity, chemistry and temperature of about a million stars in the hunt for fossils. The HERMES results should begin to emerge around 2015.

For more information:
Research School of Astronomy and Astrophysics, Australian National University, Canberra
Professor Ken Freeman, Tel: +61 (2) 6125 0264, kcf@mso.anu.edu.au, mso.anu.edu.au/

Profiling and fingerprinting the stars

But already, another Australian-led innovation in astronomical instrumentation is providing researchers with the critical information they need to understand the motions of stars within different parts of our galaxy, such as its main body, the bulging core, and the extended halo that surrounds it. Researchers are also searching for evidence of galactic cannibalism—swarms of stars that could be remnants of dwarf galaxies consumed by the Milky Way.

The innovation, called the 6dF instrument, is being used by a multinational consortium, the RAdial Velocity Experiment (RAVE), to measure the radial velocities of more than half a million stars. It is mounted on the Australian National University's UK Schmidt Telescope at Siding Spring in New South Wales. Radial velocity is movement toward or away from the observer along the light of sight, as distinct from motion across the line of sight. The survey, which began in 2003, will be completed in 2011.

"Using 6dF's robotic fibre optics system, we can measure about 100 stars at once and quickly build up a very large database," says Fred Watson from the Australian Astronomical Observatory, who manages the RAVE project.

RAVE has also recorded the spectra of all its target stars, enabling the astronomers to fingerprint them chemically, providing information vital for understanding stellar evolution.

"These fingerprints are already giving us insights into the way our galaxy has developed over its 12-billion-year history," Fred says.

For more information:
Australian Astronomical Observatory, New South Wales
Professor Fred Watson, Tel: +61 (2) 6842 6301, fgw@aao.gov.au, aao.gov.au and www.rave-survey.aip.de/rave/

Stellar immigration

If the Milky Way did grow by swallowing up smaller galaxies, then another team suspects it knows where in the Milky Way some of those alien stars are hiding.

Duncan Forbes of Swinburne University of Technology and his Canadian colleague Terry Bridges are using Hubble Space Telescope data to identify clusters of alien stars, using the fact that their age and chemical composition differs from their neighbours.

Globular clusters are dense spherical collections of about a million stars of the same age. Held tightly together by gravity, they move together as a unit. Based on the Hubble data, Duncan and Terry think that, over the past few billion years, about a quarter of the globular star clusters in our galaxy—tens of millions of stars—formed elsewhere before moving into the Milky Way.

The two researchers think that many of the alien clusters may initially have formed in mini- or dwarf galaxies of about 100 million stars that were later swallowed up by the Milky Way. And when the larger galaxy structure was broken down, the clusters remained intact.

"Astronomers have already confirmed the existence of two accreted dwarf galaxies in our Milky Way—but our research suggests that there might be as many as six yet to be discovered," Duncan says. "This will have to be explored further, but it is a very exciting prospect that will help us to better understand the history of our own galaxy."

The work was carried out in Canada as part of an Australian Research Council International Fellowship.

For more information:
Swinburne University of Technology, Melbourne
Professor Duncan Forbes, Tel: +61 (3) 9214 4392,
dforbes@swin.edu.au,
astronomy.swin.edu.au/~dforbes/

PHOTOS: (TOP LEFT) RAVE PROJECT MANAGER, FRED WATSON, WITH THE UK SCHMIDT TELESCOPE. CREDIT: SHAUN AMY. (ABOVE, TOP) DUNCAN FORBES IS IDENTIFYING ALIEN STARS. CREDIT: PAUL JONES. (ABOVE) NAOMI MCCLURE-GRIFFITHS WITH THE PARKES RADIO TELESCOPE. CREDIT: DAVID MCCLENAGHAN © 2011 CSIRO.

Planets

Defending the Earth against solar attack

In May 1921, a massive burst of protons and electrons from the Sun, known as a coronal mass ejection, enveloped Earth. If that same event happened today, a recent report from the American National Academy of Science argued, it would take down one-third of the US power grid, causing an estimated $10 trillion damage to industry which would need up to a decade to repair.

So, the development by University of Sydney physicists Iver Cairns and Vasili Lobzin of the Automated Radio Burst Identification System (ARBIS) software—which can provide up to three days' warning of such an event, allowing protective action to be taken—is significant.

The program automatically samples chunks of data from the Learmonth (Western Australia) and Culgoora (northern New South Wales) Solar Observatories for the specific frequency patterns which herald particular types of solar bursts. When there are reasons for concern, the software automatically sends out warning emails to recipients all over the world.

ARBIS is the legacy of more than 60 years of listening to the radio emissions of the Sun, a field pioneered by Paul Wild, former chair of Australia's national science agency, CSIRO. Solar physics flowered in Australia during the 1950s, 60s and 70s, according to Paul Cally of Monash University, whose interests include studying the complex and ever-fluctuating magnetic fields around the Sun, and helioseismology, probing the internal structure of the Sun by analysing its electromagnetic vibrations.

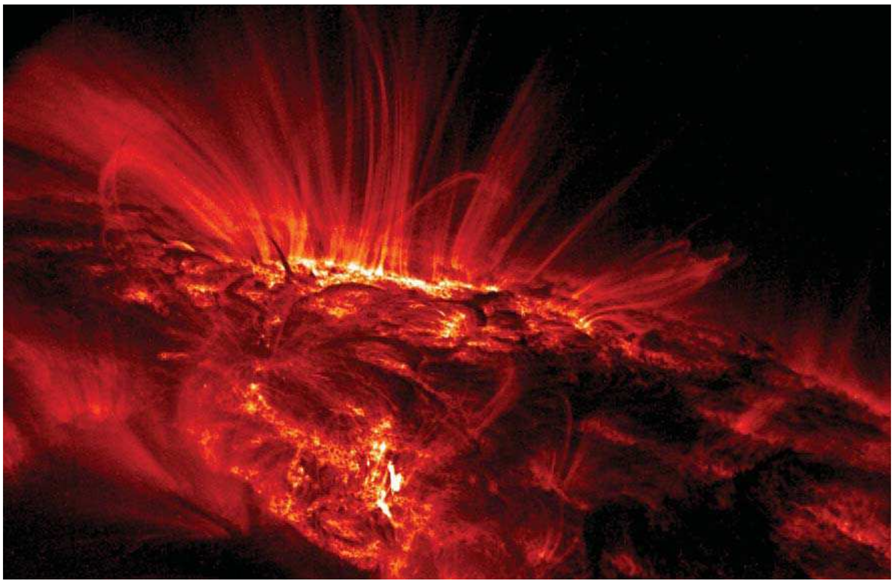
"A lot of researchers are not aware of the significant historical role the study of the Sun has played in development of astronomy and astrophysics," he says.

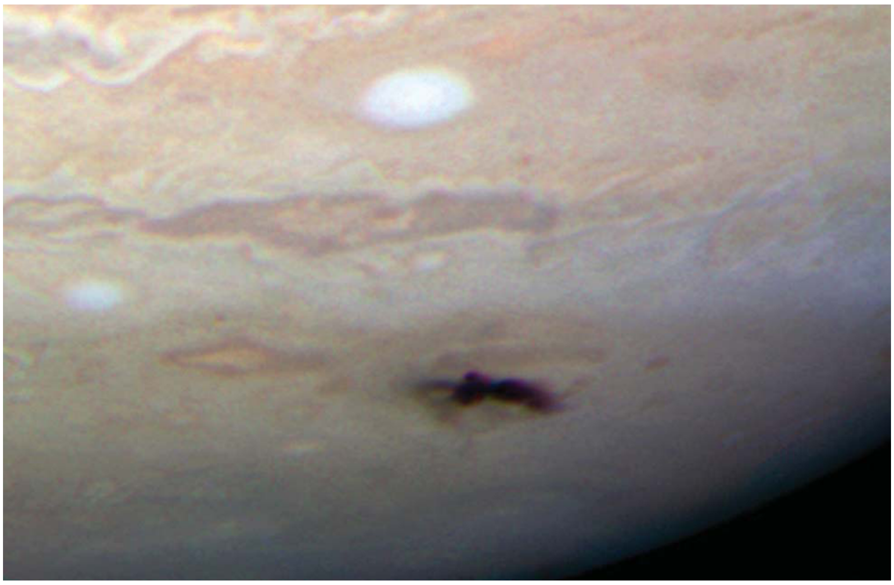
He notes that CSIRO will contribute the tuneable electromagnetic filter at the centre of the visible imager and magnetograph—an important instrument for probing the structure of the Sun—to be carried by the European Space Agency's Solar Orbiter, which is expected to be launched early in 2017.

For more information:
School of Physics, University of Sydney
Professor Iver Cairns, Tel: +61 (2) 9351 3961,
cairns@physics.usyd.edu.au,
http://www.physics.usyd.edu.au/~cairns/

For more information:
School of Mathematical Sciences,
Monash University
Professor Paul Cally, Tel: +61 (3) 9905 4471,
Paul.Cally@monash.edu,
http://web.maths.monash.edu.au/~cally/

PHOTOS: (TOP, RIGHT) SUNSPOT LOOPS IN ULTRAVIOLET. CREDIT: NASA/TRACE. (ABOVE RIGHT) THE DARK SPOT ON JUPITER FIRST DISCOVERED BY AMATEUR ASTRONOMER ANTHONY WESLEY, AS PHOTOGRAPHED BY THE HUBBLE SPACE TELESCOPE ON 23 JULY 2010. CREDIT: NASA/ESA/H. HAMMEL (SPACE SCIENCE INSTITUTE, BOULDER, COLO.)/THE JUPITER IMPACT TEAM.





