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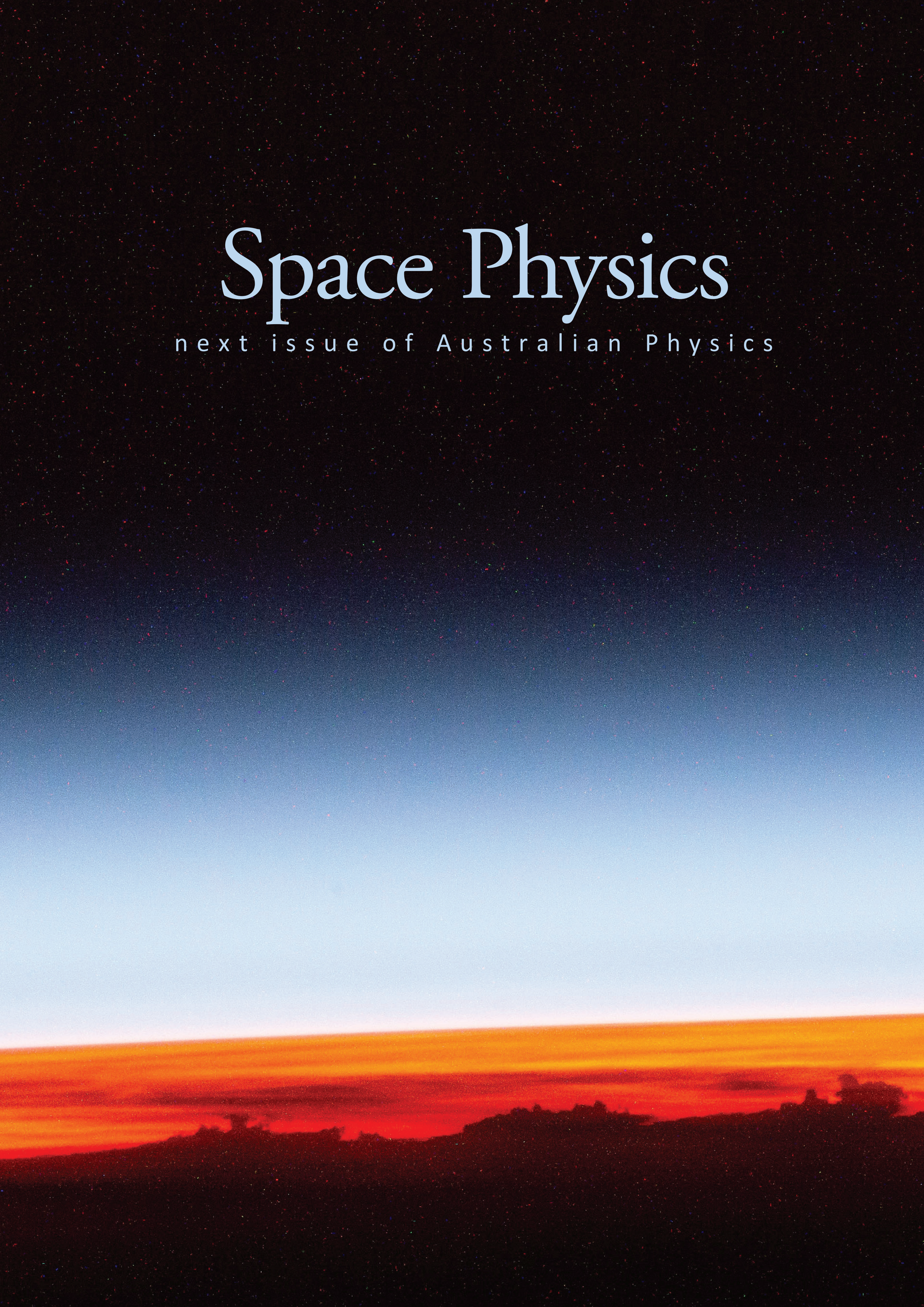
Space Physics
next issue of Australian Physics

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Two Goannas/Bula Gugaa, Sean James Cassidy. The goanna is the totem of the Wiradjuri Nation and the two goannas, joined at the hip depict an elder mentoring a student. The shape they create is a figure 8 which alludes to the 8 Aboriginal Ways of Learning. The design forms part of an installation that sits in the Rotary Peace Park in Parkes NSW and was an indigenous and non-indigenous collaboration.

image opposite: "First Rays of an Orbital Sunrise", NASA, Jan 2022

Australian Institute of Physics

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

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Editorial

Learning and Discovery

Welcome to the first issue of Australian Physics for 2022.

Teaching is central to our mission as physicists. There are many modes and approaches to this, and some can connect to cultural contexts very intimately. In this issue, we have an article from the Ub Ubbo Exchange, exploring the space between art, science, indigenous culture and connection to the land. It highlights how learning can happen in different ways. The connection to Physics is perhaps more subtle here - it may lie in the 'negative space' about what we don't teach.

We also have writing examining existing ways in which we educate ourselves, casting a spotlight on recommendations from the International Conference on Women in Physics. This connects to a broader awareness we collectively raised on the recent International Day of Girls and Women in Science. Events like these are important catalysts for much-needed change, and they celebrate how equitably including women in science and physics will create better workplaces, culture, and outcomes for everyone.

And there is more to celebrate. For example, Keith Bannister won the 2021 Prime Minister's Prize for Physical Scientist of the Year for his work on fast radio bursts. This issue includes a summary of both the person and their achievements.

Each issue, we include at least one article which could be described as more technical. Benjamin Pope's article on the James Webb telescope provides both a technical description of this amazing instrument and celebrates the discoveries which it will allow future generations to make.

Next issue, we will be looking into space in more detail, although not among the stars but much closer to home (not more revealed here).

In the interim, we hope by then state of conflict in eastern Europe will have long returned to peace again. Our thoughts are with our colleagues and friends drawn into a terrible conflict.

Best wishes,
David Hoxley and Peter Kappen.

From the Executive

Welcome to the first edition of Australian Physics in 2022. After a challenging two years, I hope this year will allow us to transition to a new normal. With pandemic pressures starting to ease, universities are going back to face-to-face teaching and it is good to see students back on campus. This includes international students, who will hopefully be back in growing numbers over the year.

One of the objectives for the AIP in 2022 is closer engagement with industry. We started this process last year and formed an AIP Advisory Panel with industry representatives to understand the needs of the sector and explore opportunities to engage more effectively with government through industry. The national executive wants to connect more closely with companies and physicists outside academia, to get a better understanding of what the AIP can offer them. This also enables us to ensure that our accreditation program meets industry needs. The latter is key to articulating the importance of a physics degree in an environment where universities seek to combine programs and reduce more costly educational components such as laboratory work. The members of the inaugural panel are:

- Peter Brooke (Platypus Investments)
- Jennifer Fishburn (ResMed)
- Bill Petreski (Strategy61)
- Amanda MacKinnell (NIOA)
- Cibby Pulikkaseril (Baraja)
- Stuart Midgley (DUG)
- Roger Leigh (Cochlear)

Making inroads into research translation will also be important for the AIP in 2022. Last year, the government developed commercialisation pathways for research in Australia. The AIP welcomes the focus on the value of research and supports the government in the view that more needs to be done in research translation. This is a great opportunity for Australia, and it is fantastic to see new government investments into this area. At the same time, we must ensure that we maintain a healthy and balanced landscape across fundamental research, applied research, and commercialisation. Without this, innovation is impossible.

One other area of activity from last year that will come into action in 2022 is the new constitution that was tabled at this year's AGM, together with a proposal for new awards. Honouring outstanding research, teaching, service, and engagement of physics at all career stages is one of the corner stones of a professional society. Last year, a working group reviewed all national AIP awards to ensure that the guidelines are clear, transparent, and equitable. They will be on the new web page shortly. Out of the process, we will also have two new awards to recognise excellence in physics: Women in Leadership and Communications. These were supported by the Executive and were adopted by the Council. The new AIP constitution will also allow the AIP to apply for Deductible Gift Recipient status, which is important in the context of approaching potential sponsors for our awards. It is exciting that external bodies want to partner with the AIP to promote excellence and our values in the community.

Our conferences are always highlights in the AIP's yearly calendar. It was fantastic to have an AIP Summer Meeting at the Queensland University of Technology last December. Jennifer MacLeod and her team organised a hybrid event with record participation, 455 registrations. I was extremely impressed how nimble the team was in context of the challenge of border closures and how well the hybrid event was delivered on short notice. The AIP Congress in Adelaide will be held in December this year and I look forward to seeing the whole community in person again. It is shaping up to be an excellent event with stellar speakers such as Nobel Prize laureate Donna Strickland. The next AIP Summer meeting is also already locked in and will be held in Canberra in the first week (4th-8th) of December 2023.

All the best for a prosperous and successful 2022!

Sven Rogge, AIP President

CSIRO Astronomer named Physical Scientist of the Year

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Dr Keith Bannister from CSIRO Space and Astronomy has been awarded the Prime Minister's 2021 Malcolm McIntosh Prize for Physical Scientist of the Year for his research on fast radio bursts. Keith is a Principal Research Engineer at CSIRO Space and Astronomy, based in the Sydney suburb of Marsfield. He studied engineering and spent five years in aerospace engineering in England, before doing a PhD in astronomy as a mature age student.

Fast radio bursts (FRBs) are incredibly intense bursts of radio energy at cosmological distances, lasting just a few milliseconds. The first FRB was discovered in 2007 at CSIRO's Parkes Radio Telescope in central NSW. Since then, many of the worldwide FRB detections have been made with the Australian Square Kilometre Array Pathfinder (ASKAP) telescope on Wajarri country at the remote Murchison Radio-astronomy Observatory in Western Australia. As Bannister notes: "ASKAP is effective at finding FRBs because it is equipped with a piece of CSIRO-designed hardware called a phased-array feed. It gives ASKAP a very large field-of-view – at any given time ASKAP can 'see' a patch of sky around the size of the Southern Cross. This helps because you don't know where or when a burst is going to happen, so the more sky you can see, the better chance you have of finding one when it happens."

(photo credit: Aran Anderson Photography)

Until recently, very little was known about the nature of FRBs, largely because none of the world's radio telescopes were able to locate the precise position of a transient burst lasting just a few milliseconds. It was unknown whether FRBs came from nearby objects in the Milky Way or from distant extragalactic sources. The breakthrough was made in 2017 by the team led by Bannister as he explains: "There are two key components. The first was a detection system that processes averaged data from the telescope in real time and works out when (and roughly where) a burst has occurred. This system has to work out very quickly, within about half a second, if a burst has occurred. The second part is what we call 'live action replay' – when a burst happens, we can stop and download the last few seconds of raw data from the telescope. We can then 'replay' that data and work out the precise position."

After measuring the positions of a number of FRBs, Bannister and his team used powerful optical telescopes in Hawaii and Chile to identify the visual counterparts. They soon established that FRBs are emitted by distant galaxies, and they were also able to pinpoint the precise location within a particular galaxy.

While the hunt is on to discover as many bursts as possible, FRBs are proving to be a useful astronomical tool in their own right: "The use of FRBs as tools is probably what I find most exciting", Bannister comments. "FRBs can be used to probe the total amount of matter, but also the amount of turbulence and magnetic field strength along the line-of-sight to the FRB. We've used FRBs to determine the total amount of normal baryonic matter in extragalactic space and it agrees very well with expectations. FRBs can also provide a different way of measuring certain cosmological parameters. FRBs haven't made a huge impact in that field as yet, but I'm hoping with a large enough sample that FRBs can make a contribution."

Progress is still being made in understanding FRBs and

Bannister was the lead author of a paper (54 astronomers at 21 institutions) 'A single fast radio burst localised to a massive galaxy at cosmological distance', published in the prestigious journal *Science* in August 2019. The paper received the Newcomb Cleveland Award in 2020, judged by the American Association for the Advancement of Science (AAAS) to be the most significant *Science* paper of the year. The front cover featured five of the 36 ASKAP dishes in Western Australia. (courtesy: AAAS; photo credit: Alex Cherny)

the field continues to evolve. "It was a long running joke in the FRB community that for many years there were more theories than there were detections", Bannister recollects. "So much so that when someone presented a plot showing that the detection number had finally eclipsed the number of theories, there was a general sense of achievement. I also think people are cautiously adopting the idea that magnetars – neutron stars with incredibly strong magnetic fields – are a likely progenitor, for at least some FRBs. But the question is by no means settled, and it's possible there is more than one progenitor type."

Although ASKAP is an exceptionally powerful instrument in its own right, it is also a precursor telescope to the Square Kilometre Array (SKA), an international multi-billion dollar project to be built in southern Africa and Australia. Construction of the low-frequency SKA – known as SKA-Low – at the Murchison Radio-astronomy Observatory will begin this year (2022). "Observationally the SKA will be a quantum leap – finding and localising many FRBs per day", Bannister comments. "Where that leads us scientifically is anyone's guess. The hope is that we can use those large numbers to measure the population trends which should give us good handles on the likely progenitors. That large sample will also be used to place constraints on cosmological parameters. It'll definitely be exciting!"

It seems that Australia will be at the forefront of FRB research for many years to come.

The Prime Minister's Prize Physical Scientist of the Year is named in honour of Malcolm McIntosh, who was awarded a PhD in Physics from the Australian National University in 1971. He held a series of senior positions in the public service in Australia, and then in Britain, for which he was knighted. Sir Malcolm returned to Australia in 1996 where he was appointed Chief Executive of CSIRO. He died in 2000 while still in office.

Revealing exoplanet formation with the James Webb Space Telescope Aperture Masking Instrument

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The recently-launched James Webb Space Telescope is poised to revolutionise astrophysics. Its unprecedented sensitivity, infrared wavelength coverage, and resolution will enable near-infrared direct imaging of exoplanets and their birth environments. Crucial to this goal is an Australian-designed component, the Aperture Masking Instrument, which enhances both the resolution and precision of high angular resolution imaging. Using a century-old technique, an array of holes in a metal plate is all that is necessary to restructure the interference pattern of light to allow exquisite self-calibration of noise – and give us a glimpse of the dusty disks around stars and the nascent planets embedded in them.

