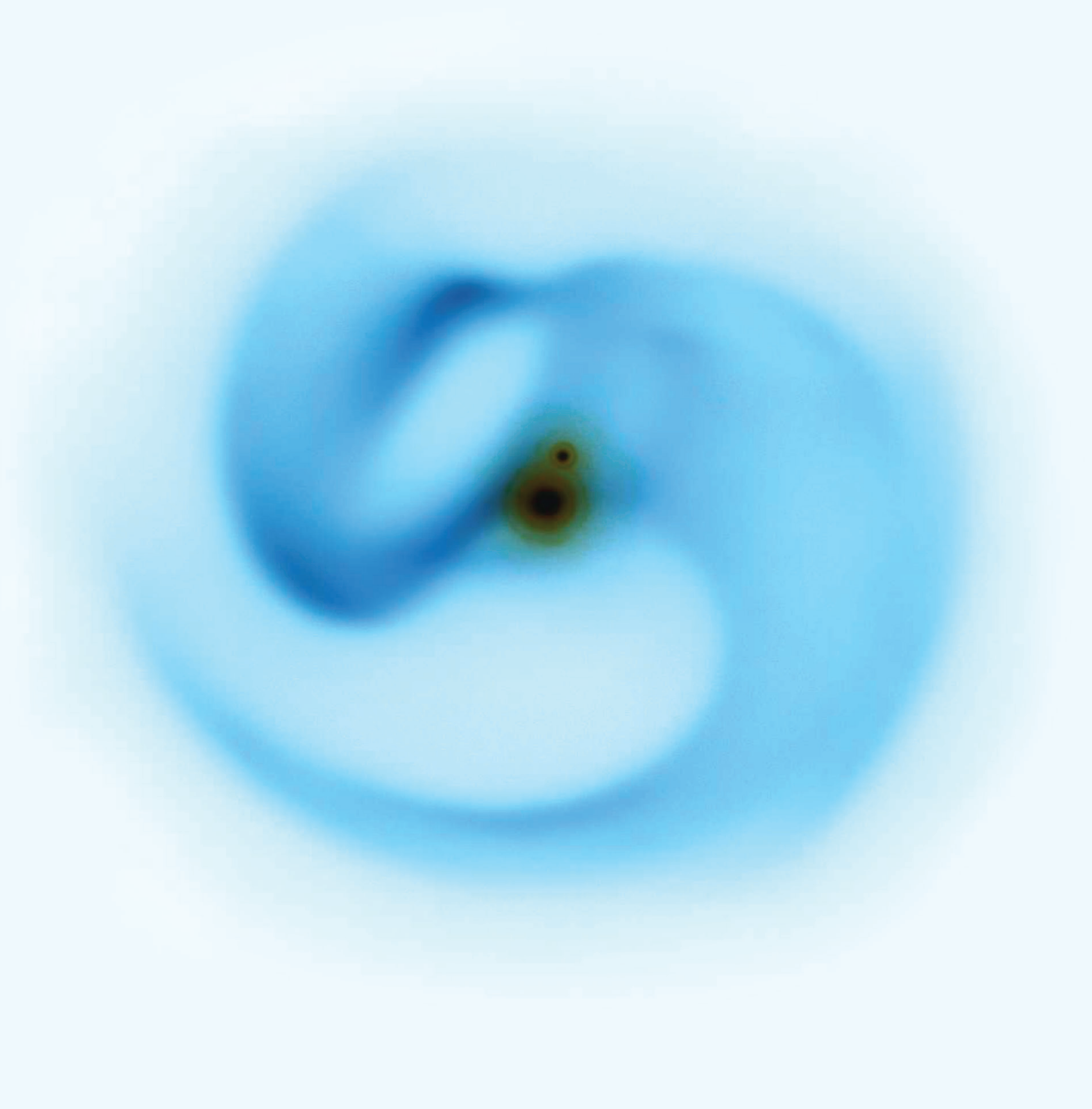
Australian
Physics

VOLUME 58, NUMBER 3, JULY-SEPT 2021



PHYSICS LABS – THEN AND NOW

APEP AND THE DEATH OF MASSIVE STARS

IN CONVERSATION WITH SHANE HUNTINGTON

Raptor Photonics – Capturing Tomorrow

Raptor photonics

The new improved Ninox 640 II

Best **VIS-SWIR** scientific camera in the market today!