An amateur crashes onto the scene

Modern astronomy seems dominated by huge, expensive and powerful machines staffed by highly trained professionals. Yet significant findings can still be made by people like Anthony Wesley, a computer software engineer and amateur astronomer who lives just north of Canberra.

About 12.40 am on 20 July 2009, Anthony—who loves to keep an eye on Jupiter with his 14.5 inch (36.83 cm) diameter reflecting telescope—noticed a small black spot near the south pole of his favourite planet. It was in the wrong place and the wrong size to be a moon, he says, and also it was moving too slowly. In fact, it was moving at the same pace as a nearby storm.

The only possibility that fitted the facts was that he was observing the debris from a collision between a fast moving body, such as an asteroid or comet, and the planet itself. But the chances of that were remote. It was an event that had only ever been seen once before, almost exactly 15 years previously when the comet Shoemaker-Levy slammed into Jupiter.

With some trepidation Anthony emailed astronomers around the world; his suspicions were soon confirmed. The professionals then used their analytical machines to determine the composition of the dust and the impacting body, as well as the force of the explosion—all very valuable information.

That should have been enough for one lifetime, but in early June 2010, Anthony did it again, glimpsing a flash of light near Jupiter's edge. A colleague in the Philippines quickly confirmed the sighting which turned out to be the fireball of an asteroid about ten metres in diameter burning up in Jupiter's atmosphere.

For more information:
Anthony Wesley, Tel: +61 (2) 6227 0891,
awesley@acquerra.com.au,
acquerra.com.au/astro

The search for other Earths

Over the last decade, Australian astronomers have found dozens of new planets as part of the global effort to discover exoplanets—planets orbiting distant suns.

One of the pioneers of that hunt for exoplanets is Penny Sackett. From late 2008 until early 2011, Penny served as Australia's Chief Scientist, advising the Prime Minister on matters relating to science, technology and innovation. But before that, she was director of the Research School of Astronomy and Astrophysics and Mount Stromlo and Siding Spring Observatories at the Australian National University (ANU).

Penny's research established that about one in every 1,000 stars is orbited by a 'Hot Jupiter'. These large planets sit extremely close to their sun, so that their orbits take just three or four days to complete. While most of the exoplanets spotted so far are Hot Jupiters, a handful of rocky, Earth-like planets have also been identified that might potentially support life.

Doubling up pays dividends in exoplanet hunt

"Twice the resolution and all the photons," is Chris Tinney's new catchphrase. It refers to new equipment being commissioned on the Anglo-Australian Telescope to hunt for planets beyond our Solar System (exoplanets). Chris, from the University of New South Wales, is a leader of the Anglo-Australian Planet Search (AAPS), which has found 32 exoplanets since 1998.

A so-called 'Doppler shift' in the spectrum of a star's light often indicates the presence of planets. Unlike previous equipment, which frequently missed some of that light, the new system uses a cluster of optical fibres to gather all the starlight, boosting efficiency and doubling the Doppler precision.

Now, a new type of intensive observation campaign also is paying dividends. AAPS has recently had two 48-night blocks of observing time, which has helped them find two small exoplanets."Our main aim is to find Solar System analogues," says Chris, "ones that have a Jupiter-like planet in a middle-distance orbit, which could be indicative of having Earth-like planets in closer orbits.

"That requires getting very high precision measurements over orbital periods the same as Jupiter (12 years) or more. We have that precision now."

For more information:
Department of Astrophysics and Optics, University of New South Wales, Sydney
Professor Chris Tinney, Tel: +61 (2) 9385 5168, cgt@phys.unsw.edu.au, phys.unsw.edu.au/~cgt/cgt/Homepage.html

Bringing undiscovered Earths into focus

How many of the planets scattered across the Universe have the potential to harbour life? An observatory being built in Tasmania is poised to help answer just that question.

Astronomers at the University of Tasmania (UTas) currently use the Mount Canopus Observatory in Hobart to search for Earth-like planets orbiting distant suns—but the growing city is compromising the observatory's view of space. "Light is driving us away," says John Greenhill, the Observatory's director.

Thanks to a $2 million donation, UTas is receiving a new 1.3-metre optical telescope, and it has also been given a new wide-field imaging camera. The University will house the telescope in an observatory, being built about 70 kilometres north of Hobart at Bisdee Tier, which will have no such light pollution problems. "The new observatory will have a camera with a much bigger field of view, so we can measure many more planetary candidates at the same time," says John.

The UTas team is part of a global network of astronomers who spot exoplanets—planets outside our Solar System—using a technique called 'gravitational microlensing'. Whenever one star passes in front of another, the gravity of the nearer star acts like a lens, focusing the light of the more distant star. Within that brightening light, planets orbiting the nearer star can be detected, including details about their size and distance from their host-star.

Most of the exoplanets discovered so far are much larger and hotter than Earth, but the gravitational microlensing technique is particularly sensitive to revealing planets more like those in the Solar System, says John. "We already have evidence that planetary systems like our own, and cool rocky planets similar to Earth-mass, may be very common," he says.

The team is currently waiting for their new telescope to arrive from Canada, where it was built. "We're optimistic that we will be able to start observations before the end of the year," John says.

For more information:
School of Mathematics and Physics, University of Tasmania, Hobart
Dr John Greenhill, Tel: +61 (3) 6226 2429, John.Greenhill@utas.edu.au, fcms.its.utas.edu.au/scieng/physics/

PHOTOS: (TOP, LEFT) AN ARTIST'S IMPRESSION OF AN EXOPLANET WITH MOONS, ORBITING THE STAR HD70642. CREDIT: DAVID A. HARDY, ASTROART.ORG © PPARC. (TOP, RIGHT) USING A NEW OBSERVATORY BEING BUILT NORTH OF HOBART, RESEARCHERS AT THE UNIVERSITY OF TASMANIA ARE GEARING UP TO FIND WHETHER THE UNIVERSE HARBOURS MORE PLANETS LIKE EARTH. CREDIT: JOHN GREENHILL, UNIVERSITY OF TASMANIA.

Inspiring the next generation

A star-studded education by remote control

The Southern Hemisphere's lunar eclipse in June 2010 drew an international audience of high school students observing it over the web. They used the 12-inch (30.48 cm) diameter optical telescope operated by David McKinnon of Charles Sturt University in Bathurst, about 200 kilometres west of Sydney. The webcast was clear and uninterrupted thanks to a new 1.5 kilometre, one gigabit per second, fibre optic link, supplied by Country Energy, which connects the telescope with the Australian universities' broadband network, AARNet.

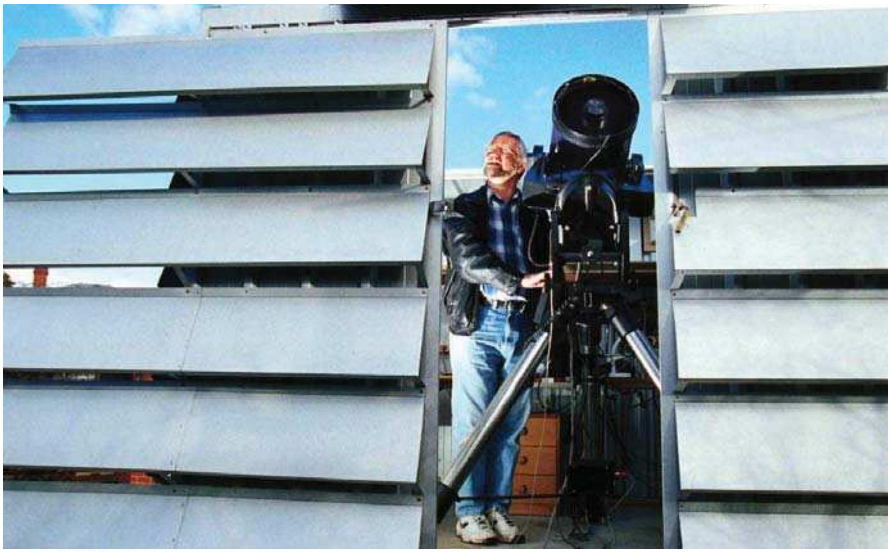
Since it was established more than a decade ago, the telescope has introduced thousands of students to the wonders of the southern sky. They have not only seen eclipses, planetary transits across the Sun, stars, supernovas, galaxies, asteroids, comets and cosmic dust, but also human-initiated events such as the 2005 NASA Deep Impact mission, where a probe was deliberately crashed into the comet Tempel 1 at nearly 37,000 kilometres an hour. The US space agency, NASA, specifically requested David to webcast their mission.

After investing in electronic charge-coupled device (CCD) cameras that David could access and guide remotely over the net, it was a short step to using the telescope as a teaching tool to allow both primary and high school students to acquire their own images. "When they are in control of the telescope and can see their exposures within seconds, they become really motivated."