In the night sky, Venus, Jupiter, and the other planets can be seen stretched on a thin line – the ecliptic – which is the same line traversed by the Sun in its annual course. This remarkable alignment led ancient astronomers to mark out the constellations on the ecliptic as the Zodiac. We now know that this is because the planets of our Solar System were born in a thin, dusty disk around the young Sun, and the planets' orbits today remain in this plane. Tenuous remnants of this disk persist today: some we see with telescopes as asteroids, millions of rocky bodies in the Solar System, ranging in size from metres to a thousand kilometres. Some fragments from asteroid collisions make it onto the Earth as meteorites, and their chemistry encodes the make-up of their parent bodies. And a strip of light visible on dark nights along the ecliptic, the 'zodiacal light', marks the smallest particles of dust, replenished by the weathering of comets and asteroids.

From the orbits and composition of the planets and asteroids, we can build up a pretty detailed picture of how our Solar System was formed. About four and a half billion years ago, the Sun was busy accreting matter. Because of the conservation of angular momentum, this matter couldn't fall directly onto the Sun, but spread out in a disk and accreted onto the star very slowly as it was able to redistribute angular momentum through viscosity. This gave a long ten million years for some truly interesting physics to happen: dust bunnies formed into grains, into pebbles, into boulders, and eventually into objects tens of kilometres in size called planetesimals. Literally 'planet fractions', some of these building blocks of planets remain as asteroids today, others were gravitationally ejected from the Solar System, and others slammed together to build the embryos of planets. The largest of these were formed early enough that there was plenty of gas left to suck up from the disk, and became Jupiter and the other gas giants; the later-born, smaller ones became the Earth and other rocky inner planets.

In broad brushstrokes, this is settled science; but in detail, the process by which small dust grains form large boulders is poorly understood; and the complex migrations of these young planets in a viscous, self-gravitating disk of material are difficult to simulate, let alone reconstruct at a remove of four and a half billion years of deep time. The situation is only complicated by the great diversity of planetary systems unlike our own revealed since the discovery of the first extrasolar planets (or 'exoplanets') in 1995 There are hot Jupiters, gas giants far closer to their star than Mercury is to the Sun [1]. There are resonant chains of planets in tightly packed systems [2] and planets that orbit perpendicular to or backwards relative to their star's rotation [3]. The most commonly found exoplanets are super-Earths or sub-Neptunes, more massive than the Earth, of uncertain composition, and with no local analogue in our Solar System [4].

Observing planetary systems around young stars at the very moment of formation is like looking back in time: we can image the strange patterns in protoplanetary disks, and remotely examine their chemistry with spectroscopy. We can probe a whole population of natural experiments, seeing how planet formation plays out around stars of different mass, composition, and in

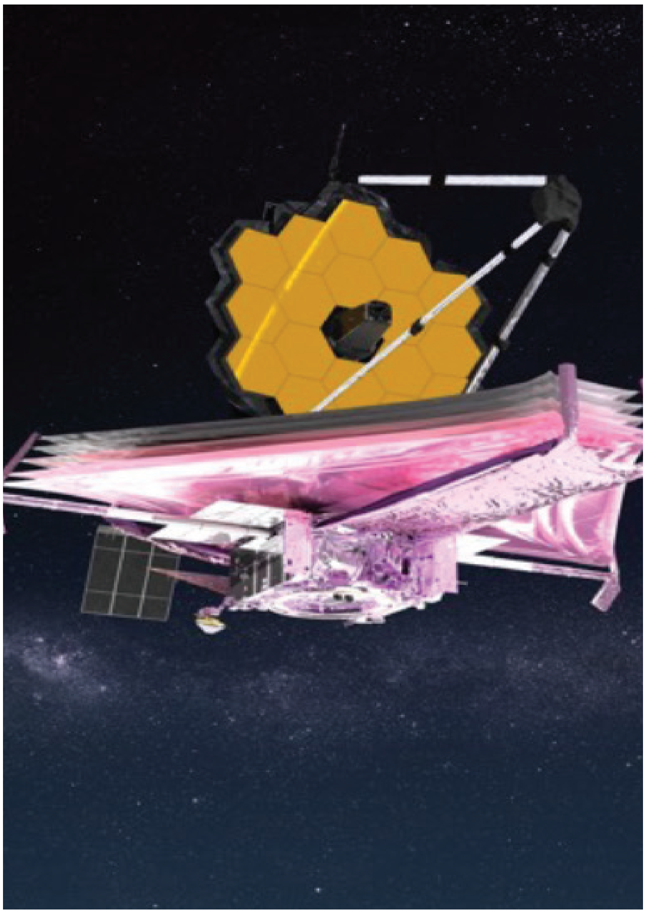

Figure 1: Artist's impression of the JWST. Credit: NASA GSFC/CIL/Adriana Manrique Gutierrez

different environments. Some of this is best done from the ground, tracing gas and its composition using submillimetre arrays like ALMA in Chile; but to image the warm dust, we need infrared telescopes far more sensitive than anything on our warm Earth – we need to go to space.

The James Webb Space Telescope

The James Webb Space Telescope launched from French Guiana on Christmas Day, 2021, after a decade of delay and a total cost of around ten billion US dollars. It is the largest infrared telescope ever launched, with a primary mirror diameter of 6.5 m.

Large telescopes are important for two reasons. The first is collecting area – if you are looking at faint objects, in many cases the limiting noise source is Poisson (shot) noise due to the fact that you catch an integer count of discrete photons, not a continuous number. The standard deviation of Poisson noise grows with the square root of count rate, and as the amount of gathered light is proportional to the mirror area of the telescope. The signal to noise ratio is therefore proportional to the diameter of the telescope.

The second is angular resolution: the wave nature of light means that a perfect optical system cannot focus to a point, but rather to a spot of finite angular size $\Delta\theta$. For an ideal circular telescope of diameter D at a wavelength λ, the width of this spot is given by Rayleigh's criterion:

$$\Delta\theta = 1.22\,\frac{\lambda}{D}$$

and for different-shaped telescopes, the same result holds with slightly different numerical prefactors of order unity. This diffraction limit means that large telescopes are essential not just for sensitivity to faint objects, but also for fine detail. To see exoplanets around bright stars, both are essential – and this is why JWST is transformative for exoplanetary science, and astrophysics in general.

In order to fit the largest ever space telescope in an Ariane V rocket, the mirror had to be made of hexagonal segments and folded up. In order to shield the cryogenically-cooled infrared instruments from the Sun, it had to unfurl a tennis-court sized sunshield made of five gossamer-thin layers. JWST is likely the most complex astrophysical instrument ever: not only did the system carry hundreds of single points of failure, but in its orbit at the second Lagrange point L2, it is too far away to service as was done with Hubble.

JWST has been such a challenging mission to develop partly because of the necessity of being all things to all people: while in this article we mainly focus on its utility for directly imaging the birth environments of exoplanets, its science requirements range from observing the very first galaxies, which at redshifts of ten are visible only in the infrared; ultra-precise measurements of supernovae and variable stars that anchor the distance ladder of cosmology and our understanding of dark energy; and observing the accretion disks around black holes and other exotic objects.

To do all of this, it must perform imaging and spectroscopy from wavelengths of 600 nm to 2.85 µm, split across four main instruments: MIRI, the Mid Infra-Red Imager; the near-infrared spectrograph and camera NIRSpec and NIRCam; and the Canadian-built near-infrared fine guidance sensor, high-resolution camera, and grism imaging spectrograph FGS/NIRISS. For exoplanet imaging, NIRCam and MIRI both carry coronagraphs, which block out starlight but let through off-axis light, ideal for looking at the outer reaches of nearby planetary systems. But for probing the inner regions, NIRISS features an Australian-designed

Aperture Masking Interferometer (AMI), which is necessary for calibrating systematic errors in the optical system to achieve the highest possible resolution.

The launch and deployment so far have gone as well as could be hoped: the mirror and sunshield have deployed successfully, and the telescope system is now being commissioned. This involves painstaking months of optical alignment, especially of the mirrors: the eighteen, 132 cm wide hexagonal segments must be positioned to an accuracy of around 100 nm in order to achieve a maximally sharp image. Even slight misalignments or distortions degrade the resolution and introduce speckles which are hard to distinguish from (say) faint planets. This is where AMI comes in – by adapting techniques developed to let telescopes on the ground see through our turbulent atmosphere, AMI allows us to determine and calibrate for optical aberrations, which will both help initially align the mirror, and produce stable interference patterns that can be post-processed to reveal detail at the diffraction limit of the telescope.

Astronomical Interferometry

Stars twinkle, and one of the least romantic, most necessary, and most challenging tasks in astronomy is to un-twinkle the stars. When looking through the atmosphere, stars are seen to vary in brightness (scintillation) and to blur out into blobs of order an arc-second across (a process we call 'seeing'). These two components of twinkling share the same origin: as light passes through the turbulent atmosphere, it encounters pockets of differing temperature and density, which vary accordingly in refractive index. In terms of geometric optics, which approximates light as travelling in rays, the atmosphere is therefore refracting the light in a disordered and constantly changing way, focusing and defocusing.

In physical optics, which treats light fully as a wave, we can consider the electric field $\boldsymbol{E}$ as plane wave propagating with wavevector $\boldsymbol{k}$ and angular frequency ω,

$$E = A\, e^{i(\boldsymbol{k}\cdot\boldsymbol{x}-\omega t)}$$

and we see that propagation of that wave is entirely expressed in terms of phase. What that means is that the atmosphere, or misaligned mirrors, impose a screen of varying delays on the light, the flat wavefront coming so far across space is now distorted and has a pattern of aberrated phases.

Even the nearest stars have typical sizes of milli-arcseconds; this corresponds to the diffraction limit of optical telescopes with diameters around 1-100m. So if you want to image the surface of a star, even at the diffraction limit, you would need a telescope of enormous diameter; and with the atmosphere in the way imposing this seeing limit of around 1 arcsec, you need some way of correcting optical aberrations. The solution to both problems is interferometry – treating light in a telescope explicitly as a wave.

Young's double slit experiment shows that light let through two pinholes separated by a baseline B spreads out on the other side in a sine wave pattern, with angular frequency 0.5 λ/B. Because electromagnetism is time-reversible, this is also the pattern you get on your camera if you block out a telescope aperture except for a pair of pinholes and look at an unresolved, distant star. If the star is of significant angular size, light from across its disk will separately form sine waves on your camera at different angles, and the result is to wash out the contrast of the fringe pattern. This therefore can be used to determine the angular size of a star very accurately.

In 1891, Albert Michelson put a mask with slits with an adjustable spacing on the Lick 12" telescope near San Jose, California, and measured the angular diameters of the moons of Jupiter [5]. After thirty years more development, Michelson & Pease used an adjustable pair of mirrors on the 100" Hooker Telescope at Mt Wilson, near Los Angeles, to measure the angular size of a star for the first time [6]: Because of its enormous size and comparative closeness, the red supergiant Betelgeuse had an effective diameter of 47 milli-arcseconds (mas), slightly smaller than its true size of 55 mas because like most stars it appears darker at the edge of its disk than at the middle. This exhausted the technological possibilities for optical interferometry until the advent of very fast, low-noise cameras – but interferometry was about to be fundamental to the dawn of radio astronomy.

On the cliffs of Dover Heights, just north of Bondi, a WWII radar station was guarding Sydney Harbour from attack. After the war, this now-civilian CSIR radar laboratory was one of a handful of independent groups turning radar to the heavens. Elizabeth Alexander in New Zealand explained mystery antenna noise as radio emission from the Sun [7]; now the team in Sydney used the Dover Heights receivers to investigate its origin.

The brilliant young physicist (and communist activist) Ruby Payne-Scott realized that even with one antenna

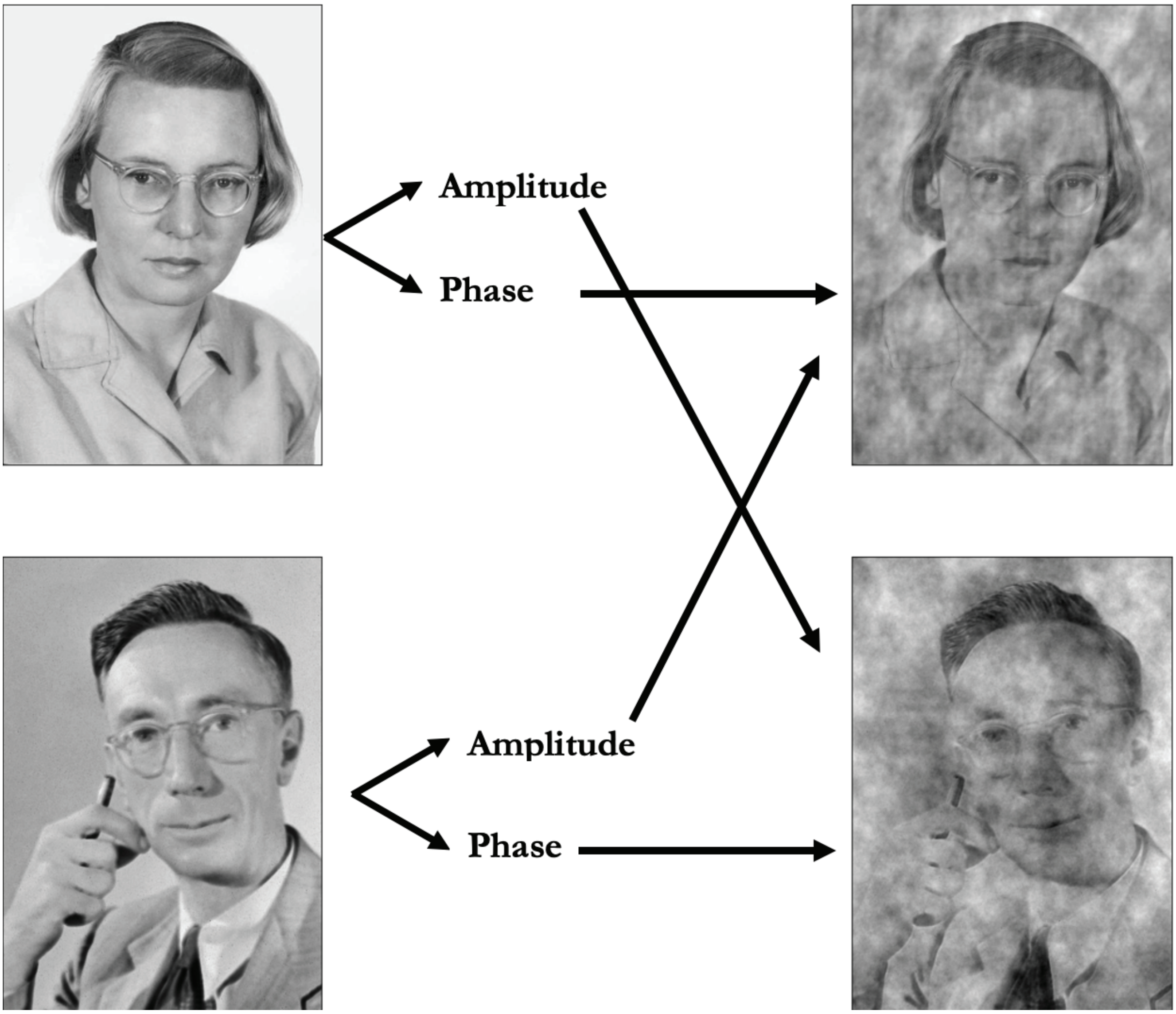

Figure 2: the Fourier transform breaks up an image into frequency components, each with an amplitude and a phase. The more important of these for placing objects in an image is the phase – as illustrated by this mix-up of two great Australian physicists and pioneers of interferometry, Ruby Payne-Scott (top; image credit Peter Hall) and Joseph Pawsey (bottom; image credit John Paul Wild).

they had an interferometer: by symmetry, radio waves from the *Sun and its reflection in the Pacific* could be made to interfere, just as if she had a double slit with one telescope on the clifftop, and that telescope's reflection in the sea below. Conducting this experiment with Joseph Pawsey and Lindsay McCready, the team found that the radio emission was mainly from sunspots – the first victory for radio interferometry [8]. Over the next decades interferometry linking arrays of multiple telescopes electronically became the mainstay of radio astronomy, constructing almost all radio images out of combinations of interference fringes between all the pairs of the array elements. Constructing the images out of sinusoids this way is mathematically simple: the fringes are a complex Fourier transform of the sky intensity, and vice versa.