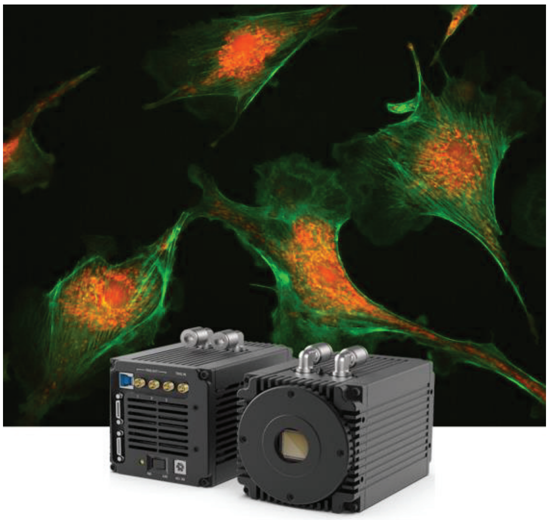
- VIS-SWIR camera
- Res: 640x512
- Pixel size:15µmx15µm
- Air Cooled to -15˚C
- 18e- Readout Noise (typ)

Ninox 640 SU

- The best performing SWIR camera in the World!
- Res: 640x512
- Pixel size:15µmx15µm
- Vacuum cooled to -80°C
- Ultra-low dark current and read-noise
- < 56e- Read Noise

Ninox 1280

- VIS-SWIR camera
- Res: 1280x1024
- Pixel size:15µmx15µm
- Cooled to -15˚C
- <50e- Readout Noise



Introducing Tucsen Photonics: Scientific Imaging Cameras

Tucsen's core products are the world's first back-illuminated sCMOS cameras (Dhyana95 and Dhyana400BSI) for life science research, astronomical discovery, physical microparticle detection, and cutting-edge medical imaging. Offering a popular high quality embedded camera (TrueChrome), which is used in industrial inspection, pathology, surgical video, jewellery inspection and other industrial applications.

LaVision Cameras for Intelligent Imaging

In Applications:

- Fluid Mechanics
- Materials Testing
- Automotive
- Sprays
- Combustion
- Industrial Imaging
- Mixing & Thermal Flows
- Fluid-Structure Interaction
- Particle Characterization

LAVISION
FOCUS ON IMAGING

All Products Exclusively distributed by:

Lastek
Photonics Technology Solutions

Contact:

sales@lastek.com.au

www.lastek.com.au

Photonic Professional GT2

The world‘s highest resolution 3D printer

Nanoscribe Photonic Professional GT2 uses Two-Photon Polymerization (2PP) to produce filigree structures of nearly any 3D shape. Flexibility in design combined with straightforward operation and a wide range of materials and substrates make the Photonic Professional GT2 an ideal instrument for science and prototyping in multi-user facilities and research laboratories.