Along with schools from the US and the Netherlands, West Kildonan Collegiate Institute in the Canadian province of Manitoba has become a regular user. Physics teacher Robin Edwards has won the province's Best Science Educator award for his work with the CSU Remote Telescope. In addition, one of his students, Alaina Edwards, was awarded the Royal Astronomical Society of Canada's Science Prize for her work on variable stars using the telescope.

In 2010, the American communication company POLYCOM donated a high definition video-conferencing unit to the project. This allows promotion of astronomical events to 17 schools in Georgia and 42 in the United Kingdom together with science professional development sessions for science teachers in Wyoming, USA, and Manitoba, Canada.

For more information:
Charles Sturt University, Bathurst,
New South Wales
Associate Professor David McKinnon,
Tel: +61 (2) 6338 4235,
dmckinnon@csu.edu.au,
black-hole-net.mit.csu.edu.au/telescope/main.asp



A student's out-of-this-world experience

Daniel Tran, a year ten student at PAL College in Cabramatta, a suburb in southwestern Sydney, has photographed the Glowing Eye Nebula, a ghostly cloud of gas that has lasted at least 3,000 years and surrounds a dying star some 7,000 light years from Earth.

Daniel took the photograph using one of the world's biggest telescopes—the giant 8.1-metre Gemini South telescope in Chile, in which Australia has a 6.2 per cent share. His precious hour's worth of observing time on the telescope was the 2009 prize for winning the Australian Gemini School Astronomy Contest, which aims to inspire the next generation of Australian astronomers by involving students in the process of real astronomy at a major professional facility.

"I thought they were pulling my leg," says Daniel about his initial reaction to hearing that he'd won the contest. The unique colour and structure of the Glowing Eye Nebula, as well as its name, all made him want to know more about it.

Students are encouraged to submit entries for targets to digitally photograph in the southern sky that are both scientifically interesting and aesthetically pleasing, explains Christopher Onken from the Australian Gemini Office. Christopher presented a framed portrait of the nebula to Daniel at his school. The prize for winning the contest also involved a live hook-up to the Gemini Observatory.

For more information:
Australian Gemini Office, Canberra
Dr Christopher Onken, Tel: +61 (2) 6125 8039,
onken@mso.anu.edu.au, ausgo.aao.gov.au

PHOTOS: (TOP) DAVID MCKINNON AND HIS TELESCOPE ARE ALLOWING STUDENTS ACROSS THE WORLD TO SEE THE SOUTHERN SKIES. CREDIT: ANDREW MCKINNON. (ABOVE) DANIEL TRAN RECEIVING A FRAMED PRINT OF HIS OBJECT OF FASCINATION, THE GLOWING EYE NEBULA. CREDIT: DAVID MARSHALL.

From Antarctica to the Outback

Antarctica provides a clear view of the heavens

Robotic observatories designed and built in Australia to operate unattended throughout the polar winter have laid the groundwork for the future development of astronomy in Antarctica.

Known as PLATO (PLATeau Observatories), they generate their own heat and power from solar energy in summer and small, highly efficient diesel engines in winter, and house scientific instruments to analyse the surrounding environment with respect to making astronomical measurements. The data they have gathered confirms that Antarctica contains some of the best observing sites on Earth.

"It is very cold, very dry and very high," says Professor John Storey of the University of New South Wales where PLATO was conceived and pioneered. "Antarctica also has very, very clear skies with good transparency. The atmosphere is stable, and there is no artificial light pollution or radio interference. In the terahertz range, for instance, the viewing conditions are ten times better than Mauna Kea in Hawai'i. That's a staggering advantage."

The work has been enough to convince China to begin construction of an observatory costing more than $25 million at Dome A in the centre of the continent, the highest point of the Antarctic plateau, an altitude of more than 4000 metres. It will be equipped with two 2.5-metre and three 0.5-metre telescopes. Japan and Europe are putting together plans to follow suit elsewhere on the central plateau. And US researchers are already working at the South Pole, where they have installed a ten metre diameter radio telescope and IceCube, a particle detector for neutrinos that extends over a cubic kilometre.

Australia is hoping to collaborate with the Chinese on key research projects looking at the early universe, the structure of dark matter and the structure of dark energy, says John, who is also the current head of the international body that co-ordinates astronomical research in Antarctica.

For more information:
Department of Physics,
University of New South Wales
Professor John Storey, Tel: +61 (2) 9385 4578,
j.storey@unsw.edu.au,
http://mcba11.phys.unsw.edu.au/~plato/
http://mcba11.phys.unsw.edu.au/~plato-f/

PHOTOS: (TOP LEFT) A BALLOON LAUNCH AT ALICE SPRINGS. CREDIT: R. SOOD. (RIGHT TOP) AN ARTIST'S IMPRESSION OF THE HAYABUSA SPACECRAFT APPROACHING THE ASTEROID ITOKAWA. CREDIT: A. IKESHITA/MEF/ISAS. (RIGHT BOTTOM) CHINESE ASTRONOMER XUEFEI GONG STANDING IN FRONT OF THE ENGINE MODULE FOR THE DOME A ROBOTIC OBSERVATORY. CREDIT: JOHN STOREY, UNSW.

Japanese spacecraft calls Australia home

On 13 June 2010, a Japanese spacecraft bearing pieces of another world parachuted down to Australian soil after a seven-year-long journey through deep space.

During its journey, the spacecraft, called Hayabusa, encountered the 530-metre-long asteroid called Itokawa in November 2005, and briefly landed on it. The Japanese Aerospace Exploration Agency (JAXA) designed Hayabusa to collect samples of the asteroid's surface. Hayabusa then landed at the Department of Defence's remote Woomera Prohibited Area in the South Australian desert. Fifty years ago, Woomera was one of the most active rocket launch sites in the world. It is still the largest land-based test range on the planet.

Although Hyabusa was plagued by malfunctions after its departure from Itokawa, the controllers, in an impressive feat of ingenuity, managed to coax it home.

Upon retrieval, the capsule was packed inside a double layer of plastic bags filled with pure nitrogen gas for transport to Japan. Scanning electron microscope studies show that, despite a series of hitches with the mission, extra-terrestrial particles from Itokawa did swirl into the spacecraft's sample scoop. Handling the particles requires special skills and technologies that JAXA is developing.

"Australia is proud to support Japan in this world-first expedition," says Innovation Minister Senator Kim Carr. "The Australian Government is investing $48.6 million in the Australian space sector through its new Space Policy Unit and Australian Space Research Program. The return of the Hayabusa is one of the many activities the unit is supporting."

For more information:
Space Policy Unit, Department of Innovation, Industry, Science and Research, Canberra
Tel: +61 (2) 6276 1166,
space@innovation.gov.au, www.space.gov.au

Alice Springs —gateway to the stars

Scientists are using the unique advantages of Australia's Red Centre to conduct high-altitude balloon flights for astronomical research. The clear air and low population of central Australia make it the ideal location for balloon-based research.

For most types of astronomy, observatories are typically built high on the tops of mountains, far out in space or high in the sky, dangling from 150-metre-tall helium balloons.

"These balloons fly at 40-kilometre altitude, giving us unfettered views of the cosmos at one per cent of the cost of a satellite," says Ravi Sood, the director of the Australian Balloon Launching Station at Alice Springs.

Stratospheric balloons have been launched from Australia since the early 1960s, including more than 100 from Alice Springs. Depending on the winds, they drift for one or two days into Western Australia or Queensland, until they are brought back to earth in a safe spot. "Alice Springs is the only site in Australia where we're allowed to launch these balloons, because of the low population density," says Ravi. "And from Australia, we get the best view of the most important regions of our Milky Way galaxy."

These advantages of Alice Springs draw a steady flow of US and European researchers to Australian shores. Current efforts include X-ray and gamma-ray studies of pulsars, black holes and other exotic celestial bodies.

NASA is testing a new super-pressure balloon that will circle the globe several times before landing in Australia again after three months.