A major problem was that, like at optical wavelengths, radio sources twinkle – because of the variable ionosphere. The important positional information is on the phase correlation Φ_{ij} between pairs of receivers ij. They tell you much more about object positions than the amplitudes – as is illustrated in Figure 4, where we swap the phases and amplitudes of photographs of the aforementioned Payne-Scott and Pawsey. While the swapped images are degraded, the faces clearly are determined by the phases and not the amplitudes. The problem is that each receiver has local phase noise φ_i , so that we can only observe corrupted data

$$\Phi'_{ij} = \Phi_{ij} + \phi_i - \phi_j.$$

If you consider a triangle of receivers, you can construct a 'closure phase' [9]

$$\begin{aligned}\Phi'_{123} &= \Phi'_{12} + \Phi'_{23} + \Phi'_{31} \\ &= \Phi_{12} + (\phi_1 - \phi_2) + \Phi_{23} + (\phi_2 - \phi_3) \\ &\qquad + \Phi_{31} + (\phi_3 - \phi_1) \\ &= \Phi_{12} + \Phi_{23} + \Phi_{31}\end{aligned}$$

The noise cancels out! This is the basis of high-resolution radio astronomy – and this idea transferred back into optical astronomy as 'aperture masking'. By masking the aperture of an optical telescope and letting through light only in a carefully chosen pattern of holes, the same closure phase trick allows us to cancel out the atmospheric variations from seeing that limit resolution from the ground. After initial demonstrations by the Cambridge group at Mauna Kea in 1986 [10], and Australian group Frater, Robertson, O'Sullivan & Norris with a plywood mask on the Anglo-Australian Telescope in 1987 [11], aperture masking interferometers now exist on all the world's largest ground-based optical telescopes.

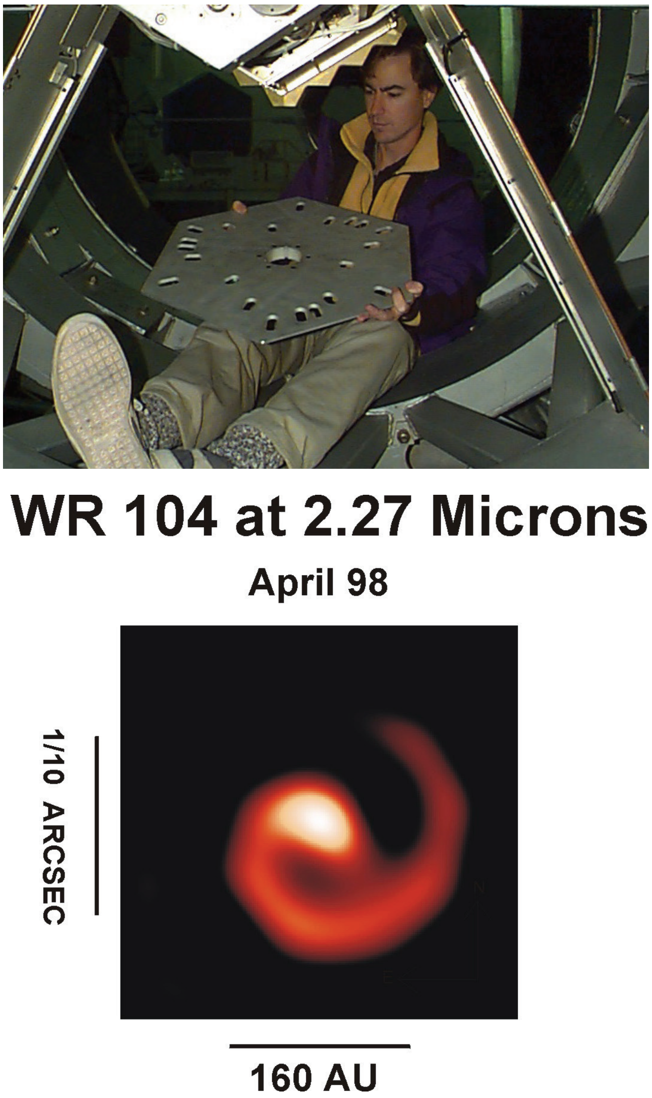

Figure 3: Peter Tuthill installing the Keck Aperture Mask (top), used to image the dusty pinwheel around WR 104 (bottom). Image Credit: Peter Tuthill.

This has led to impressive results like the Keck aperture masking experiment, where a Berkeley team led by Peter Tuthill, now at the University of Sydney, installed an aperture mask on the world's largest ground-based telescope, the Keck 10 m, and imaged dusty nebulae around dying stars like WR 98a and WR 104 [12,13] and IRC +10216 [14]. The same technique pushed to its limits has been applied to look for evidence of proto-planets accreting from their disks, like in the controversial system LkCa15 [15], but a firm detection will require much higher precision than is obtainable from the ground – an ideal target for JWST.

Aperture Masking on JWST

The NIRISS Aperture Masking Interferometer (AMI) [16], with a mask designed by Tuthill, is the only JWST instrument with a direct Australian hardware contribution, alongside work from colleagues in Canada and Baltimore. It can be put into place via one of the two filter wheels, and with wavelength channels available from 2.8 μm to 4.8 μm, it is an observing mode best suited to imaging dust at a resolution of ~100 mas in protoplanetary disks.

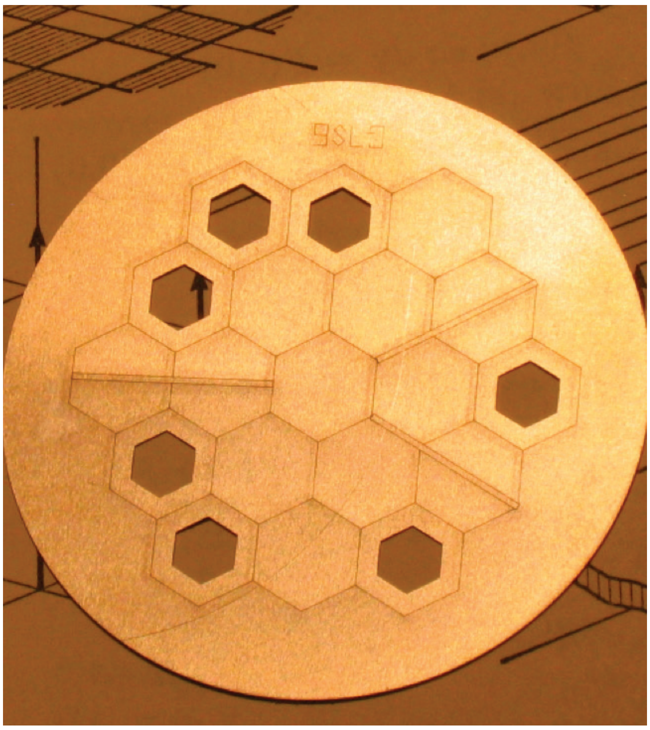

Figure 4 - the JWST NIRISS Aperture Mask. Image Credit: Anand Sivaramakrishnan, Space Telescope Science Institute.

Because of their hardware contribution, the AMI team have been able to schedule Guaranteed Time Observations of some targets of their choice outside of the normal competitive time allocation process. These will be the first planned observations with AMI, likely to take place in the first year of JWST operations. I am very happy to be involved in preparations for these planned observations and data analysis.

Saavik Ford, from the City University of New York & American Museum of Natural History, plans to look at the actively accreting supermassive black hole at the centre of the galaxy NGC 1068, to image the reservoir from which fuel is flowing in. Previous ground-based images [17] have shown tantalising clues that winds from the black hole are pushing away material that would otherwise fall in, but only the precision of JWST will resolve this unambiguously.

As part of a program of observations of the coolest brown dwarfs, which have masses in between those of stars and planets, Loïc Albert from the Université de Montréal is planning to use both aperture masking, and the related technique of kernel phase interferometry, to search these systems for orbiting planets and faint binary companions. Different models of brown dwarf formation – essentially, whether they form around stars like giant planets, or whether directly from gas clouds like stars do – make different predictions as to the fraction of brown dwarfs with binary companions, and can be distinguished by sensitive binarity surveys [18].

The majority of AMI observations planned so far, however, are of young exoplanets and protoplanetary disks. Doug Johnstone, from the University of Victoria, British Columbia, leads a program to look at transitional disks – protoplanetary disks that already show structural features like gaps and rings. Simulations indicate that these can be caused by the gravitational effects of planets [19]; but also that they can in other circumstances be consequences of the disk's self-gravity, or pressure bumps occurring at the 'snow lines' where temperature falls off enough away from the star that silicates, water, or carbon monoxide can freeze out of the gas [20]. Two little blobs of Hα emission recently seen from the ground in the transitional disk PDS 70 have been interpreted as light from active accretion onto protoplanets [21]. The planned JWST observations will confirm this, and look for similar evidence for the putative planets carving gaps in the transitional disks HD 135344B, and HD 100546.

In older systems like our own, the zodiacal light so attractive on a dark night may be a curse for exoplanet hunters: many stars show excess infrared emission consistent with being surrounded with tens or hundreds of times more zodiacal dust than our Sun – so much that the scattered light could completely drown searches for exo-Earths. Tuthill will be observing a benchmark dusty debris disk system with detected exozodiacal light, η Corvi [22], using JWST to probe for patterns in the dust sculpted by otherwise-unseen planets.

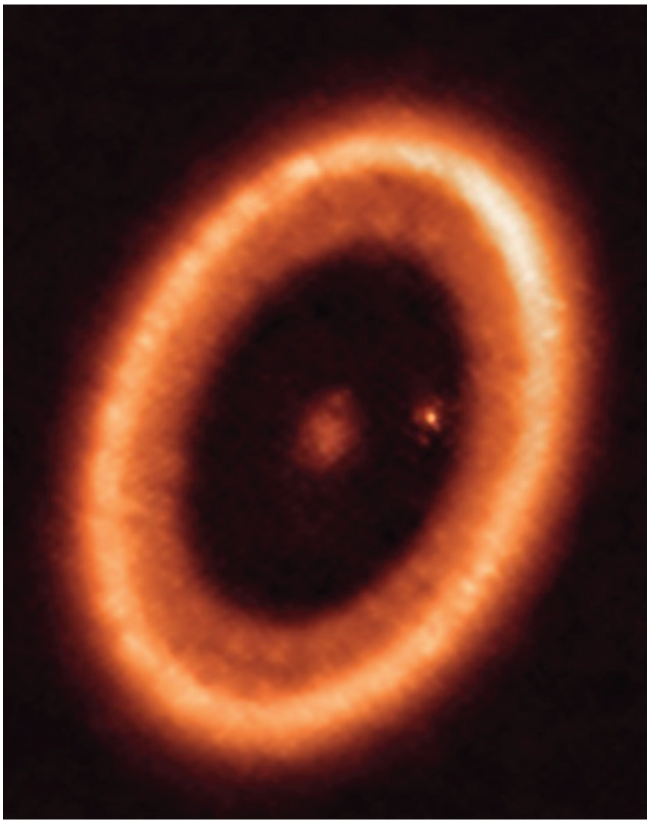

Figure 5: The transition disk PDS 70 as seen by ALMA at millimetre wavelengths. The little blob of dust at 3 o'clock is thought to be a disk around a newborn planet, in which moons are forming; the outer ring is thought to be shaped by this planet's gravity. This will be one of the first disks to be observed at infrared wavelengths by JWST AMI. Image Credit: ALMA (ESO/NAOJ/NRAO); M. Benisty et al.

The few exoplanets that can be directly imaged so far have mostly been found using ground-based coronagraphic cameras, which suppress the glare of the star to pick out the fainter planets. This has found a number of spectacular systems of planets orbiting far from their star, like the four known planets orbiting HR 8799 [23,24]; but the suspected closer-in planets are blocked by the coronagraph.

Julien Rameau, from the Université de Montréal, will use AMI to observe HR 8799, and similar directly-imaged systems HD 95086 and HD 115600, and reveal inner planets where ground-based telescopes cannot.

This aperture mask, to me, is an appealing example of how a very analogue technology based on simple, analytical physics can nevertheless be important in a project as modern as JWST. One small piece of metal, and some simple mathematics, will let us glimpse the births of planets in real time.