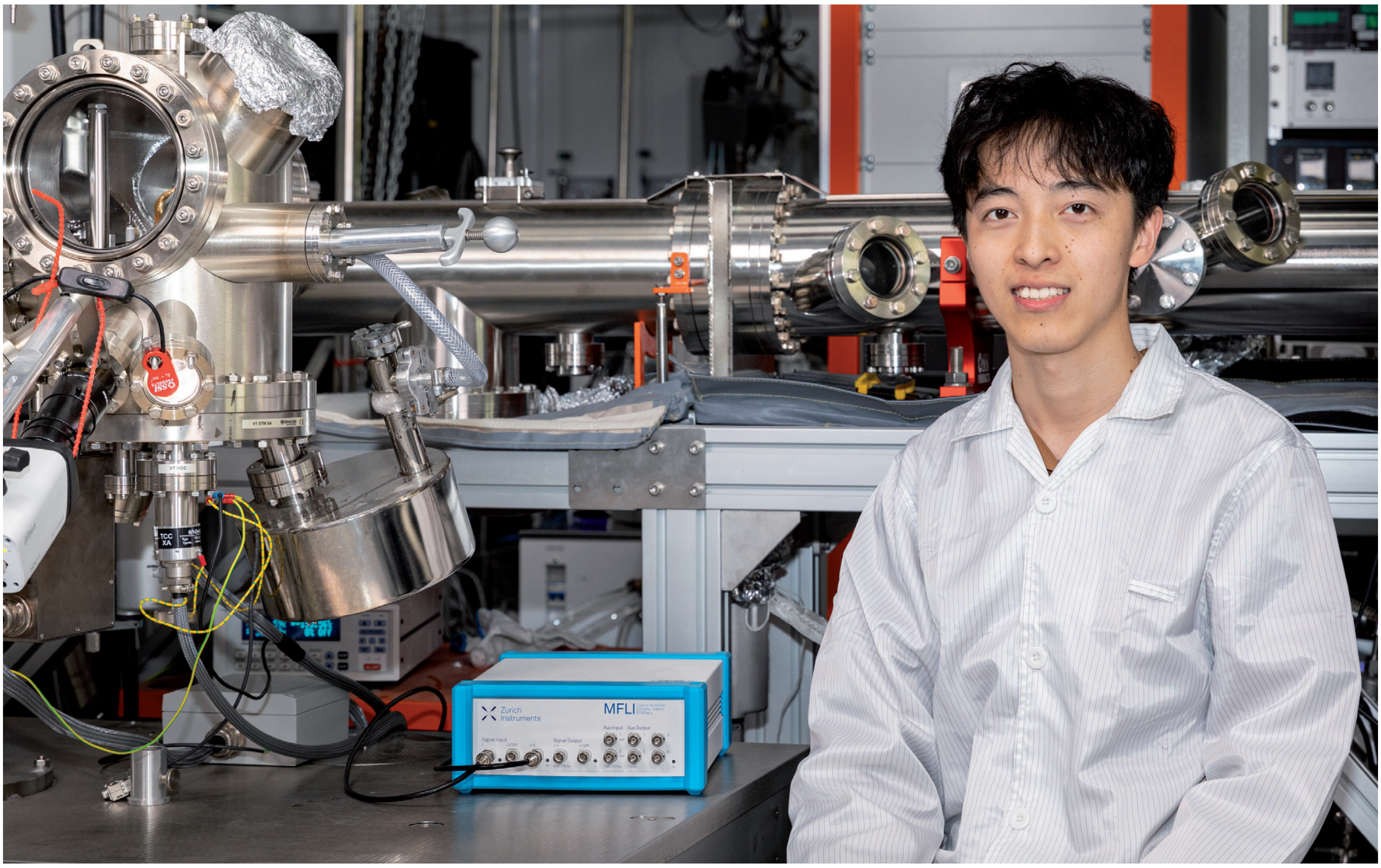
DESIGNED FOR RESEARCH AND RAPID PROTOTYPING IN

- Microfluidics
- Micromechanics
- Biomedical engineering
- Micro-electromechanical systems
- Mechanical metamaterials
- Photonic metamaterials and plasmonics
- Microoptics
- Nanostructures

Contact our sales agent
Warsash Scientific

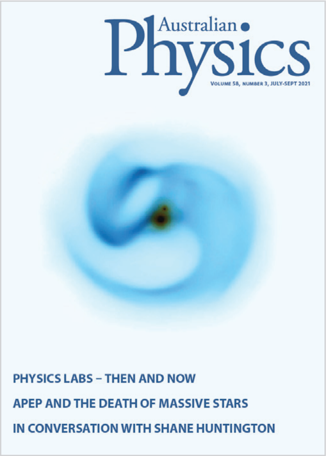
+61 293 190 122
sales@warsash.com.au
www.warsash.com.au

Warsash Scientific
Advanced Instruments for Research & Industry




Zurich Instruments
MFLI

CONTENTS



Australian Physics
VOLUME 58, NUMBER 3, JULY-SEPT 2021

PHYSICS LABS – THEN AND NOW
APEP AND THE DEATH OF MASSIVE STARS
IN CONVERSATION WITH SHANE HUNTINGTON

Mid-infrared image of the Apep star system displaying the speculator sinuous dust spiral being sculptured by the massive binary located at the centre. Credit: ESO/Callingham

Australian Institute of Physics

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

AIP contact details:
PO Box 480, West Ryde, NSW 1685 Phone: 0478 260 533
aip@aip.org.au