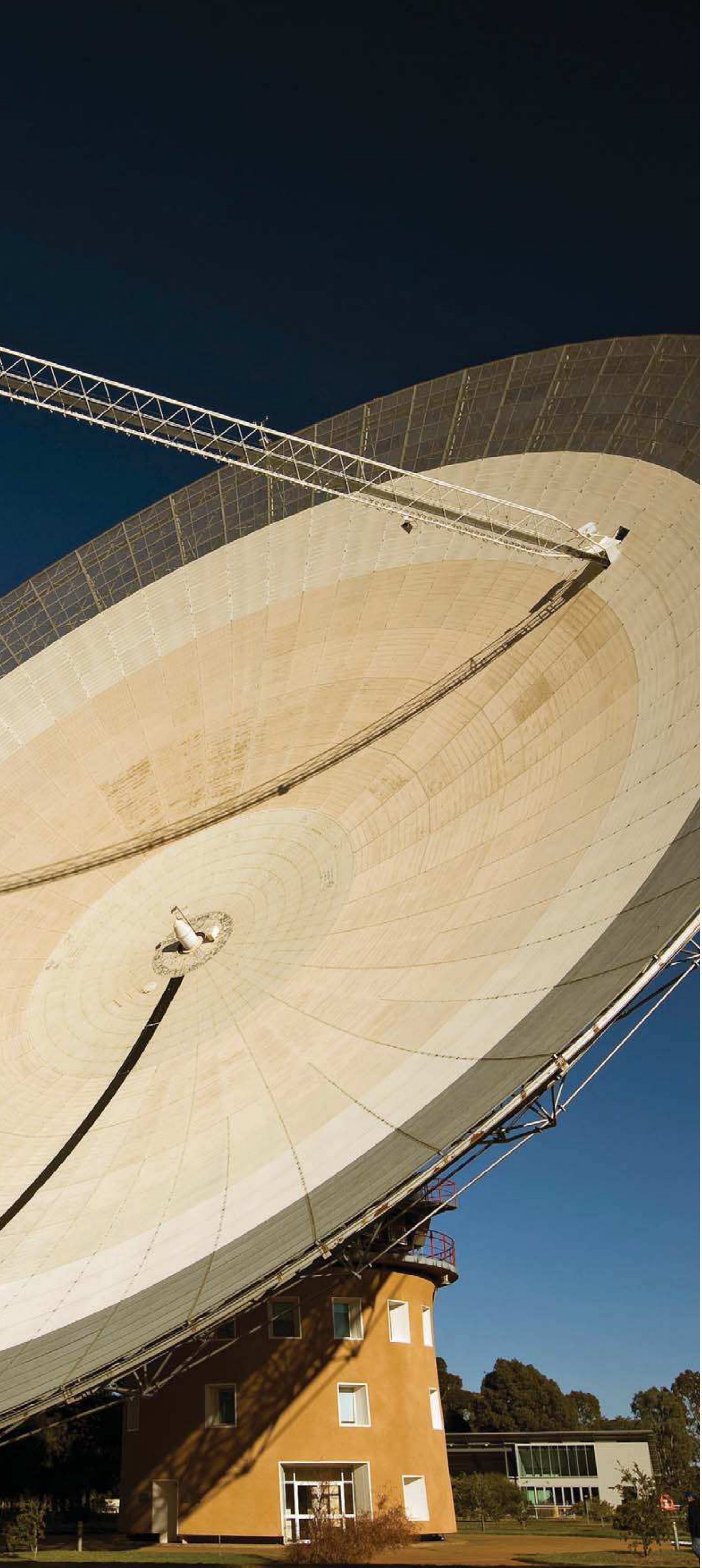
For more information:
School of Physical, Environmental and Mathematical Sciences, University of New South Wales at Australian Defence Force Academy, Canberra
Professor Ravi Sood, Tel: +61 (2) 6268 8765,
r.sood@adfa.edu.au,
www.unsw.adfa.edu.au/pems/research/astro

Radio astronomy

Radio waves were detected from the Sun and our galaxy before World War II. But radio astronomy—the use of radio waves as a tool for studying the cosmos—developed rapidly only after the war, powered by the new expertise in radio techniques, and in radar particularly, to which the conflict had given birth. Australia was one of the pioneers, led by CSIRO's forerunner, the CSIR (Council for Scientific and Industrial Research). At the end of war, CSIR's radio group stayed together to continue research in peace time uses of radio waves.

CSIRO's research grew rapidly with the creation of the Parkes radio telescope, known locally simply as 'The Dish', and later the Australia Telescope Compact Array built for Australia's Bicentenary.

Today, Australia is poised to take the lead in radio astronomy again, competing to host the international Square Kilometre Array (SKA), a vast radio telescope consisting of several thousand small antennas, which will be 10,000 times more powerful than any existing instrument. In the meantime, CSIRO is already building the Australian SKA Pathfinder, and a consortium of US, Australian and Indian universities and institutes have begun collecting data from the Murchison Widefield Array. Both are demonstrator projects for the SKA, but are also cutting-edge radio telescopes in their own right.



Radio astronomy's rapid growth down under

The CSIRO Radiophysics Laboratory in Sydney houses an impressive concentration of radio experts. Perhaps it should not come as a surprise, then, that much of the sophisticated radio-based technology needed for astronomy has been developed in Australia.

"Radio is a very complicated field of electronics, still very much a black art," says Terry Percival, a pioneer of radio telescope arrays. "But [the Radiophysics] laboratory has radio in its genes. It's a collection of more than 100 people including 60 or 70 PhDs in radio."

Radar—the radio equivalent of echo-location in bats—was developed in the 1930s. It allowed remote location and tracking of moving military targets, such as aircraft and ships. In Australia, the Radiophysics Laboratory was created in 1939 within CSIRO's forerunner, the CSIR, to develop the technology for use during the Second World War.

The lab had a highly talented group of researchers, and after the war, the CSIR decided to keep them together to explore peaceful uses for radio. Many of the researchers started working on radio techniques for aircraft navigation and range-finding. Some began to study the physics of clouds and rain. But one group, led by Joe Pawsey, decided to investigate cosmic radio waves. "This was the beginning of Australian radio astronomy, a remarkable period of excitement and discovery," says CSIRO Fellow and former director of CSIRO's Australia Telescope National Facility, Ron Ekers.

PHOTO: CSIRO'S PARKES RADIO TELESCOPE.
CREDIT: DAVID MCCLENAGHAN / CSIRO.

Radio waves from a distant galaxy

CSIRO scientists and engineers turned surplus wartime radar equipment at Dover Heights in Sydney into a radio telescope, and with this discovered two radio sources that turned out to be galaxies millions of light-years away. Until then, people had thought that such radio sources were simply stars. "The finding was shocking," says Ron. "These were the first extragalactic radio sources." Using the same telescope, the researchers also detected radio emissions from the pulsar in the Crab Nebula, the remains of an exploded star. In another project, Pawsey's group built a dish-type telescope at Dover Heights, and with this pinpointed the centre of our galaxy. These discoveries put Australian radio astronomy on the world map.

Pawsey's group was also the first to describe the concept of aperture synthesis, a technique for combining signals from many receivers in a way that mimics the output of instruments with a much larger aperture. A number of radio telescopes have since been built on this principle, including the Molonglo Cross, built near Canberra by the University of Sydney in 1967. It still flourishes today under the name of SKAMP, and is now serving as a demonstrator of technology for the international Square Kilometre Array telescope (see page 32).

The Dish

During the 1950s, CSIRO also began pursuing a different option for radio astronomy—a large single-dish telescope. The resulting 64-metre parabolic reflector, built near Parkes in New South Wales, was opened in 1961, and is still going strong. Repeatedly enhanced with new equipment, today 'the Dish' is 10,000 times more sensitive than when it was first built. The Parkes telescope is well known for its role in receiving TV signals from the 1969 Moon landing, but its scientific record is even more notable: it is the second most highly cited radio telescope in the world (in terms of citations per paper).

By the 1970s, other new telescopes had sprung up around the world. Australia had fallen behind, and remained so until the advent in 1988 of the CSIRO Australia Telescope Compact Array near Narrabri in northwestern New South Wales, built as a project for the Bicentennial celebrations of the European settlement of Australia. An imaging radio telescope based on aperture synthesis concepts, it is an array of six 22-metre dishes on rails, spread over six kilometres. The vast majority of the technology was designed and manufactured in Australia. This served to stimulate an antenna export industry that recouped much more than the original $50 million the government put into constructing the telescope.

Hosting the next generation

The next goal is the Square Kilometre Array (SKA)—an international project involving about 20 countries to build a telescope consisting of several thousand small antennas over a baseline of 5,000 kilometres. It will be 10,000 times more powerful than any existing instrument. A team from Australia and New Zealand is competing with a group of Southern African countries to host the telescope. The core site of the Australia–New Zealand bid is at the Murchison Radio-astronomy Observatory (MRO), 315 kilometres northeast of Geraldton in Western Australia.

The Australian Government has already committed nearly $230 million on preparatory projects for the SKA bid. These include CSIRO's Australian SKA Pathfinder (ASKAP) radio telescope (see page 33), being built now at the MRO, which will test some of the technologies for the SKA. It will be fully operational by 2013. Also at MRO, part of the Murchison Widefield Array (see page 35), a powerful telescope for studying low-frequency radio sources and composed of flat tiles, is already operational. The first stage of the iVEC Pawsey Centre, which will process the data produced by the new telescopes, opened in Perth in 2010 (see page 34).

The legacy of Australian radio astronomy has been vast, with many indirect benefits. For instance, CSIRO's invention of technology that made possible fast, practical, wireless local-area-networking—now known as Wi-Fi—was built on two strands of radio astronomy research: looking for radio signals from black holes, and techniques developed for cleaning up signals from space that had been distorted by the Earth's atmosphere. Wi-Fi technology is now used in homes and offices around the world.

For more information:
CSIRO Astronomy and Space Science
Professor Ron Ekers, Tel: +61 (2) 9372 4600, Ron.Ekers@csiro.au

Recording the impact of a super-massive black hole

At the centre of a nearby galaxy lurks an object of huge interest, a super-massive black hole. CSIRO scientists have used their radio telescopes to take a picture of the galaxy surrounding it, a task some thought could not be done, because of the sheer size and radio brightness of the scene. The image of Centaurus A took about 1,200 hours of observations and a further 10,000 hours of computer processing to put together, but the work is already beginning to bear fruit.

"We didn't generate this image just to make a pretty picture," says lead scientist Ilana Feain of CSIRO Astronomy and Space Science. "We want to understand in detail how the energy from super-massive black holes influences the formation and evolution of their host galaxies."