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About the author

Benjamin Pope is a Lecturer in Astrophysics and ARC DECRA Fellow at the University of Queensland. After studying for his undergraduate and master's degrees at the University of Sydney, he did his DPhil in Astrophysics at Balliol College, Oxford, followed by a NASA Sagan Fellowship at New York University. He researches exoplanets and stellar astrophysics using space telescopes.

Excavating bridges for future streams

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Readers may recall the front cover of Issue 57(4) from Aug/Sep 2020 featured artwork by Sean James Cassidy from the Parkes Ub Ubbo Exchange collective, visually situating the radio telescope in the context of local land and culture. We invited the collective to contribute an article to Australian Physics exploring the space between art and science with particular reference to connections between first nations, land, and country.

The human species evolved from the elements of the Universe, from the very land that supported it. Because of this, humans are fundamentally connected with that land and its rhythms. Art and Science evolved with the human species and therefore are deeply linked with the human condition.

Art and Science can be seen to be similar in the spark and drive of the inquiring mind and in the necessity for keen powers of observation. Where they differ is that Science is the quest for facts and Art seeks to explore the imagination and satisfy the need for human expression. Generally, artists and scientists have been thought to view things differently but is there a greater benefit for the brain to cultivate and enhance the neural pathways so these two views can coalesce?

Symbols are powerful. One could argue that Art and Science have developed their own languages through symbols. Is it time or possible, to create a new, universal language or is this already underway and will it provide an accessibility for a wider audience with a greater array of mindsets, intelligences and varied life journeys?

It's the Vibe

From our earliest time, humankind has been linked to and influenced by the natural world. Every sense was activated and our skin touched the earth. We flowed with the rhythms of the land, days and nights, changing seasons, growth and decay. This connection to the land permeated every aspect of life.

As Art and Science developed in parallel with the human species, they both were created from a deep connection to the land. Art reflected the shapes and colours of the environment. Birdsong, insect and animal noises and natural movements like wind and water influenced art, song, music, dance and stories. It answered the need for expression. The actual process of art used hands or sticks to scrape pictures into the earth, it carved into wood and stone. The crushing of rock or gathering of plants for colour or the preparing of bark, papyrus or pelts, was direct and immediate and lasting.

Millennia Wandering

What chance our molecules collide?

Millennia wandering, did they suddenly find purpose

Or have they always sought this circumstance?

Millions of days have brought them to this day,

And in another million million moments they will exist,

Meandering randomly or propelled.

No longer you and I, they may travel

Far from here, and perhaps repeat

The kind energy of our collision.

Jim Cassidy

[https://youtu.be/9kGcPwAWMag]

Echoes of these ancient influences are evident in cultures around the world. Celebrations of the planting and harvest, with music, song and dance, are still held. For example, the T'boli of Mindanao on the Philippines perform a song to honour a creation myth of Lake Sebu and the ascension of a female ancestral figure, Boi Henwu, into the heavens. This song links her with the song of the scarlet-breasted barbet, a forest bird, her symbol in the natural world and a wooden percussion instrument that simulates this birdsong [1]. Similarly, in a Northern Buddhist ceremony of healing, coloured, crushed rocks are used to draw intricate designs or Mandalas. These are believed to transmit positive energies to the environment and the people who view them.

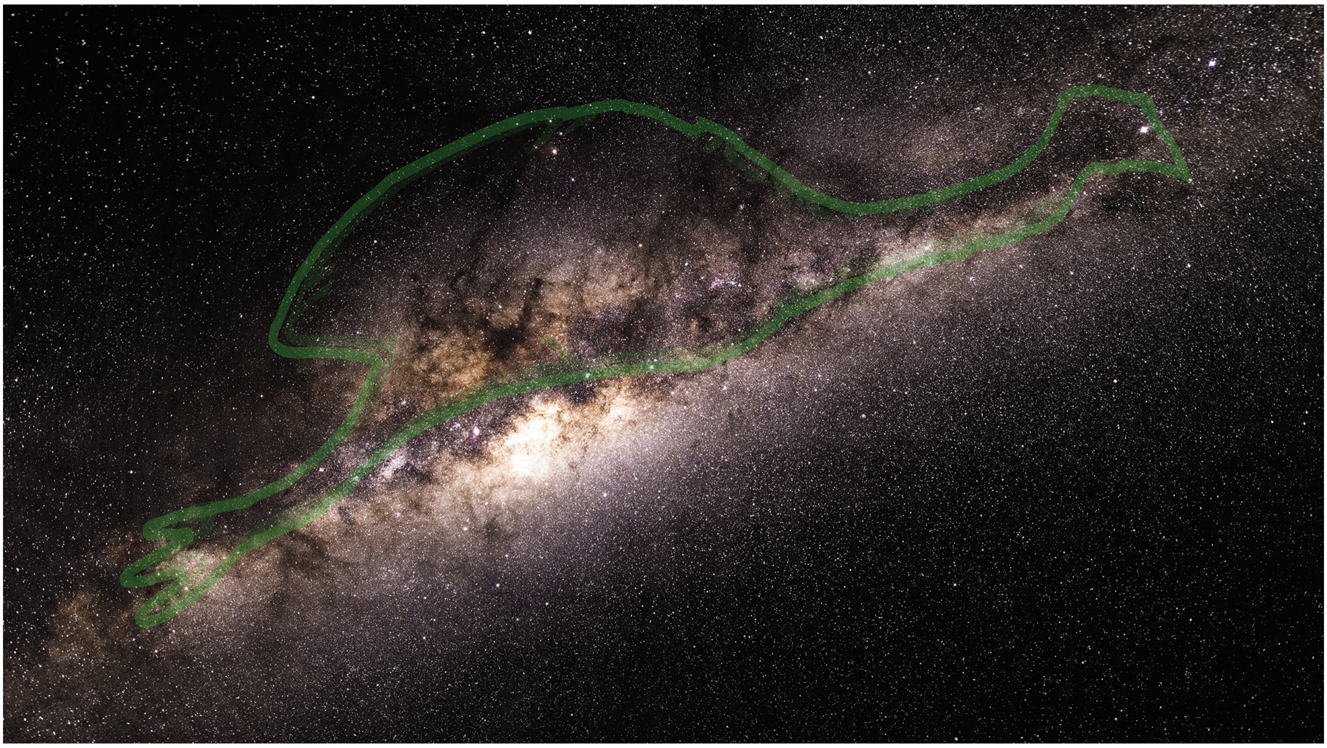
Science developed as a response to the efforts of daily life and attempted to craft more efficient methods of living. Examples include the reactions created by mixing certain plant gums with kangaroo droppings to produce a superglue, or the shape on the leading edge of wood to enable a boomerang to fly. The Coolgardie Safe, which used capillary action and evaporative cooling to keep food from spoiling, was the 'household fridge' of Australia from the 1890s until the mid-twentieth century. It is thought to have been partly inspired by watching Aboriginal people carry water in special bags made of wallaby skin, which used the same principles of heat transfer to keep the water cool [2]. Firestick farming is the ancient cultural practice of Australian indigenous peoples, of using fire to manage land. In the face of increasingly destructive fires in Australia, this technique is now being respected and learnt about, for modern firefighting and prevention techniques.

Negative space

It is from this fundamental connection through the cosmos to land, that we embark on this discussion. Let us look at the example of negative space. Artists, past and present, have viewed an image, not in isolation but in context with and in reaction to other components in the environment and a recognition of their influences on and connection with each other. Negative space was used in ancient times. Some Australian aborigines identified the big emu in the sky, which is found in the dark patches of the night sky between the stars. To some, this celestial emu shape was a seasonal indicator with one of its angles heralding the season when emu eggs, a rich source of food, were being laid. Today, this concept forms an artwork by Scott Sauce Towney, a Wiradjuri artist from Peak Hill, and featured on a coin minted as part of the recent Star Dreaming series.

Yindyamarra - Learning from and living with nature

As humans we have relied on our instincts to survive. However, increasingly, the urbanisation of the land is leading to an ever-growing disconnect with the rhythms of the natural world. In the expansion of our population and cities, there is a real danger of whole generations being excluded and severed from their instinctive histories. Menus become restricted by monocultures, food cultivation tends to be more removed and we risk a lessening of knowledge about seasons and the foods that grow in each of them. It is not so far-reaching to comprehend a life totally devoid of contact with Mother Earth where our natural body rhythms are disrupted by artificial lighting, insulated from the elements, brought up in apartments without gardens or backyards



Big Emu in the Sky Photograph by Marc Payne.

Wiradjuri artist, Scott Sauce Towney with coin. Photographs courtesy of Parkes Champion Post.

and feet only touching the ground through synthetic-soled shoes. Should we not be seeking to tap into the vibrations emanating from our deep past, to reconnect with our elemental rhythms and intuition? Real effort would need to be exerted to visit a natural space, roam a forest, walk barefooted on earth, grass or sand, hug a tree and immerse your body in untreated or salty water. If we lose our essence, do we risk losing our humanity?

The Wiradjuri word, Yindyamarra, is a powerful word of deep meaning. It encompasses a whole view of respectful listening to, understanding of and sensitivity towards the thinking about, learning from and living with Nature. It is the knowledge that everything interacts and is connected. This way of thinking promotes a different mindset and therefore a different approach to absorbing information.

This approach is in part, explained through the Eight Aboriginal Ways of Learning. This employs a holistic view of interconnected ways to engage all the senses. All processes are linked, influenced by and interact with each other. Many Australian schools are now investigating this framework. One example is Orange Public school who with local Aboriginal community members have organised the Eight Aboriginal Ways of Learning into a dynamic learning cycle to inform their curriculum planning [3].This framework can provide a different approach to engaging and supporting all students and their range of learning styles.Our recent project, The Art of Resilience (2020) [4, 5],was an arts competition for the youth of the Parkes Shire in the central west of New South Wales. It was held as a response to a prolonged and severe drought, bushfires and then the Covid pandemic, to assist young people's mental health. We discovered the impact of the Arts in the participant's lives. All spoke of the importance and benefits of art to their wellbeing. Their interviews revealed a perspective on life that was unique to country kids, who used their experiences of and their relationships with the land to decipher and communicate their feelings (see also The Art of Resilience video available at https://youtu.be/NapQw208JUk).

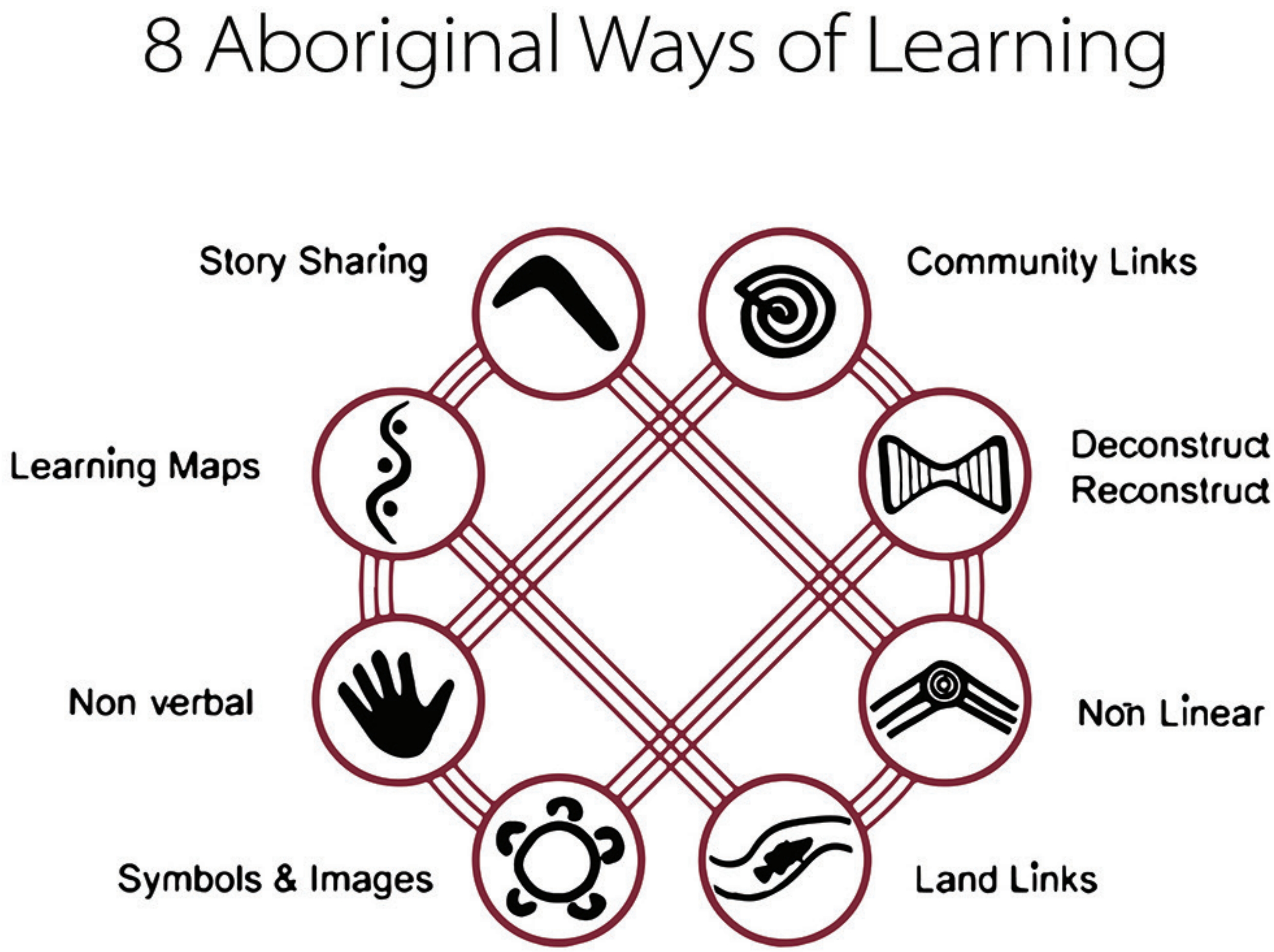
Tell them they're dreamin'

Humankind's earliest art was ephemeral [6-8]. It was created in the moment, intended for the immediate audience until it merged back into the natural world. Ephemeral art is the egoless expression of spontaneity, with its value not counted in ownership, money or fame but in the need to connect. Its purpose was to give direction and information, to tell stories and express emotions and was intended to be fleeting. As a sense of awe merged with knowledge and experience, there came the desire to record this valuable information to provide intergenerational communication. More permanent art was created as a witness to this power.

"Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution." (Albert Einstein)

Ideas are a reaction of the imagination to stimulation, past experiences and, possibly, inherited memories through tribal consciousness. Our responses are based on our intelligence including the ability to reflect, our intuition, instinct and temperament. Skills provide the capacity to give proof to these ideas.

Imagination is the spark that urges the artist to communicate and express. Creating works is the bridge. The art is in the mark making and the science in the process, stimulating a new language. Artists make multiple and rapid decisions and mathematical



The Eight Ways of Learning as Symbols. "The 8ways or Aboriginal Pedagogy, belongs to a place, not a person or organisation. They came from country in Western New South Wales. Baakindji, Ngiyampaa, Yuwaalaraay, Gamilaraay, Wiradjuri, Wangkumarra and other nations own the knowledge's this framework came down from." So, we Acknowledge the Elders and Peoples from these nations. (DET Bangamalanha Centre)

calculations about distance, proportions and perspective when creating a work. They prompt physical and chemical reactions with the mixing of colours, the fusing of metals or the firing of clays. Like a ritual dance, an artist's marks are a response to, and from a relationship with, the subject and medium. Past experience and instinct guide the action, movement and process. The weight and force of mark-making should be detectable by the audience through the pencil or brush strokes. The shaping of clay should communicate the emotion of the artist and their response to the subject. An artist can do this successfully if they have an honest alliance and connection with the medium. One of many examples of this connection is Sean James Cassidy's Ante-Chamber to Dream. It was created to invoke the warmth and cleansing smoke of ancestral fires merging with patterns echoing a Celtic history. The work encompasses elements of tribal and perhaps, universal consciousness. Sixteenth century paint-layering techniques were combined with timber marquetry, a skill taught to Sean by his grandfather. The ghostly images of the diamonds are drawn from a recurring image seen by Sean after reading and is a direct consequence of his dyslexia. It was, in part, the similarities of the patterns with those of traditional tapestry from the Philippines and the intuitive nature of the response to the media, that led Professor Virginia Dandan to invite Sean to study art as a universal language and teach 16th century art techniques at the University of The Philippines.

In Virginia's words: "An artist's choices are not arbitrary but instinctive, relying on the knowledge and skills gained through individual and shared learning." [9] For some artists, the spark of imagination can sometimes be ignited and energised through collaboration. The sharing of ideas and learning from others, who may inhabit a different headspace, can provide new tools and catapult energies in new directions.

Throughout history, collaborations, either sought or

Ante-Chamber to Dream (Sean James Cassidy).

accidental, have occurred between artists and scientists. Albrecht Dürer's cartographic and anatomical work greatly influenced 16th century science. Maria Sibylla Merian was the first to document, through illustration, the metamorphosis of the butterfly which prompted a new era of scientific investigation in the fields of entomology, animal behaviour and ecology. Merian also collaborated with indigenous communities in Suriname, valuing and respecting their traditional ecological knowledge.

During an Ub Ubbo Exchange cultural study tour to the Philippines, Scott Sauce Towney, a Wiradjuri artist from Australia collaborated with Lope Bosaing, an Applai (Kankanaey) clay artist from the Cordillera area, Northern Philippines. They created an ornamental clay shield using Sagadan clay imprinted with textures of weathered Australian wood. Sauce carved Wiradjuri patterns into the clay, a medium he had not worked with previously, helping to preserve ancient iconographies in a modern context.

Not a dichotomy

Artists and scientists appear to look at the world differently and from different perspectives. Generally, art seeks to express spontaneously, drawing on instinct, intuition and emotion whereas science uses the rational technique of inquiry where the drive is to understand, explain and predict. But are these disciplines really different or mutually exclusive and is it time to explore a re-evaluation of approaches?

Laura Otis puts forward the argument that, "While prevailing neurological and psychological models of studies of the mind have a tendency to generalize, fascinating data is lost when we eschew the study of individual minds." She suggests that perhaps it is time to challenge the concept of separate visual and verbal thinking styles and embrace both and "develop the emerging science of the human brain into a science of human brains." [11]There is a diverse range of thinking styles, and history identifies many influential artists, scientists and mathematicians who explored and drew inspiration from both artistic and scientific pursuits. Leonardo da Vinci was probably the epitome of this.

With the growing understanding of the neuroplasticity of the brain, the idea that the brain can change its own structure and function through thought and activity reveals the exciting possibility of new pathways to new creations, discoveries and inventions.

Top row (LTR): Lope's ceremonial meat jar; Lope and Sauce in discussion; Lope demonstrating the clay imprint method; bottom row (LTR): Wood textures in clay; Sauce carving Wiradjuri iconography into clay shield; Historic Wiradjuri carving on scar tree, in the care of Henry Parkes Museum, Parkes [10]

Conclusion

The evolution of the human species is an epic story, a story deeply connected to the very land we are derived from. Woven throughout this story is that of Art and Science, arising from the human desire and need for expression, communication and understanding. Could our future be powerful in the creation of greater opportunities and accessibility for a wider audience? Could more open acceptance of different mindsets enable the creative intersection of knowledge bringing the possibility of the development of a universal language through which we will all be able to understand each other?

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Philippines. Nathan Kopp (Senior Product Designer, WooliesX) for advice on software development. Dr Amy Peden (School of Population Health, UNSW Sydney) for editing and referencing support.

About the authors

Kerrie Peden has worked as an educator for almost 40 years, spanning general classroom teaching, early intervention, English as a Second Language, music, dance and drama. She grew up in Parkes, NSW before studying at the Sydney Conservatorium of Music. At the time, the Department of Education was considering introducing specialist music teachers in Primary schools and Kerrie switched courses in anticipation. They are still considering.

During her career, she encountered students, like her nephew, Sean James Cassidy, who found learning difficult through traditional teaching methods. She worked to achieve better outcomes by exploring different learning styles and teaching methodologies. The Arts became an integral part of her mainstream teaching.

Presently, she is writing, working on projects with Ub Ubbo Exchange as a board member and running a community choir, a mental health initiative in response to crippling drought. She watches with joy, the development and learning of her four grandchildren.

Sean James Cassidy lives and breathes art and has all his life. As a child he drew on every piece of paper in the house and also every wall. While his severe dyslexia, was a frustration at school, he now sees it as a strength enabling him to think and view from an alternative perspective.

Sean studied Fine Arts at Goulburn TAFE, Drawing at Julian Ashton Art School, 16th century painting techniques at the Charlie Sheard School and Graphic Design at the Enmore Design Centre. He established Ub Ubbo Exchange with Lope Bosaing, an Applai clay artist in The Philippines in 2007, providing study tours and cultural exchanges between Australia and the Philippines.

Sean enjoys collaborative projects with people from different backgrounds and disciplines. He believes in the protection of different languages and mindsets as the possible provider to, as yet, unanswered questions.

Physics Education workshops at ICWIP2021: discussions and recommendations

***Jacinta den Besten, Elizabeth Angstmann, Tetyana Antimirova, Gillian Butcher, Kate Jackson, Yvonne Kavanagh, Ana Lopes, Stephanie Mayes, Deena Naidoo, Maria Parappilly, Manjula Sharma, Gráinne Walshe and Pornrat Wattanakasiwich.**

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Many girls are choosing to opt out of physics studies and related careers before they reach university. Many of those who begin in undergraduate physics do not persist. Education is a powerful way to address this issue. This was the focus of the education workshop at the International Conference on Women in Physics 2021 (ICWIP2021). This article describes the discussions that took place during the workshop and the conclusions we drew. It is time to carefully consider what we teach and how we teach it. Humanising the curriculum to make it relevant to students and teaching in a way that motivates and engages all students with class discussions and hands-on experiences, showing the diversity of people working in physics and explicitly addressing 'imposter syndrome' is beneficial for all students but especially girls.

The under-representation of women in physics academia and education as well as industry is well documented [1] as are the benefits of targeted programs, such as mentoring and role models, to encourage girls to pursue physical science interests and careers [2]. Yet the perpetual leaky pipeline continues to hinder such programs providing too few role models and mentors while placing a large burden on a few, only contributing to turning the leak into a flood [3]. When you gather a set of people with a vested interest in female representation in physics from all cultures and corners of the world to discuss this very problem, you can ask questions such as: is this a cultural issue, an economic, or a social issue? You can compare and contrast experiences and stories, take away ideas that have worked in other countries or communities and work together to voice common and diverse problems and the potential ways forward.

The unique aspect of these discussions is that irrespective of location, culture, economic or social circumstance, the stories around education were very similar. The small number of girls taking up physics. The small number of women employed in physics academia and education. The pervasive stereotypes and the subsequent dismissal of women's contribution to the field, both past and future. The consequential imposter syndrome, administerial and promotional barriers that arise from the biases. How does one solve this cyclic problem, when to get more girls interested in the physical sciences, we need more women in senior positions and to get more women into senior positions, we need to foster and grow the talent in our schools and universities? Education and recruitment

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are important ways to increase the participation of girls, and eventually women, in physics. One aspect which is often not adequately addressed is entry into the pipeline. The focus is generally on the pipeline which is leaking, but how do we maintain or even increase the entry into the pipeline? Address the inputs into the supply chain. Again, the commentary is much the same, girls often do not choose or are dissuaded from physics, and in some cases do not have access to education, let alone science education or physics [4]. Where there is access, education and retention throughout the education systems as well as recruitment through engagement, exposure, visibility and utility of physics is paramount. Perhaps, when influential women gather, the leaky pipeline and the entry into the pipeline should be given concerted effort.

This article advocates for, and draws attention to, a need for a more balanced approach: a focus on entry and engagement into the pipeline together with fixing the leaks. Are there deliberate actions which may increase the inputs into the supply chain?

ICWIP Conference

The International Conference on Women in Physics (ICWIP) is a flagship conference of the International Union of Pure and Applied Physics (IUPAP). Participation is by invitation with country representatives sharing posters on the status of women in physics in their countries as well as scientific papers. The 7th ICWIP chaired by the Chief Scientist of Australia, Dr Cathy Foley, was set to occur at The University of Melbourne in 2020. Postponed to 11 to 16 July 2021, ICWIP was delivered virtually and attended by almost 400 participants from 50 countries [5]. Invited speaker sessions included one on successful WIP programs with Australia's Women in STEM Ambassador, Prof Lisa Harvey-Smith, and one on Men as Allies hosted by the President of the Australian Institute of Physics, Prof Sven Rogge.

A key aspect of ICWIP is the discussion of hurdles and sharing of experiences with the explicit aim of generating recommendations around specific topics for IUPAP. Perhaps a somewhat unique feature of the ICWIP conferences is the explicit and intentional/purposeful inclusion of the topic of Physics Education, an initiative continued by the current Chair, Dr Gillian Butcher, of the IUPAP Working Group on Women in Physics, WG5. The authors of this paper led the design and delivery of the Physics Education component of ICWIP2022.

The Physics Education workshop used a flipped approach, with participants provided videos to watch beforehand. The videos were varied in content and style, seeking to seed ideas for discussion on female engagement and participation in physics education.

Physics Education Workshop #1

In the first of two workshop sessions participants spent 15 minutes with each of the speakers in a 'world café' format discussing various aspects of women in Physics Education. Time was spent sharing individual lived experiences with a focus on recruitment, participation and engagement of women in, and through physics education. The idea was to discuss what could be done within various spheres of influence to improve the experience of and encourage more women to enter physics. The video presenters and Australian themed breakout rooms are listed below with a short description of their video.

Tiger Quoll Room: *What can I do individually? What is in my power?* (A/Prof Elizabeth Angstmann and Dr Kate Jackson – University of New South Wales). The video provided a number of interventions and outcomes for creating a more inclusive learning environment for all students, but particularly the female students in a First Year Physics programme. Lessons learnt and personal experiences were then shared during the world café.

Sugar Glider Room: *STEMming the tide: Fostering girls to turn to STEM, in particular Physics* (Prof Maria Parappilly and Stephanie Mayes – Flinders University). The video described the measurable impact on student engagement including a pronounced effect on females through teaching and outreach programs. The work demonstrates the importance of a quality outreach program for encouraging girls' interest in science and in particular physics.

Quokka Room: *Women in Physics- Making the invisible visible through education* (Dr Yvonne Kavanagh – Institute of Technology Carlow, Dr Gráinne Walshe – University of Limerick, and Dr Gillian Butcher – University of Leicester). The video offered examples of initiatives on how national physical associations and similar larger structures can increase the participation and engagement of female students. The participants were then invited to consider how they as individuals or a small collective can attract support and funding for such initiatives.

Echidna Room: *What can departments, institutions and larger structures do to purposefully increase participation and engagement of female students?* (A/Prof Tetyana Antimirova – Ryerson University, Prof Deena Naidoo – University of the Witwatersrand, and Dr Ana Lopes – The University of Sydney). This video focussed on the department and teaching culture and how this impacts both students and female staff often pronounced due to the gender ratio and perceived status in physics. The workshop opened discussion around what a healthy work environment looks like for staff to best support student learning.

Bilby Room: *A conversation: Curriculum to personal experiences* (A/Prof Pornrat Wattanakasiwich – Chiang

Mai University and Prof Manjula Sharma – The University of Sydney). This video was presented in a discussion format relaying personal experiences around the idea that gender balance is often not explicitly recognised in many cultures and poses the question of how to increase awareness. Participants were asked to share their own experiences and ways they have managed to increase awareness.

Physics Education Workshop #2

Based on the discussions from each room, common themes, based on spheres of influence, emerged. The participants chose the theme most applicable to them and were involved in that thematic discussion for the entire workshop, exploring the individual and common challenges in that sphere and collectively develop recommendations for IUPAP to adopt. The themes along with the main points of discussion are detailed below.

Kangaroo Paw Room where the sphere of influence was *institutional and societies* was facilitated by A/Prof Tetyana Antimirova, whose interests include the impact of technology and enquiry-based, active learning on students' learning outcomes in large introductory physics classes, the demographic effects on student's learning outcomes and research-informed curriculum development, and Dr Yvonne Kavanagh who advocates for institutional societies and associations to support women in physics.