AIP website: www.aip.org.au

AIP Executive
President Prof Sven Rogge
aip_president@aip.org.au
Vice President Prof Nicole Bell
aip_vice_president@aip.org.au
Secretary Dr Kirrily Rule
aip_secretary@aip.org.au
Treasurer Dr Judith Pollard
aip_treasurer@aip.org.au
Registrar Prof Stephen Collins
aip_registrar@aip.org.au
Immediate Past President Prof Jodie Bradby
aip_past_president@aip.org.au

Special Projects Officers
- Medals, Awards and Prizes Dr Joanna Turner
aip_awards@aip.org.au
- Policy Dr Gerd Schröder-Turk
aip_policy@aip.org.au
- Outreach Dr Tim van der Laan
aip_outreach@aip.org.au
- Finance Dr Stephan Rachel
aip_finance@aip.org.au

AIP ACT Branch
Chair (vacant)
aip_branchchair_act@aip.org.au
Secretary Dr Wayne Hutchison
aip_branchsecretary_act@aip.org.au

AIP NSW Branch
Chair Dr Scott Martin
aip_branchchair_nsw@aip.org.au
Secretary Dr Frederick Osman
aip_branchsecretary_nsw@aip.org.au

AIP QLD Branch
Chair Dr Till Weinhold
aip_branchchair_qld@aip.org.au
Secretary Mr Joel Alroe
aip_branchsecretary_qld@aip.org.au

AIP SA Branch
Chair Prof David Ottaway
aip_branchchair_sa@aip.org.au
Secretary Dr Laurence Campbell
aip_branchsecretary_sa@aip.org.au

AIP TAS Branch
Chair Dr Krzysztof Bolejko
aip_branchchair_tas@aip.org.au
Secretary Dr Jason Dicker
aip_branchsecretary_tas@aip.org.au

AIP VIC Branch
Chair Dr Daniel Langley
aip_branchchair_vic@aip.org.au
Secretary Dr Sherman Wong
aip_branchsecretary_vic@aip.org.au

AIP WA Branch
Chair Dr Stuart Midgley
aip_branchchair_wa@aip.org.au
Secretary Dr Stephanie Black
aip_branchsecretary_wa@aip.org.au

Australian Physics

A Publication of the Australian Institute of Physics

GUIDELINES TO CONTRIBUTE
Articles or other items for submission to Australian Physics should be sent by email to the Editors. Only MS Word files will be accepted; a template with further guidelines is available online at the AIP websites (www.aip.org.au).The Editors reserve the right to edit articles based on space requirements and editorial content.

ADVERTISING
Enquiries should be sent to the Editors.

Published four times a year.

Print Post approved PP 224960 / 00008
ISSN 1837-5375

PRODUCTION & PRINTING
Pinnacle Print Group
1/3B Newlands Road, Reservoir VIC 3073
pinnacleprintgroup.com.au
Ph: 8480 3333

Editorial

…let's talk about progress instead

Let's not talk about coronavirus for a moment. We're not in denial–across the community, we are just… weary. Let's instead talk about progress.

In STEM we progress with inclusion and diversity. Quantitatively, progress is modest; qualitatively, the conversation is focussed on improving diversity. Overleaf, Nicole Bell reflects on the recent IUPAP International Conference on Women in Physics, and the AIP's commitment to engaging underrepresented groups in our discipline. Progress is underway, there is work to do, and it is up to us to roll up our sleeves and get to it.

Progress also comes through effective communication. Recently, we were in conversation with Shane Huntington, a science communicator and radio host based in Melbourne. Shane shared his motivations to step into and out of research, what he has learnt about bringing science closer to society, and the significance of a piece of fabric from the Wright Brothers' first aeroplane. In the same theme, Les Kirkup critically examines what physics teaching lab programs can and should look like in the near future, and Deb Kane calls for contributions to the AAPPS Bulletin. We echo her call to make the most of this opportunity to communicate physics in the Asia Pacific region.

Sometimes allusions and metaphors can help communicate the essence of scientific enquiry. Joseph Callingham and his team successfully piqued people's interest when they named star system 2XMM J160050.7-514245 after the Egyptian demon of chaos *Apep*. This naming helped them to tell a story about their new insights into how massive stars die. *Apep* also made it on the cover of this issue.

Whichever kind of progress you would like to contribute to, feel free to take some inspiration away and help develop physics and science 'out there'.