At a mere 12 million or so light-years away, Centaurus A is by far the closest galaxy to our own to contain an active super-massive black hole; it is about 50 million times the mass of the Sun. The galaxy was first recorded at Parramatta, Australia's first major observatory, and its long history and close proximity have made it a popular subject of study—so much so that it has become something of a model system for studying galaxies. In 2009 an international conference in Sydney was devoted solely to Centaurus A—during which the new image was unveiled.

“The image shows powerful radio emissions billowing out from just around the black hole. These radio jets extend millions of light years away from the black hole itself, beyond the visible galaxy into the comparatively empty intergalactic medium,” says Ilana.

The picture of Centaurus A was constructed from a mosaic of observations taken by CSIRO’s Australia Telescope Compact Array and the Parkes radio telescope.

“This image shows how the jets interact with the interstellar and intergalactic medium. When we combine this information with observations from other telescopes that operate across the electromagnetic spectrum from the infrared through the optical to high energy gamma rays, we can start to piece together the physics of the history of these galaxies.”

For more information:
CSIRO Astronomy and Space Science
Dr Ilana Feain, Tel: +61 (2) 9372 4268,
ilana.feain@csiro.au, atnf.csiro.au

Mega star nursery gives birth to new knowledge

Enormous collapsing clouds of cosmic gas and dust may yield clues on how massive stars form, which is an enduring mystery of astronomy.

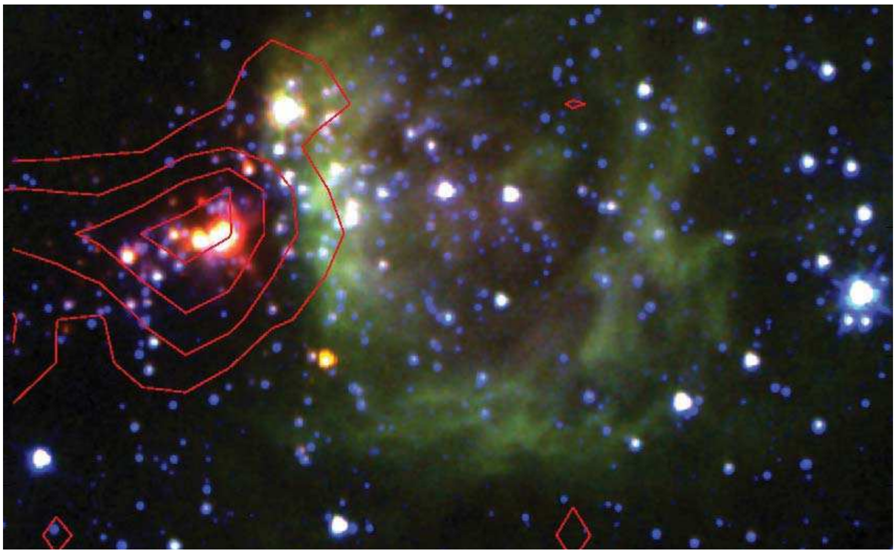
One such cloud, called BYF73, has been studied by a research team using CSIRO’s Mopra radio telescope. Peter Barnes, an Australian researcher working at the University of Florida in the US, leads the team. The massive hydrogen cloud is collapsing in on itself and will probably form a huge cluster of young stars.

Observations of clouds like BYF73 allow astronomers to test theories of massive star formation in great detail. Astronomers already have a good grasp of how stars such as our Sun develop from clouds of gas and dust. But for heavier stars—more than ten times the mass of the Sun—they are largely in the dark, despite years of work.

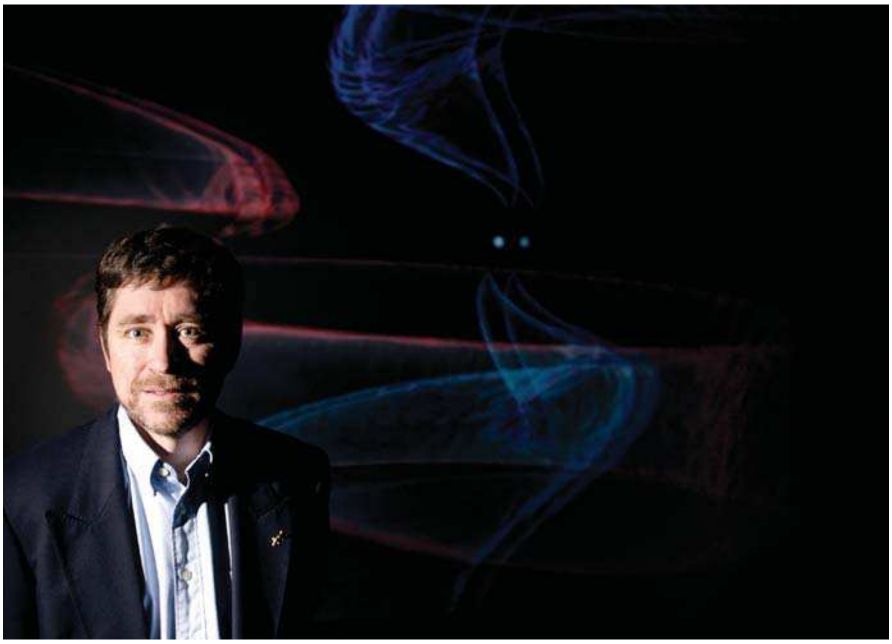
“Massive stars are rare and they will only form when large clouds of gas collapse,” Peter explains. “Most are well over 1,000 light years away, making them hard to observe.”

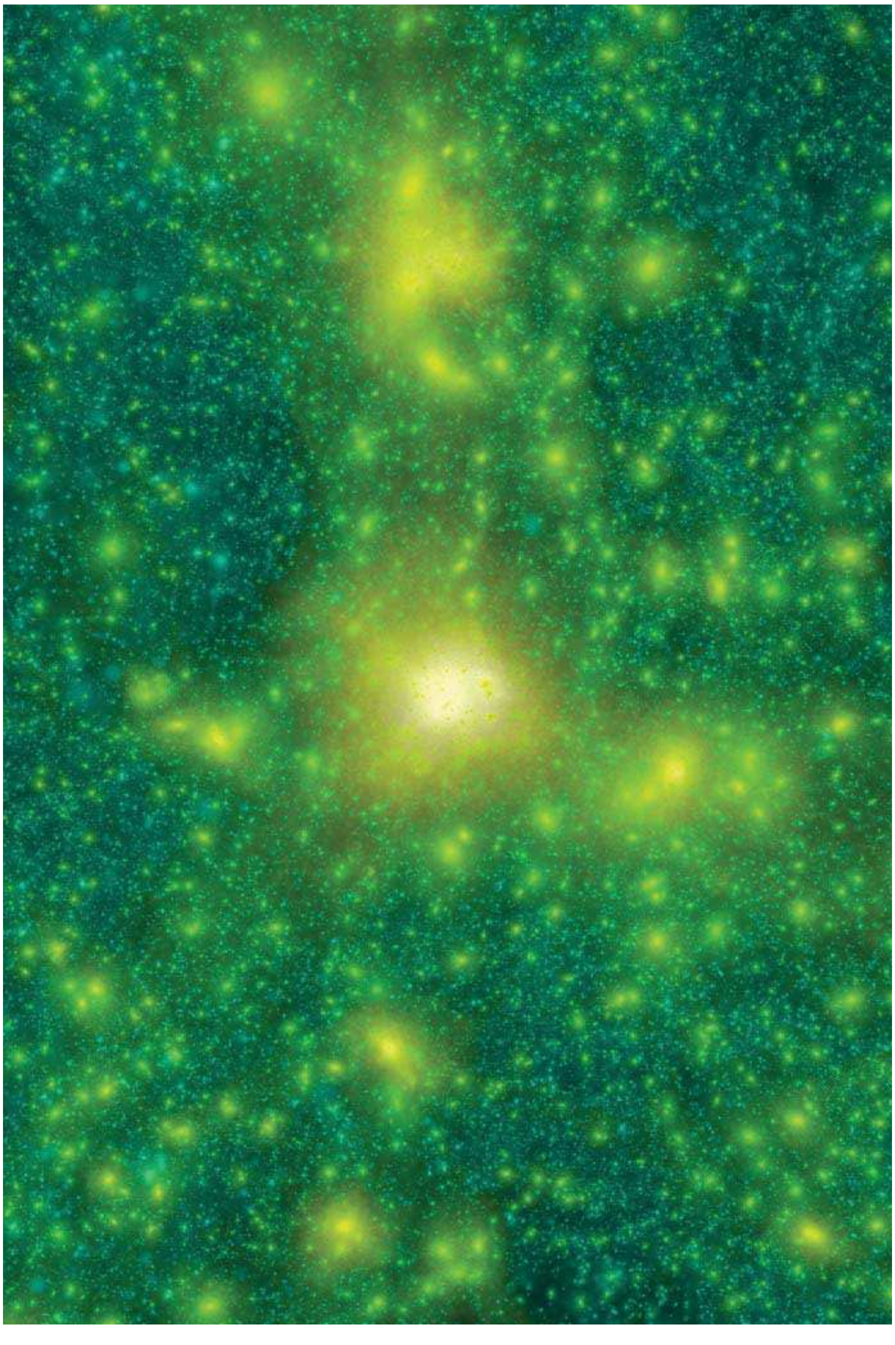
Follow-up observations made with the Anglo-Australian Telescope showed signs of massive young stars that have already formed at the centre of the BYF73 gas clump.