The participants were invited to share thoughts on how societal perceptions of physics influence female participation in physics-related professions. The following persistent issues that negatively affect the rates of female participation in the field were identified:

- There is a widespread false perception that it is "better" for females to study life sciences than invest their efforts into physics and mathematics-related disciplines [6].

- Women are often encouraged to enter allied health fields and to avoid STEM fields altogether.

- Societal perception that physics is a "difficult subject" and the "idea of brilliance" (one has to be smart in order to do it) associated with it reduces a number of potential entries in the field [7].

Grevillea Room where the sphere of influence was departmental and outreach was facilitated by Prof Maria Parappilly, who has established a number of successful outreach programs encouraging female students to pursue a STEM career, and Prof Deena Naidoo, who is interested in how departments can support female Physics students at the tertiary level in their learning, career and teacher training.

Ensuring the visibility and the opportunity to engage with the physics community for female students and pre-service teachers was discussed in this workshop. Participants were invited to share and discuss successful programs and what would be required to create such resources:

- Invest in female students by designing outreach programs strategically and intentionally to engage them.

- Increase the visibility of women in different careers, fields and stages of careers/education for female students

- Provide teacher training programs as teachers are the most influential people in student's lives.

Waratah Room where the sphere of influence is *the individual* was facilitated by A/Prof Elizabeth Angstmann, who is the First Year Physics Director at UNSW and chair of the Australian Institute of Physics, Physics Education Group, and A/Prof Pornrat Wattanakasiwich, who has interests in student learning in Physics and teacher training.

The conversations focussed on what individuals can do in their teaching to empower and improve the experience of female students. A prominent theme was the need to address imposter syndrome (students doubting their ability and feeling like a fraud). Participants had addressed this in several ways, such as running a short "belonging" exercise [8], where students reflect on their feelings about the course and transition to university to help them realise that this is a common experience. Other participants had shared their own struggles with students, showing that failures are a normal part of academic journeys.

Other ways to empower students that were discussed include regularly meeting with a few current students to listen (and implement) their suggestions on how to

The University of Sydney Girls in Physics Program runs workshops and tours for high school students.

improve the course, and giving students choice in topics learnt and assessment when appropriate (acknowledging this does not work in all courses). These strategies show students their input is valued.

Another frequent theme was "humanising" the curriculum to stimulate students' interest through the inclusion of historic stories or making connections to the real world.

Recommendations to IUPAP

The recommendations put forward to IUPAP from these discussions were:

- Increase awareness of imposter syndrome and bias by developing and delivering workshops for academics through conferences. The workshops should provide tips and strategies for countering these, going beyond theory.

- Give some priority to physics education for females in their policies and projects. For example, gather data, nuanced to different cultures on why females choose and continue with physics.

- Increase awareness of IUPAP amongst physics educators so that IUPAP's programs gain traction and become visible to future generations.

- Organise the gathering of qualitative and quantitative data, and providing guidance on its quality, for measuring research output which is fairer to females.

- Consider ways in which metrics can be developed for parameters associated with teaching and its evaluation with an eye on the fact that females are more likely to receive inappropriate/irrelevant feedback and critique.

- Establish a working group to consider reinvigorating the curriculum and the teaching of physics with the objective of providing a contemporary and 'balanced' physics education.

These were forwarded to the Chair of the IUPAP Working Group on Women in Physics, Dr Gillian Butcher for her team to consider for presentation to IUPAP.

The dominant theme: Curriculum

While recommendations were put forward in all spheres of influence from the individual to the institutional, the one recommendation that appeared prominently in all discussions was around the necessity for reinvigoration of the physics curriculum at all levels. Reviewing how physics is taught and the curriculum content delivered, ensuring it is accessible to girls and women, that it features female role models providing a contemporary, relevant and balanced physics education. The provision of best standard physics curriculum recommendations to education systems world-wide was universally considered an important and the most constructive direction for IUPAP to adopt in order to improve the inequity around women and girls' participation in physics education.

The physics curriculum needs to be applicable to the student diversity in order to be more engaging, relevant to their present and future lived experience, and provide active learning experiences through hands-on activities and problem solving. This would require reviewing the breadth of topics and applicable contexts as well as the pedagogy in delivering the curriculum. Understanding why some areas of physics such as biophysics [9] have a larger female contingent can inform us on how we can move forward.

Discussion and conclusion

It is also important to recognise here that diversity within industry and the workforce has been shown to increase economic outcomes, boost productivity and promote innovation [10]. However, according to the Global Gender Gap Index (2020) and the Commonwealth of Australia (2021) [11], the STEM workforce is predominantly male dominated. In today's technologically focused society, the lack of women in STEM is a concerning issue. While, over several decades, attention has focused on the leaky pipeline by improving institutional climate [12, 13], education and entry into the pipeline needs more concerted attention. In attempts to improve entry into the pipeline and increase interest in STEM careers, initiatives such as enrichment programs have been implemented [14] and seek to combat the commonly held belief that STEM subjects and careers are challenging [15]. Further exploration of successful outreach programs and how they incorporate the curriculum, mentorship and gender visibility should be incorporated to provide insights into the curriculum review.

Finally, any widely researched, reviewed and carefully structured proposals for the curriculum by the IUPAP should be seriously considered for adoption by all curriculum bodies and will require the institutional associations and societies to advocate for this change.

In conclusion, there is an under-representation of females in physics at all levels. We can take steps towards addressing this problem by carefully considering the curriculum we deliver and how it is delivered, and ensuring the curriculum humanises physics by showing its relevance and importance to everyday life and society. We need to connect with school teachers and work together to address these issues as many girls are choosing not to study physics or engineering long before they start at university. A critical part of this is building capacity in the teaching workforce as well as outreach and social connections and support systems.

About the author

Jacinta den Besten is the Director of First Year Physics in the School of Physics at the University of Melbourne, and deputy chair of the AIP Physics Education Group. While her main focus is in physics education and outreach, she is also a long-term advocate for diversity in physics and was the inaugural chair of the School of Physics Equity and Diversity committee and is a current member.

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Vale Tony Klein

Bruce H J McKellar (brucehjmac@gmail.com)
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Emeritus Professor Tony Klein AM FAA died at the age of 85, after his distinguished career in physics and in the service of physics and physicists. We write to celebrate his life and work.

Tony graduated with a Batchelor of Electrical Engineering from the University of Melbourne in 1958, after migrating with his family by a much delayed journey from Timisoara, Romania, which began in 1939 and finished in Victoria in 1953. He attended University High School just in time to do his matriculation with high honours and enter the University of Melbourne. He joined the Australian Atomic Energy Commission at Lucas Heights just as the construction of its first nuclear reactor was beginning. After spending time at the Argonne and Oak Ridge reactor facilities in the US he came to the University of Melbourne as a Senior Lecturer in 1965. Moving upwards through a Readership in 1976 and a Personal Chair in 1983, he became Head of the School of Physics from 1987 to 1996, retiring in 1999.

Soon after Tony arrived in Melbourne he was working with David Caro, Geoff Opat and Bill Wignall on a program which started accelerator-based high energy physics in Australia, by analysing bubble chamber photographs taken at the Brookhaven Synchrocyclotron. Tony's electronics experience was the key to automating the analysis. In the early 1970s the analysis of the results of bubble chamber experiments moved to in-house software analysis of electronic data, so Tony and Geoff moved to probing fundamental physics with neutron beams.

In 1975 Tony spent a sabbatical at the highest flux nuclear reactor in the world, l'Institut Laue-Langevin in Grenoble, France, the first of many visits. He and Opat provided the first experimental verification that the rotation of a spin half particle through 360 degrees changed the sign of the wave function — a basic assumption of quantum mechanics which was justified by the accuracy of the predictions of atomic structure and other data, but which had not been observed previously. With collaborators, they also provided the first experimental verification of the Aharonov-Casher effect — the phase acquired by a particle carrying a magnetic moment moving in a circle around a static electric charge. Their results remained the most accurate from experiments which employed a closed path around the charge until 2012.

While producing this physics research Tony was actively pursuing his delight in communicating science to others. In the 1960s, he and Geoff Opat began the July Lectures in Physics to communicate recent or interesting aspects of physics to high school teachers. Expanded to include the general public, the July Lectures in Physics are now a University of Melbourne, or even a Melbourne, institution. In July 1969, Tony was asked by the ABC to do voice-commentary explaining the technology behind the voyage of Apollo 11 during its mission and he provided the commentary for the live TV broadcast in Australia of the Armstrong-Aldrin moon landing. He was invited back to provide commentary for the Apollo 12 and Apollo 13 missions.

In the 1980s, a significant number of the existing academic staff in the School of Physics at Melbourne were coming up for retirement. An external review of the School recommended that a number of new appointments be made ahead of these retirements to ensure a smooth transition to the next generation and to renew the School's teaching and research efforts. During his long tenure as Head of School (1987-1996), Tony was responsible for making these important appointments. In all, ten new continuing academics were hired in various research fields. These individuals have formed the backbone of the School over the last twenty years, with four of them serving as subsequent Heads of School and six becoming Fellows of the Australian Academy of Science. As well as providing new personnel, Tony also presided over a concomitant period of change in the strategic research directions of the School: the Opat-Klein Fundamental Experiments Group morphed into the present Optical Physics group, experimental and theoretical elementary particle physics were expanded and strengthened, and a group in astrophysics and astronomy was created from scratch. Another major development led by Tony was the extension of the Physics building eastwards to house larger and more modern first-year teaching laboratories.

Tony worked extensively to promote physics and physics causes in the University of Melbourne, and in Australia. Inside the University he was one of the members of the University Council elected by the Professors for many years, taking a particular interest in the support of staff and departments. He played an active part in the Australian Institute Physics (AIP), on the Victorian Branch Committee from 1976 to 1982, and as the Chair of the Branch in 1981 and 1982. At the national level he was the President of the Australian Institute of Physics in 1989 and 1990. In his time leading the AIP he worked very hard to make sure that physics had a role in the national science policy discussion, recognising that physics was in the most parlous state of any of the scientific research fields in Australia. He also became the second President of the Australian Optical Society in 1985 and 1986.

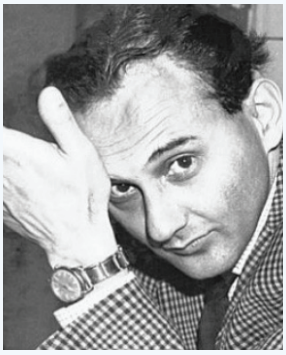
Elected to the Australian Academy of Science in 1994, he vigorously pursued the interests of physics and physicists through the National Committee for Physics, and many of the committees of the Academy, including its advisory committee on nuclear reactors. Remarkably he attended each of the annual Science at the Shine Dome meetings for the 24 years from his election to 2018, always asking relevant and demanding questions. He served as the Chair of the Victorian Regional Group of the Academy from 2002 to 2017, always looking for possible Victorian nominations to the fellowship and organising an annual celebration of those who were elected. His legendary annual Christmas Parties provided chances for the fellows and their families to converse and to be entertained, and for Tony to tell some of his infinite supply of jokes.

Tony also served on the Standards Advisory Committee of the CSIRO National Measurement Laboratories from 1985 to 1995, as its Chair for the last 5 years. He was also the Chair of the Research and Ethics Committee of the Victorian Eye and Ear Hospital from 1991 to 2010, and the Beam Instrument Advisory Committee for OPAL, the Australian Research Reactor from 1997 to 2007.

Tony's work for the University of Melbourne was recognised by one of the 2017 University of Melbourne Awards. His enduring contribution to the identity and standing of the University through research, institutional leadership and contribution to intellectual and public life is recognised by a plaque placed in Professor's walk. In the same year he received the W. H. Beattie Steel (lifetime achievement) Medal of the Australian Optical Society in 2017. He was appointed an Honorary Fellow by the AIP in the late 1990s. National recognition came with his appointment as a Member of the Order of Australia in 1999.

Following his retirement, Tony retained an office in the School of Physics, coming in most days and continuing to be a lively presence at School colloquia and seminars. He maintained his informal role as a mentor and advisor, providing valuable guidance to the new generation of academics.

All of his friends and those who have worked with him miss him greatly. We send our sincere condolences to his wife Suzanne and his family.



Tony Klein in 1969 and more recently. Images from The Australian Jewish News (www.australianjewishnews.com/experts-apollo-11-memories/) and the Australian academy of Science (www.science.org.au/profile/tony-klein).

#PhysicsGotMeHere

This occasional column highlights people who have a qualification in physics but are in roles we might not traditionally associate with physicists. The information is drawn from the 'Hidden Physicists' section of the AIP e-bulletin.

Dr James McCaw

Professor of Mathematical Biology at the University of Melbourne

I'm a mathematical biologist, specialising in infectious diseases epidemiology. At the University of Melbourne, I lead a diverse team of research scientists with backgrounds in physics, mathematics, biology, public health and computer science. We all have a strong desire to improve public health by studying how infectious diseases spread through the population. We do this through the development and application of mathematical models to laboratory, clinical and epidemiological data.

My career in epidemiology came as a surprise to me. In 2005, having just completed a PhD in theoretical physics – where I attempted to characterise chaotic dynamics in quantum systems – I saw a job advertisement in the Melbourne School of Population and Global Health. They were advertising for an 'infectious diseases modeller' and wanted to recruit someone with a background in physics, engineering or mathematics. I had no idea what it was about, but I was curious.

A little investigation led me to some fascinating mathematics: the application of non-linear dynamical systems theory to infectious diseases data. An31d I discovered that physicists had been foundational in establishing the field. Indeed, Lord Robert May of Oxford, who sadly passed away on 28 April 2020, had begun his career in nuclear physics in Sydney. He had seen the opportunities for mathematics to contribute to the life-sciences, first in ecology and then in the infectious diseases of humans. In 1992, with Roy Anderson, he co-authored the now seminal book Infectious Diseases of Humans: Dynamics and Control. I had the pleasure of meeting with him in Oxford on a few occasions. And as it so happens, he was a life-long friend of my PhD supervisor, Professor Bruce McKellar.

Anyway, I took a chance and applied for the job. My dream of a post-doctoral position in physics was put on hold. Infectious diseases epidemiology – and a post-doc in a medical faculty – awaited me. I never looked back.

Today, 16 years on, I've found my way back across campus, employed as a member of academic staff in the School of Mathematics and Statistics as Professor of Mathematical Biology. I retain a 20 per cent appointment in Population and Global Health. I still consider myself a physicist, of sorts. My education certainly shaped how I see the world, and how I attack problems. I examine data, using it to motivate the structure of non-linear dynamics models. I then study the bifurcation structure of those models, their transient dynamics and asymptotic behaviour. Just as in physics, my research is an interplay between theory and experiment. It's just that the problems aren't those that appear in traditional physics text books.

The COVID-19 pandemic has put my research field on the map. The Susceptible-Infectious-Recovered (SIR) model and the reproduction number (R0) are suddenly common knowledge. This is incredibly exciting to see. Epidemiology, and biology more broadly, is changing – and it isn't just about 'data science analytics' and machine learning.

I think there is a more fundamental change on the way. We are shifting our viewpoint for how we make sense of the biological world. Models, once largely conceptual (and secondary to the empirical study of the diverse and deeply complex systems that characterise biology) are becoming quantitative and more highly valued. Pictures are giving way to equations. Hand-waving arguments are giving way to dynamical systems. Interrogating biological data with these models provides new insight. It reveals discrepancies. It hints at overlooked mechanisms. Sense can be made of the structures and patterns emerging.

Transmission dynamics models – and their application to data – have been a crucial component of the COVID-19 response. Since 2005, I have worked closely with the Australian government on pandemic preparedness. And in January 2020 I was asked to join the Australian Health Protection Principal Committee as one of just a handful of 'invited experts'. In this role I have been advising government and National Cabinet on everything from the early border closure with China to a risk-assessment of emerging 'variants of concern' and the possible implications for our hotel quarantine system. In between, I've advised on school closures, mask-wearing, stay-at-home orders and almost every other policy decision faced by our governments. Models, and 'physics thinking' have formed the foundation for my thoughts, views and advice.

My training in physics – plus a decade of on-the-ground training in infectious diseases biology, epidemiology and public health – was the ideal preparation to make a contribution to our emergency response. Physicists know how to develop models and study out-of-equilibrium dynamics. And the emergence of a novel pathogen, spreading into a fully-susceptible population, which itself is responding with restrictions and other measures designed to limit transmission, is most-certainly an out-of-equilibrium dynamical system.

What better training than in physics?

Dr Rebecca Pearce

Paediatric Intensive Care Doctor (Fellow) at Monash Children's Hospital

I have just finished my training in Paediatric Intensive Care. My job involves looking after some of the most unwell children in the hospital and, sometimes, in the state. I'm involved in the treatment of unwell children who need additional support for their heart, lungs, kidneys or neurologic states, or more intense monitoring after an operation. I've looked after kids if they are unwell with infections or exacerbations of their underlying medical conditions. A lot of my patients are babies with complicated heart malformations, kids with

cancer or kids who have been involved in accidents and trauma. It sounds stressful and a little crazy, but I don't work alone and have an amazing group of doctors, nurses, allied health and support staff who are all involved in the various aspects of the patient's care and time in PICU. In addition to the medical side of things, I'm also part of the team supporting parents and families through an emotional and stressful time of their lives.

I began my career with a Bachelor of Science with honors at Monash University in 1996. I majored in Physics and Anatomy; already veering off the well-worn traditional physics track into something a little different. My physics honors project was again a fusion of my interests, where I used microtomography (micro-CT scanning) to compare the differences in normal and diseased mouse bones to what you can see looking down a microscope.

In 2000 I decided to embark on a medical career and began a Medical degree at the University of Sydney. Keeping both sides of my interest going, during my time studying medicine I got to teach physics to university and high school students. I helped them participate in doing physics experiments which was a lot of fun and drew me to education in general which I still participate in.

I started work at the Canberra Hospital as a junior doctor in 2004. I had originally planned to do surgery and got onto the surgical training pathway, but also managed to spend some time overseas training in paediatric surgery, which I really resonated with. When I returned to Sydney I continued training in paediatric surgery. My plans of what I wanted to eventually do ended up changing, like many things do, and I started training in Paediatric intensive care. I managed to use my love of travel to spend time working in the UK and NZ.

I'm now back in Melbourne and have finally finished up my long and varied training time. I now work as a fellow in Paediatric intensive care which involves both patient care and supervision of junior doctors in

our unit. I worked at the Royal Children's Hospital between 2019-2021. And from February 2021 I am at Monash Children's Hospital. I am now focussing more on education and special interest project and research which will aid in my clinical management of patients.

I've found that there have been real benefits of having knowledge of physics and how it applies to the medical area. A strong scientific background is a bonus in medicine and a lot of physics is applied to the study of physiology - and intensive care is a lot of applied physiology! Even just the understanding of radiation and imaging-related physics concepts is so useful in medicine and a real bonus to have. The soft skills I have also have their basis in my physics studies - the ability to discuss medical concepts with both colleagues and the non-scientific families and for both groups to understand what I'm talking about is really important in terms of everyone being on the same page with a particular patient's treatment.

Physics around the world

Bitcoin encryption is safe from quantum computers – for now

How big does a quantum computer need to be to accomplish something useful? Physicists from the University of Sussex, UK recently set out to answer this question for two pragmatic computational tasks: breaking the encryption used in Bitcoin transactions and simulating the behaviour of an agriculturally important nitrogen-fixing molecule. By estimating the number of quantum bits, or qubits, that different types of quantum computers would need for each task, members of the team say their theoretical study should help other researchers decide which designs to pursue.

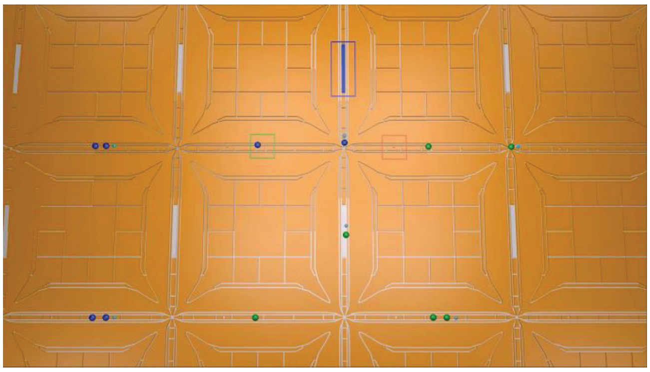
Although there is no standard hardware platform for quantum computers, two of the most popular ways of engineering qubits involve superconductors and trapped ions. In either case, the number of qubits available to perform quantum operations is significant, explains Mark Webber, a PhD student at Sussex who is also involved in a Sussex spin-out called Universal Quantum. Using more qubits, he adds, may enable quantum computers to tackle important real-world problems on practical timescales even on platforms for which individual qubit operations take longer – as is the case for trapped-ion machines compared to those based on superconducting qubits.

In a study published in AVS Quantum Science, Webber and his collaborators set out to explore this balance between qubit number and operation times for superconducting and trapped-ion qubits. "The question really is, how big does your quantum computer need to be to solve really impactful problems? And how does that answer change when we're talking about a trapped ion platform or superconducting platform?" Webber tells Physics World. Winfried Hensinger, a Sussex physicist and the study's co-author, adds that by looking closely at the available hardware, the team's work "immediately links to the actual hardware designs we can build and capitalizes also on the advantages of these hardware designs".

Assume an error-corrected machine

The Sussex team began by considering common algorithmic methods that could be implemented on a quantum computer. Importantly, the physicists focused on codes and algorithms that are self-correcting, meaning they assume errors in calculation will occur and that have built-in mechanisms for rectifying them before users see the results. "This paper is using some of the most up-to-date methods on the algorithm side, and also the up-to-date methods on the quantum error correction side," notes Gavin Brennen, a physicist at Macquarie University, Australia, who was uninvolved with the work. "And they focused on two key problems that are of use to the world."

(extracted with permission from an item by Karmela Padavic-Callaghan at physicsworld.com)



A blueprint for a quantum computer that uses trapped ions as qubits. (Courtesy: Ion Quantum Technology Group, University of Sussex)

The first electron counts – how anaerobic microbes 'breathe' iron

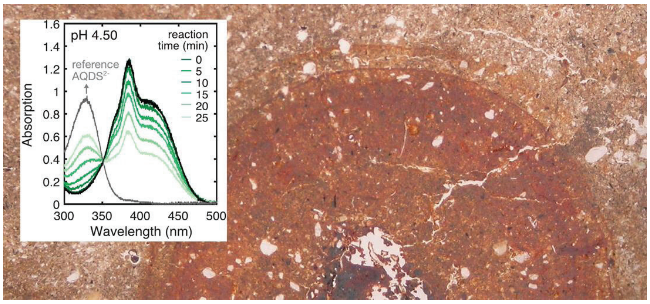
Life has a way of adapting to challenging environments. While humans – as well as animals and plants in general – rely on oxygen to burn their nutrients, some microbes in low-oxygen habitats have learnt to rely on iron-containing minerals as a substitute.

Scientists at ETH Zurich and the Swiss Federal Institute of Aquatic Science and Technology have now reported that the speed of two-electron transport from microbes to extracellular minerals may be best described by just considering the ease with which the first electron hops over. Using insight from electrochemical experiments combined with UV-Vis spectroscopy, the researchers reconciled literature data on the rate and energy balance of a reaction that is crucial to micro-organisms in anaerobic environments.

Most living species power various biological functions by passing electrons through a sequence of carriers of decreasing potential energy within a respiratory chain. Such a chain needs a constant source of high-energy electrons, usually from food (ingested or generated by photosynthesis) or another substrate, plus a sink to suck up low-energy electrons after they have done their useful work.

For most ecosystems, oxygen acts as this terminal sink; but under low-oxygen conditions, cells need to find alternatives. For example, minerals in the soil that contain iron in an oxidized form can take up these electrons. Because these grains of rock are located outside the cell, some microbes use extracellular electron shuttles (EES) – small molecules that can transport one or two electrons – to ensure efficient delivery. Therefore, the final stage of respiration in such organisms involves the release of electrons stored in EES to the iron mineral.

For any chemical reaction, two quantities are often of interest: how fast the reaction progresses – expressed as the reaction rate – and the free energy balance, which determines the direction of the reaction. Although these are not generally related parameters, Marcus Theory predicts that the transfer of an electron between two molecules will be faster if it is more energetically favourable (except in what is termed the "inverted" Marcus region). However, this correlation was not obvious in existing data describing the transport of two electrons from an EES to iron.



Anaerobic respiration: Iron oxide accumulations around plant roots in a floodplain soil; inset: spectroscopic trace of oxidation of an extracellular electron shuttle. (Courtesy: Andreas Voegelin, Eawag/ETH Zurich; PNAS 10.1073/pnas.2115629119)

This quandary motivated the Swiss team's experiments. The energy change involved in a reaction can be found mathematically by subtracting reduction potentials of the participating molecules. "Our biggest challenge was to find reliable values for the standard reduction potentials of EES," explains first author Meret Aeppli (now at Stanford University). "These values were indispensable for the calculation of Gibbs free energies."

Importantly, the researchers were able to determine this potential for each step of the two-electron process, not just an average value describing the overall reaction. Their results showed how the transfer of the first electron releases less energy than that of the second electron. When the researchers compared results from three different EES to the respective reaction speeds, they observed a consistent correlation only for the energy associated with the transfer of the first electron.

"We show that rates of iron oxide reduction by reduced EES scale with the free energy of the less exergonic [less favourable] first of the two electron transfers," says Aeppli.

(extracted with permission from an item by Simon Lichtinger at physicsworld.com)

Mysterious X particle spotted in quark-gluon plasma at CERN

A mysterious "X" particle comprising four quarks and first seen in 2003, has been found in the quark–gluon plasma produced in heavy ion collisions at the Large Hadron Collider (LHC). The observation was made by physicists working on CERN's Compact Muon Solenoid (CMS) experiment and if confirmed, it could help researchers understand the structure of the exotic particle. Further studies of the particle could help explain how familiar hadrons such as protons and neutrons formed from the quark–gluon plasma believed to have been present in the early universe.

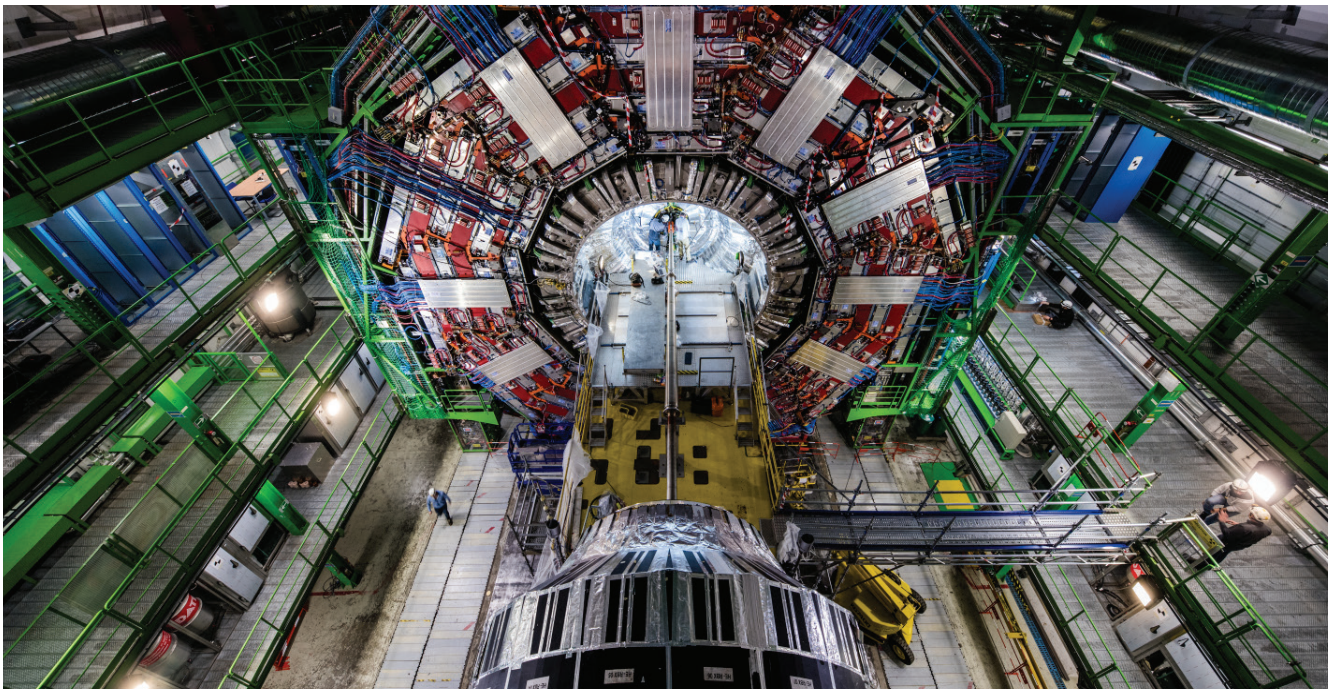
The exotic X particle – formally known as X(3872) because of it 3872 MeV mass – was first spotted by the Belle experiment in Japan. It has subsequently been studied by other experiments at electron–positron colliders and hadron colliders, but its nature is not fully understood. It could be a tightly bound tetraquark (a particle comprising four quarks) or a more loosely bound "molecular" state comprising two mesons (each containing two quarks).