For more information:
Astronomy Department,
University of Florida, USA
Dr Peter Barnes, Tel: +1 352 392 2052 x283,
peterb@astro.ufl.edu, www.astro.ufl.edu/~peterb



PHOTOS: (PREVIOUS PAGE) PARKES TELESCOPE IN 1965. CREDIT: CSIRO. (THIS PAGE, TOP) THE MASSIVE DENSE CLOUD OF HYDROGEN (SHOWN BY THE RED CONTOURS), CALLED BYF73, APPEARS TO BE COLLAPSING IN ON ITSELF DUE TO GRAVITY, FORMING HUGE PROTOSTARS (SEEN AS RED). CREDIT: NASA/IPAC/SPITZER SPACE TELESCOPE, AAO AND CASS. (ABOVE) PARTICLES EMITTING RADIO WAVES STREAM MILLIONS OF LIGHT-YEARS INTO SPACE FROM THE HEART OF THE GALAXY CENTAURUS A. CREDIT: ILANA FEAIN, TIM CORNWELL & RON EKERS (CSIRO). ATCA NORTHERN MIDDLE LOBE POINTING COURTESY R. MORGANTI (ASTRON), PARKES DATA COURTESY N. JUNKES (MPIFR).





Supercomputers bring theory to life

Over aeons of time cosmic gas comes together, stars begin to form, supernovae explode, galaxies collide. And computational astronomers can watch it all unfold inside a supercomputer. That's the kind of work post-doctoral fellows Rob Crain and Greg Poole are doing at the Swinburne Centre for Astrophysics and Supercomputing.

In late 2010, one of Crain's simulations of galaxy formation appeared on the cover of the prestigious weekly British science journal, *Nature*. And Poole's simulations of the evolution of the structure of the Universe have earned him a place in an international research team undertaking the largest project in the history of the Hubble Space Telescope—the CANDELS survey to investigate galaxy evolution across 12 billion years of cosmic time.

"The supercomputer is the astronomer's laboratory," says Darren Croton, also from Swinburne and chair of the Australian National Institute for Theoretical Astrophysics. "We use them to apply our knowledge of the Universe and build models of how we think the details work. Then we can test our models with observations.

"Supercomputing technology has really marched forward recently. And that means that theoretical astrophysics has taken off. Simulations can be used to predict where to point our billion-dollar telescopes for maximum scientific return, so we don't waste observing time. Theorists have become valuable members of large observing teams, and help guide them and interpret their results."

Australia's forté in the field, says Croton, is tracking cosmic gas. The big new Australian telescopes like SkyMapper and the Australian SKA Pathfinder (ASKAP, see page 33) will give us an unprecedented view of how stars and gas in galaxies behave, he says. "Stars form where the gas is, so it's hard to fully understand the process of star formation at a galactic level until you understand the gas processes. I think this is a real niche area which plays to the strengths of Square Kilometre Array (see page 33) and ASKAP."

For more information:
Swinburne Centre for Astrophysics and Supercomputing
Dr Darren Croton, Tel: +61 (3) 9214 5537, dcroton@swin.edu.au, astronomy.swin.edu.au/~dcroton/

PHOTOS: (TOP) MATTHEW BAILES IN THE SWINBURNE VIRTUAL REALITY THEATRE IN FRONT OF AN IMAGE OF THE DOUBLE PULSAR DISCOVERED WITH CSIRO'S PARKES RADIO TELESCOPE. CREDIT: SWINBURNE UNIVERSITY OF TECHNOLOGY. (LEFT) A DEPICTION OF THE DISTRIBUTION OF MATTER IN AN OBJECT NEARLY TEN MILLION LIGHT YEARS ACROSS AND A THOUSAND TIMES THE MASS OF THE MILKY WAY. THOUSANDS OF THESE EXIST IN THE OBSERVABLE UNIVERSE. CREDIT: GREG POOLE, SWINBURNE UNIVERSITY OF TECHNOLOGY.

PlayStation graphics chips drive astronomy supercomputer

The technology used in your PC or PlayStation is also helping drive a revolution in radio astronomy—the replacement of custom-built hardware with flexible software and data solutions.

"Hardware solutions for radio astronomy have been evolving, but computer power has been evolving much faster," says Matthew Bailes, from the Swinburne Centre for Astrophysics and Supercomputing. The Centre has developed software systems that are now used in Australia and overseas.

The rapid advance of computer processing power and network speeds have been a boon for the High Time Resolution Universe Survey, headed by Matthew, which uses CSIRO's Parkes telescope to scan the sky for fast-occurring, short duration radio signals.

"Ten years ago, it was impossible to get anything more than a few megabytes per second of data reliably into a computer for processing—now we get gigabytes per second," says Matthew. "We've taken 250 terabytes in the last year alone, compared to only ten terabytes over seven years for the previous survey."

Swinburne's latest frontier is supercomputers that use graphics processors developed for PCs and games consoles. These graphics chips can handle far more data than normal processors for a fraction of the price of custom-built hardware. And they'll be needed, since "in terms of information capture, the amount of astronomy done in the next three years will equal all the astronomy done in the previous history of mankind," Matthew explains.

For more information:
Swinburne Centre for Astrophysics and Supercomputing, Melbourne
Professor Matthew Bailes, Tel: +61 (3) 9214 8782, mbailes@swin.edu.au, astronomy.swin.edu.au

Putting Einstein to the ultimate test

Einstein's general theory of relativity predicts them, and they could be scattered throughout the Universe. But so far, gravitational waves—'ripples' in the fabric of space and time—have never been detected. Several Australian teams of astronomers are trying to catch the first signs of one.

Using CSIRO's Parkes radio telescope, some of these astronomers are hunting gravitational waves by studying signals coming from pulsars—the collapsed cores of exploded stars. Spinning at up to hundreds of times per second, pulsars emit highly regular radio pulses that appear to flash on and off like a lighthouse. And that's the key to detection.

"If a gravitational wave sweeps through Earth, the pulsar signals detected at our telescope will arrive later or earlier than we would expect them," says George Hobbs of the CSIRO's Astronomy and Space Science, and a member of the Parkes Pulsar Timing Array project. Gravitational waves could come from pairs of black holes circling each other. Others could be lingering from a time shortly after the Big Bang.

"Parkes' ability to see the southern sky is ideal for this project and may lead to the first detection of gravitational waves," says George. "And when the Square Kilometre Array is built, it will be the perfect telescope for studying the waves in detail."

The hunt for invisible ripples

Meanwhile, at the Australian International Gravitational Research Centre at Gingin in Western Australia, 65 kilometres north of Perth, David Blair from the University of Western Australia and his team have been exploring techniques of using lasers to detect gravitational waves directly .

Gingin is also the favoured site for one of the most sensitive machines searching for gravitational waves, a Laser Interferometer Gravitational-Wave Observatory (LIGO) detector. Two of these detectors have already been established in the US. Late in 2010, the US National Science Foundation (NSF) offered to provide Australia with its own $140-million LIGO machine—as long as Australia can find a further $140 million to build a facility to house it.

Locating a LIGO detector in the Southern Hemisphere would allow the origin of any gravitational waves to be pinpointed much more accurately. Other types of telescopes could then be trained on the spot, enabling different sorts of observations to be made efficiently.

It would also bring huge advantages to Australia, says Jesper Munch of the University of Adelaide, chair of a consortium of five universities set up to advance the proposal. "LIGO-Australia would put this country at the forefront of the relevant technology."