Others have suggested it may be more bizarre still. "A common hypothesis is that the X(3872) might be a superposition of a conventional charm–anticharm pair and either a tetraquark or a molecule," says particle physicist Tom Browder of the University of Hawaii, who was part of the Belle collaboration and now works on its successor Belle II.

Insights into hadronization

Studying the X particle's production in a quark–gluon plasma could help to resolve this debate. This is because different internal structures are predicted to have different decay rates within the quark–gluon plasma. Another reason to study this system is that the normal matter in the universe (protons and neutrons) is thought to have condensed from a quark–gluon plasma a fraction of a second after the Big Bang – a process called hadronization. Studying the decay of exotic particles like X(3872) into normal particles could provide valuable insights into this process.

(extracted with permission from an item by Tim Wogan at physicsworld.com)



X marks the spot: the CMS experiment at CERN undergoing an upgrade. (Courtesy: Maximilien Brice/CERN)

Product News

Lastek Pty Ltd

Ninox 640 SU High resolution, low noise, Deep cooled, digital SWIR camera.

Raptor Photonics continues to push the boundaries in scientific SWIR imaging with the launch of the Ninox 640 SU, a vacuum cooled to -80°C InGaAs camera, offering ultra-low dark current for longer exposure times up to 5 minutes. Combining a low read noise of <56e- in high gain and a dark current reading of <300e/p/s at -80°C, the Ninox Ultra is one of the most sensitive SWIR cameras available on the market and perfect for imaging weak signals using longer exposure times. It offers a resolution of 640×512 and has a 15µm x 15µm pixel pitch. The camera also offers a high intra-scene dynamic range of 56dB in high gain, enabling simultaneous capture of bright and dark portions of a scene. The Ninox 640 SU follows on from the launch of the Ninox 640 and Ninox 1280 cameras, which have attracted a lot of interest in applications including astronomy and in-vivo imaging.

MIRO ALTITUDE: Gentec-EO's new top-of-the-line power meter for laser beam measurement now available!

The much-anticipated MIRO ALTITUDE from Gentec-EO is now available for purchase worldwide. This new laser beam measurement instrument is designed to help engineers and service technicians increase their productivity thanks to numerous new features in both hardware and software.

With MIRO ALTITUDE, Gentec-EO brings numerous new interesting functions and features to its line of product:

- 10” high-resolution, anti-glare touchscreen, just like one would expect nowadays for a professional work tool.
- With its modern and intuitive user interface, MIRO ALTITUDE is so simple to use that it is literally plug-and-play. It was designed to take full advantage of its larger-than-life screen so you can see at a glance all that matters to your measurement at all times.
- Remarkably strong and durable metal casing that you won’t be afraid to break in the field or during transportation.
- More connectivity possibilities than ever before with: Ethernet, RS232, GPIO, external trigger, sync out, analog out, USB-C and 2 USB. No doubt you’ll be able to do the setup you need for optimal productivity.
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- 3 display modes, including one that lets you time-travel to check past data points without interrupting

the current measurement session, and another mode with extra large size digits that you can view from across the room.

- Measure up to 10x faster (detector-dependant) with XNR AnticipationTM, which is probably the fastest measuring capability ever brought to a measurement instrument in this industry.

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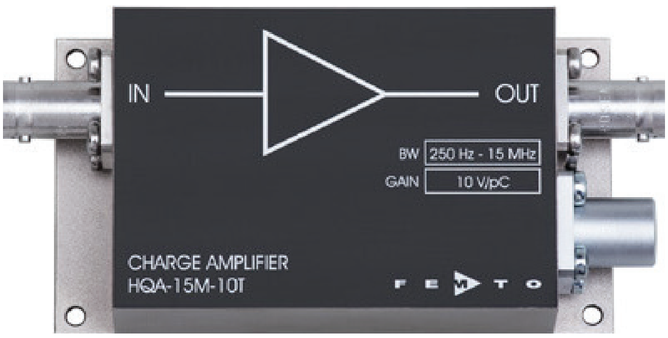
- Save and organize your recorded measurement sessions and screenshots or move your files to your USB stick.

- MIRO ALTITUDE is compatible with all Gentec-EO detectors, both power and energy.

Femto: Quartz Tuning Fork Charge Amplifier from 250 Hz to 15 MHz [FEMTO.png]

With the extremely low-noise quartz tuning fork charge amplifier HQA-15M-10T, FEMTO has added an application-specific amplifier to its product range. The HQA-15M-10T is a charge amplifier specially developed for pure AC sources which, on average over time, neither have nor generate a DC component. Accordingly, the HQA does not require any resetting of the integration stage. It is best suited for quartz tuning forks, such as used in atomic force microscopy (AFM). Pyro- and piezoelectric detectors as well as longitudinal resonators are further suitable signal sources.



FEATURES

- High gain of 1 x 1013 V/C

- Wide bandwidth from 250 Hz to 15 MHz

- Low input noise of 40 zC/√Hz and 700 pV/√Hz

- Excellent signal-to-noise ratio across the full bandwidth

- Ideal for AC coupled charge sources such as pyro- and piezoelectric detectors, tuning fork quartz crystals and longitudinal resonators

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Lastek Pty Ltd (+61) 08 8443 8668
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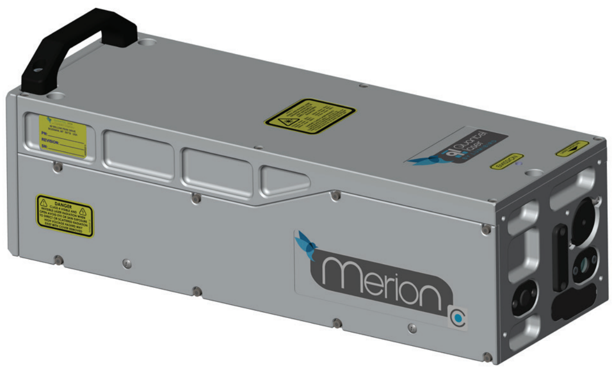
Coherent Scientific

Quantel Merion C by Lumibird

The Merion C is the latest development from Lumibird-Quantel laser diode-pumped nanosecond Nd:YAG range. The Merion C delivers 100 mJ @ 1064 nm up to 400 Hz and can be equipped with fully integrated harmonic generators, down to 266 nm, to cover a wide range of applications.



All key components such as laser diodes, gain modules and laser driver electronics are internally designed, ensuring full vertical control of the entire process.

It represents the best solution for demanding applications like LIDAR, LIBS or material processing.

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- Easy installation and an interchangeable power supply to reduce the effects of downtime

- Pump diode warranty: 2 billion shots

Introducing the New Bruker Dimension IconIR AFM

Introducing the New Dimension IconIR, a system that combines Bruker's industry-leading Dimension Icon® AFM and nanoIRTM photothermal IR nanospectroscopy to establish new standards in nanoscale property mapping. The IconIR delivers a comprehensive correlative spectroscopy and microscopy solution for quantitative nanochemical, nanoelectrical and nanelectrical characterisation on a single platform.

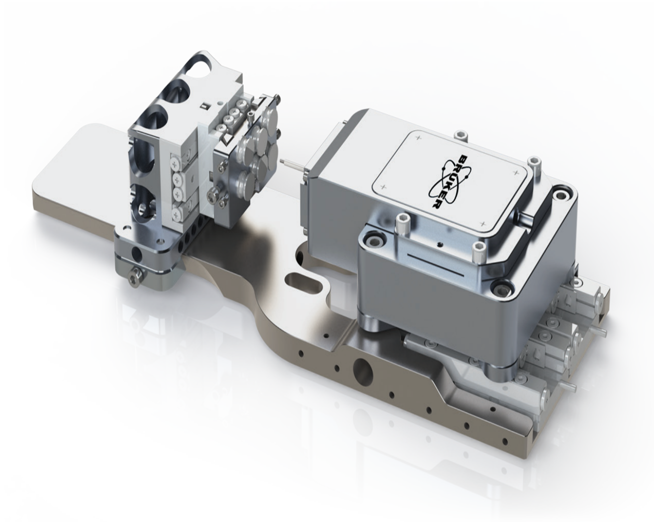
Featuring sub-10nm chemical imaging resolution with monolayer sensitivity, the system's large-sample architecture significantly extends the capacities of the Dimension Icon, the world's most used large-sample AFM platform, to provide ultimate sample flexibility and renowned performance.

The standard system supports samples of up to 150mm, with options for larger samples also available. Bruker's patented suite of photothermal-based AFM-IR spectroscopy modes is the most comprehensive available, with hundreds of publications demonstrating its success as the world's leading nanoIR technology.

Introducing High load DMA for Hysitron PI89

Bruker's Hysitron PI 89 SEM PicoIndenter is now available with High Load DMA, enabling nanometre-to-micron dynamic property measurements. High bandwidth 500mN and 3.5N transducers with advanced control electronics fully optimise large-scale dynamic testing and provide industry-leading performance and sensitivity.

High Load DMA is useful for analysing high-strength materials, studying large pillar and particle compression, profiling higher indentation depths, identifying compression of large 3D lattice structures and soft materials, and characterising higher strain in cantilever samples.



To schedule you virtual demo to see how the Hysitron PI 89 provides researchers with greater capabilities, versatility, and performance please contact:

Christian Gow
sales@coherent.com.au
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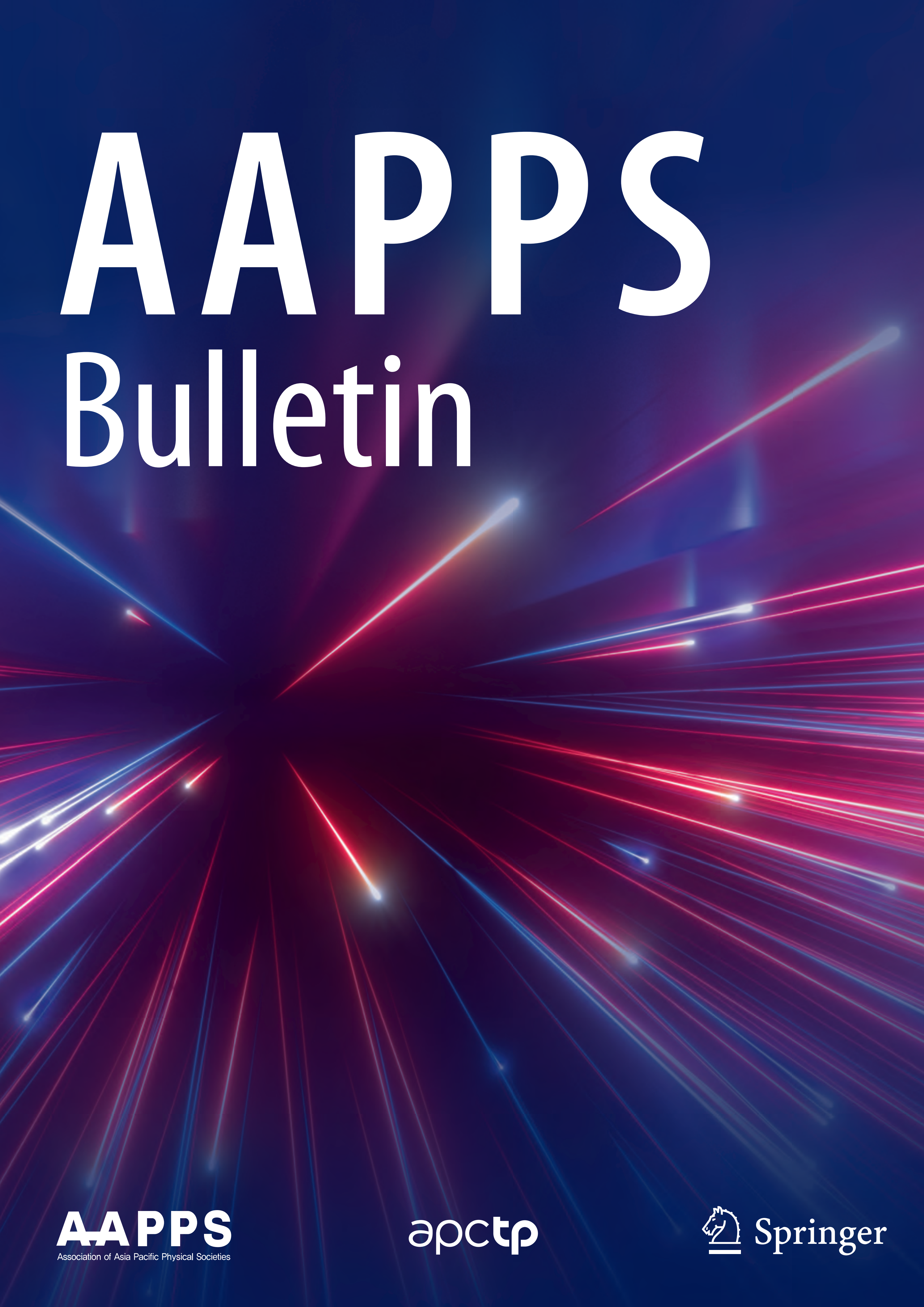
AAPPS Bulletin



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