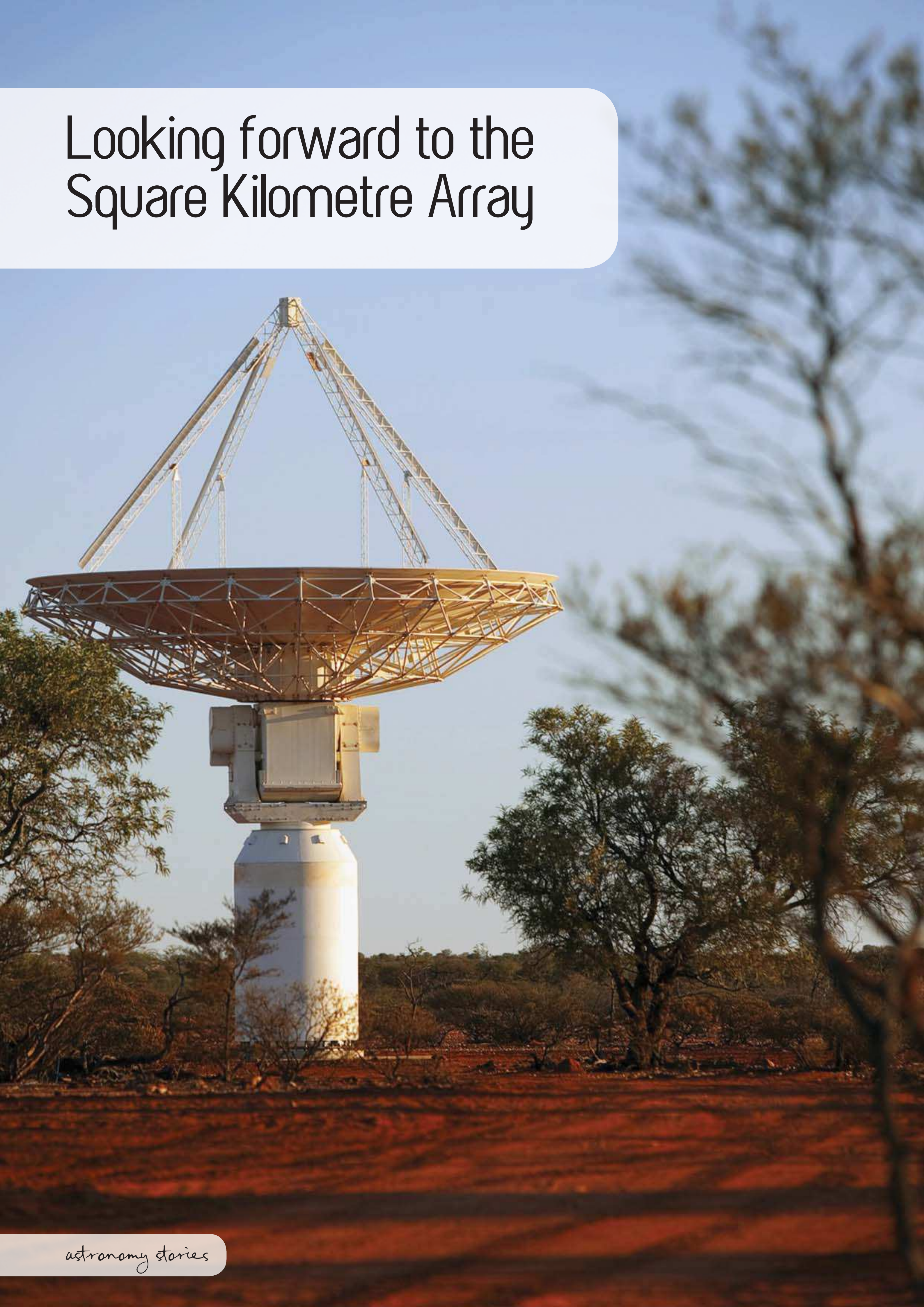
In fact, Australian technology is already contributing to the LIGO project. The US LIGO detectors are being upgraded to be ten times more sensitive, and the Australian Consortium for Interferometric Gravitational Wave Astronomy is part of that effort. Researchers at the Australian National University (ANU) in Canberra, and at Adelaide University, are in the middle of a four-year project to produce optical components that will stabilise the LIGO laser system.

"Einstein predicted them, but thought we'd never be able to detect them," says David McClelland, Director of the ANU's Centre for Gravitational Physics. "Now, we're on the cusp of the first direct observation of gravitational waves."

For more information:
CSIRO Astronomy and Space Science
Dr George Hobbs, Tel: +61 (2) 9372 4652, George.Hobbs@csiro.au, www.atnf.csiro.au/people/George.Hobbs

For more information:
ANU Centre for Gravitational Physics, Canberra
Professor David McClelland,
Tel: +61 (2) 6125 9888,
David.McClelland@anu.edu.au,
anu.edu.au/physics/cgp/index.html

Looking forward to the Square Kilometre Array



Big science tackling the big questions

The race is on to win the right for Australia to host the biggest telescope project that the world has ever seen. Known as the Square Kilometre Array (SKA), it will consist of thousands of separate radio dishes and other antennas spread across an area the size of a continent.

Merging the signals received by each of the antennas will effectively produce one giant antenna hundreds or thousands of kilometres wide—providing the sharpest-ever pictures of the sky, along with incredible sensitivity to faint signals.

A combined Australia-New Zealand effort—'Team anzSKA'—is competing with a southern African-based group of countries for the right to host the facility. Team anzSKA comprises the Australian Government, the New Zealand Government, CSIRO and the Government of Western Australia.

If successful, the core of the facility will be at the Murchison Radio-astronomy Observatory (MRO) site in remote Western Australia, about 300 kilometres northeast of Geraldton; but hundreds of the antennas will be scattered across Australia and New Zealand.

Australian scientists are confident that the anzSKA bid will have what it takes to win the hosting rights. "Our candidate core SKA site in outback Western Australia offers the outstanding radio quietness needed to maximise the scientific potential of the SKA," explains Brian Boyle, SKA Project Director for Australia and New Zealand. "To capture the faint radio signals of the cosmos, a radio telescope as sensitive as the SKA needs almost perfect radio quietness," Brian notes. "Radio noise, the bane of radio astronomers, is typically generated by human activity and the use of roads, railways, farm equipment, home electrical devices, radios and mobile phones. The MRO is the ideal environment for the SKA—naturally radio quiet and located in a region where population density and activity is extremely low."

With up to 50 times the sensitivity and 10,000 times the survey speed of current radio telescopes, the $2.5-billion SKA will be the world's landmark astronomical facility for the first half of the 21st century, driving innovations in antenna technology, signal transmission and processing, and super-computing.

The facility will enable researchers to tackle numerous outstanding problems in astrophysics, with particular emphasis on five key projects:

– studying the extreme environments of pulsars and black holes to put Einstein's theory of gravity, general relativity, to its most exacting test yet
– understanding how the three major components of the Universe—matter, dark matter and dark energy—have evolved
– investigating the end of the cosmic 'Dark Ages,' when the first black holes and stars appeared
– probing for places and conditions where life might have arisen elsewhere in the Universe, and
– examining the origin and evolution of one of the Universe's most enigmatic features—cosmic magnetism.

"The SKA will help unlock some of the biggest mysteries of the Universe—but more intriguingly, it is likely to make future discoveries that we can't even begin to imagine," says Brian, summing up the scientific potential of the SKA.

The SKA will be an international facility, funded by all the member countries. A final decision on the winning proposal will be made in 2012. Construction will begin in the second half of this decade, with completion expected by the mid-2020s.

However, astronomers won't have to wait that long to start using powerful new radio telescopes. As part of the 'run off' to host the SKA, the two competitors are each building demonstrator facilities. In southern Africa it is MeerKat. In Australia, two key demonstrators are being built: CSIRO's Australian Square Kilometre Array Pathfinder (ASKAP); and the Murchison Widefield Array (MWA), which is run by a consortium of universities and managed by Curtin University in Perth. Both will be located at the MRO.

For more information:
CSIRO Astronomy and Space Science
Tony Crawshaw, Tel: +61 (2) 9372 4528,
Tony.Crawshaw@csiro.au, www.ska.gov.au

Australia's SKA demonstrator already booked out

It's not due to begin operating until 2013, but astronomers from around the world are already lining up to use CSIRO's Australian Square Kilometre Array Pathfinder (ASKAP). In fact, the first five years of ASKAP's operation are already booked out, with ten major international Survey Science projects looking for pulsars, measuring cosmic magnetic fields, studying millions of galaxies, and more.

ASKAP might be a demonstrator project for the much larger SKA, but it will also be a cutting-edge telescope in its own right. The 36-dish ASKAP features a new 'focal plane array' technology that gives it a huge 30° field of view. "So instead of concentrating on one small patch, we can cover the whole sky in a fairly short space of time," says Simon Johnston, ASKAP project scientist.

A large dynamic range—the difference between the strongest and weakest signals picked up—is another advantage. "We're aiming to get a dynamic range 10 to 100 times better than CSIRO's current flagship telescope, the Compact Array," says Simon.

"It's important to stress the international nature of the science that will be done on ASKAP," says Phil Diamond, Director of CSIRO Astronomy and Space Science. "That's a big thing for us, because the SKA is an international project. We want to ensure that ASKAP is international in scope, not just Australian only."

Mapping magnetism reveals cosmic history

One international team waiting to use ASKAP is planning the largest-ever survey of magnetic fields in the Universe—revealing new details of cosmic history.

"Magnetic fields are important because they basically tell gas in the Universe how to move," says Bryan Gaensler, an astrophysicist at The University of Sydney. "And because gas is the ingredient that makes galaxies, stars and planets, it's vital we know magnetism's influence if we're to understand how the Universe has evolved."

Magnetic fields in distant space can't be measured directly. Astronomers have to rely on the effect magnetism has on the polarisation of electromagnetic waves (such as radio waves and light waves) reaching their telescopes.

Bryan heads the team that will use CSIRO's ASKAP to conduct the survey, which is called POSSUM—the POlarisation Sky Survey of the Universe's Magnetism. ASKAP will be the ideal facility when it comes online in 2013.

"Previous studies covered either a big part of the sky but not to a great depth in space, or probed to a great depth but only over a small area. POSSUM will go both wide and deep," says Bryan. "We'll improve on the current best survey by a factor of 100."

Studying the effects of cosmic magnetism, however, is only one part of the challenge. Astronomers still don't have a full understanding of where all the magnetism came from in the first place. Bryan hopes POSSUM will help to answer that question too.

For more information:
CSIRO Astronomy and Space Science
Dr Simon Johnston, Tel: +61 (2) 9372 4573,
Simon.Johnston@csiro.au,
atnf.csiro.au/projects/askap/index.html

For more information:
Sydney Institute for Astronomy,
University of Sydney
Professor Bryan Gaensler, Tel: +61 (2) 9351 6053,
bryan.gaensler@sydney.edu.au,
askap.org/possum

PHOTOS: (PREVIOUS PAGE) CSIRO'S NEW ASKAP ANTENNAS AT THE MURCHISON RADIO-ASTRONOMY OBSERVATORY (MRO) IN WESTERN AUSTRALIA, 2010. CREDIT: WA DEPARTMENT OF COMMERCE. (THIS PAGE, ABOVE) BRYAN GAENSLER IS SURVEYING THE UNIVERSE'S MAGNETIC FIELDS. CREDIT: THE UNIVERSITY OF SYDNEY.

Tracing cosmic rays from radio pulses

The energy of ultra-high energy (UHE) cosmic rays that strike the Earth's atmosphere make the energy produced from particle collisions by the Large Hadron Collider look puny. A team based in South Australia is now developing the techniques and technology to find out where such energetic particles could possibly originate. They ultimately hope to use the proposed SKA telescope to conduct their search.

"We think some cosmic rays are produced in the remnants of supernovae—exploding stars—but where the most energetic ones come from, that's a mystery," says Justin Bray, a PhD student hunting for their source as part of the LUNASKA (Lunar Ultra-high-energy Neutrino Astrophysics using SKA) project led by Ray Protheroe at the University of Adelaide and Ron Ekers at CSIRO.

The trouble is that cosmic rays are charged, so their trajectories are bent by magnetic fields, making it impossible to track their specific origin. However, theory predicts that whatever is producing the rays should also produce UHE neutrinos. "Neutrinos are uncharged and travel in straight lines, so if we are able to detect them then we might be able to detect the sources of cosmic rays," says Ray.

Although UHE neutrinos can't be detected directly, they should be detectable indirectly. As they strike the Moon, theory predicts that they should produce a particle cascade and a tell-tale radio pulse, as long as astronomers keep looking for long enough. The more sensitive the telescope, the more of these pulses should be detectable, and so the shorter the wait to catch one.

A CSIRO-led team is currently developing the necessary signal processing hardware using the dish at Parkes, Australia's biggest current radio telescope. In addition, the team is developing technology needed to detect the pulses with the proposed SKA, the opening of which will mark the start of another phase of the UHE neutrino hunt. "If we don't spot a neutrino with the dish at Parkes, we'll have the technique worked out so that we can use the SKA when it's ready," says Justin.

Managing a data mountain

The world's largest telescope, the Square Kilometre Array (SKA), is expected to generate more data in a single day than the world does in a year at present. And even its prototype, CSIRO's ASKAP, is expected to accumulate more information within six hours of being switched on than all previous radio telescopes combined.

Such gargantuan streams of data require serious management, and that will be one of the jobs of the $80 million iVEC Pawsey Centre in Perth, which is due to be completed in 2013.

"There are two issues here," says Andrew Rohl, Executive Director of iVEC, a joint venture between the CSIRO and the four public West Australian universities, which will manage and operate the facility. "The raw data is being generated by telescopes out in the desert, and we have to get it to a computer to reduce that data and to generate useful products out of it. So the first problem is to get it to Perth, and the second is to process that amazing quantity of information."

Solving that first problem means mastering high-speed data transfer. "The only way to transmit quickly the huge amount of data that would be generated by the SKA telescope is by high speed networks," says Chris Phillips, who works on the problem at CSIRO Astronomy and Space Science. "We're talking terabits per second." Transferring one terabit a second is the equivalent to transferring 50 full DVDs every second. "Over the last few years we have had to develop custom software to efficiently utilise high-speed networks because standard software just couldn't cope."

Black holes in real time

In a test of their technology, two Australian radio telescopes worked with others in China and Japan to observe a distant black hole. Connecting the telescopes electronically using high-speed data transfer allowed astronomers to collaborate in real-time, rather than waiting months for the data to be stored on disks and then shipped around the world. "That demonstration showed the world that Australia can be the data processing centre for these international experiments," Chris says. In the next two years they plan to increase data transfer rates tenfold.

Once the data has been collected, it has to be processed. Powering the high-performance computers needed to process that data avalanche will take a lot of energy. The Pawsey Centre will need the power supply of a large shopping centre. "A lot of that energy will be turned into heat," says Andrew.

However, at least part of the energy needed to keep the computers cool will come from a renewable source—geothermal energy. In June 2010, the Government announced a $47.3 million green energy investment in the SKA project, to build a geothermal cooling plant for the Pawsey Centre and to build a solar array at MRO to power the observatory itself.

The Centre, which will be equipped with one of the 20 most powerful supercomputers in the world, will cut its teeth on data processing for ASKAP and MWA telescopes.

For more information:
iVEC
Professor Andrew Rohl, Tel: +61 (8) 6436 8831, ed@ivec.org, ivec.org

For more information:
CSIRO Astronomy and Space Science,
Dr Chris Phillips, Tel: +61 (2) 9372 4608, Chris.Phillips@csiro.au

For more information:
School of Chemistry and Physics, University of Adelaide
Associate Professor Ray Protheroe, Tel: +61 (8) 8303 4748, raymond.protheroe@adelaide.edu.au, physics.adelaide.edu.au/astrophysics/lunaska/index.html

For more information:
CSIRO Astronomy and Space Science,
Professor Ron Ekers, Tel: +61 (2) 9372 4600, Ron.Ekers@csiro.au

Telescope of tiles

Far outback in Western Australia, 32 tiles—flat, stationary sensors—each carrying 16 dipole antennas have begun collecting scientific data.

These first tiles will ultimately form part of a much bigger array of 512 tiles, the Murchison Widefield Array (MWA)—Australia's second Square Kilometre Array (SKA) demonstrator project. Like CSIRO's Australian SKA Pathfinder (ASKAP), the MWA is being built at the remote, radio-quiet Murchison Radio-astronomy Observatory (MRO).

The MWA is designed to study celestial radio sources at low frequencies, a poorly known part of the radio spectrum between 80 and 300 megahertz. The array is 'steered' electronically, which means the direction the telescope points depends entirely on how the signals from its stationary antennas are combined and processed.

The facility is a collaboration between several universities and research institutions in the US, Australia and India. The site for the full telescope was prepared in 2010, and the final array will begin operating within a couple of years, says MWA Board Vice Chair, Steven Tingay of Curtin University, the International Managing Organisation for the $30 million facility.

As the working tiles are being tested for the final array, the MWA itself is testing technologies to be used when the world's largest telescope, the SKA, is built. But the MWA will be a powerful instrument in its own right, and already has been earmarked for three significant research projects. One will take measurements of the Sun and material in the plasma surrounding it; another will survey low-frequency radio emissions across the sky, particularly those that are transient. And the third will detect and analyse hydrogen from the 'Epoch of Re-ionisation' in the early Universe when the gas changed from being almost neutral to extensively charged or ionised.

When did the first stars begin to shine?

After the Big Bang, the Universe was a cold, dark place—until the first galaxies and stars formed and shone their light into the gas that pervaded space, resulting in the re-ionisation of cosmic hydrogen.

The state of the Universe during re-ionisation has been simulated using computer models by Stuart Wyithe, a physicist at the University of Melbourne. Stuart is probing to determine exactly when and how re-ionisation occurred, what kind of stars were responsible and whether black holes were involved.

"We have an idea of what the Universe was made of, and we have a theory of gravitation and how structure formed," says Stuart. "The goal is to use that framework to try and understand how the first galaxies interacted with the intergalactic medium around them."

That's where the MWA comes in. "Current Hubble [Space Telescope] pictures of the early Universe do not reveal enough star formation to have re-ionised the Universe, so there must have been something else contributing to it," adds Stuart. "They could be less luminous galaxies, or they could be something else."

Stuart and his colleagues now plan to use the MWA to peer back toward the Universe's 'Dark Ages', to see if their computer simulations are right.

Stuart received one of the Prime Minister's Prizes for Science in October 2011—the Malcolm McIntosh Prize for Physical Scientist of the Year.

For more information:
International Centre for Radio Astronomy Research, Perth
Professor Steven Tingay, Tel: +61 (8) 9266 3516, steven.tingay@icrar.org, mwatelescope.org

For more information:
School of Physics, University of Melbourne
Professor Stuart Wyithe, Tel: +61 (3) 8344 5083, swyithe@unimelb.edu.au, physics.unimelb.edu.au

PHOTOS (PREVIOUS PAGE): THE MURCHISON WIDEFIELD ARRAY IS A TELESCOPE WITH NO MOVING PARTS. CREDIT: DAVID HERNE, ICRAR. (THIS PAGE) A HUBBLE SPACE TELESCOPE IMAGE OF SOME OF THE EARLIEST GALAXIES THAT MAY HAVE BEEN RESPONSIBLE FOR 'LIGHTING UP' THE COSMOS. CREDIT: NASA, ESA, R. WINDHORST (ARIZONA STATE UNIVERSITY) AND H. YAN (SPITZER SCIENCE CENTER, CALTECH).

Index of organisations, instruments and facilities

USTRALIAN ASTRONOMY 2012...STORIES OF AUSTRALIAN ASTRONOMY 2012...STORIES OF AUSTRALIAN ASTRONOMY 2012...STORIES OF AUSTRALIAN SCIENCE 2012...

Published by

Science in Public Pty Ltd
82 Hudsons Road
(PO Box 2076)
Spotswood Victoria 3015 Australia

niall@scienceinpublic.com.au

Find us online at
www.scienceinpublic.com.au/stories
and register for regular updates on
Australian science.

Science in Public @scienceinpublic