Finally, we kept some news to the prominent last paragraph. We would like to extend a warm *Welcome!* to Dr Clara Teniswood, who recently joined the editorial team. Keep an eye out for her bio in this issue, and her contributions to future issues of *Australian Physics.*

Best wishes,
David Hoxley and Peter Kappen.

From the Executive

COVID-19 through a diversity lens

As I write, three Australian cities are again in lockdown. Colleagues around Australia are contending with a myriad of pandemic-imposed challenges to their research programs, while grappling with "Zoom fatigue".

A significant and, perhaps, lasting change imposed by the pandemic is the way in which we conduct conferences and network with colleagues. Last week, Australia hosted the IUPAP International Conference on Women in Physics, ICWIP2021, organised in partnership with the CSIRO, the AIP, and numerous Australian physics departments and physics-based government organisations. Originally scheduled to be held in Melbourne in 2020, this meeting was shifted to a fully virtual experience, co-chaired by Swinburne Pro-Vice Chancellor Sarah Maddison, and Australia's Chief Scientist and former AIP president Cathy Foley.

Described by Cathy as a "global, digital, women in physics movement", over 370 participants from around the world attended online workshops and networked during virtual social events. While the online format certainly has drawbacks—for one, it is very hard to replicate the quality of networking opportunities afforded by in-person, face-to-face, meetings—the covid/zoom era has ushered in some positive changes. It has broken down barriers, making international conferences accessible to those who might otherwise have been prevented from attending due to family responsibilities, time constraints, or the financial and logistical challenges faced by scientists from developing nations.

While many of us are itching to return to in-person conferences and workshops as soon as normal travel arrangements resume (I know I am!), we should think about which aspects of this "new normal" we wish to retain as we seek the right balance between virtual and conventional conference formats.

The ICWIP highlighted the challenges, opportunities, and progress made in the important task of making our discipline more diverse. While female physicists in high-income countries had different experiences to women in developing nations, there was nonetheless much commonality of experience. Women in STEM ambassador Lisa Harvey-Smith reminded us that, as scientists, data matters! We know how to measure, record, evaluate, and take evidence-based action. There have certainly been many positive initiatives around the world, including the Australian Athena Swan program. Yet, there is more work to be done. We all have a responsibility to call out things that are not right. In a "men as allies" session, chaired by AIP president Sven Rogge, Brian Schmidt commented that, in fact, it is often easier for men to call those things out.

Coincidentally, last week, the Australian Academy of Science released a report on the "Impact of COVID-19 on Women in the STEM workforce". While the pandemic has impacted the entire STEM workforce, particularly our early career researchers and others in precarious employment situations, pre-existing gender inequity has been exacerbated.

The report revealed that, of those women considering leaving the STEM workforce, lack of opportunities was nominated as the top reason (36%) followed by job insecurity (25%). While men nominated those reasons too, the percentages were lower. Interestingly, nearly half of the women who listed lack of opportunity were in permanent roles, perhaps reflecting structural barriers to progression. On a more positive note, the report found that the main reasons women remain in STEM are personal passion for their work (59%) and work fulfillment (46%).

These are important issues in which we all have a stake, and AIP is committed to increasing the engagement of under-represented groups in physics, via the work of the DEGAP group and beyond. Only through ongoing conversations will we cement the changes needed to make our field stronger and more diverse.

Nicole Bell, AIP Vice President

In conversation with Shane Huntington, OAM

Shane Huntington is a fixture of the Melbourne science communication scene, widely known as the presenter of 3RRR's 'Einstein A Go-Go' radio show since 1993. He is also a physicist. In 2020, he was awarded the Medal of the Order of Australia for his service to science as a communicator. This is an edited excerpt of his recent conversation with the Editors of Australian Physics.

Origins in research

I was always innately curious about the world and loved the challenge of trying to explore new things. My PhD measured the non-propagating optical fields around an object, what we call evanescent fields. You need to put a local probe within a few tens of nanometres of a surface in a controlled way. That was my area of love, basically optics on the nanoscale.

I remember trying to do this on a particular object for three or four months and failing. This is what science is about - it's not winning every day. I tell young scientists today that a great scientist is someone who, when something special happens on one day in a year, has the skills and capability to know this, when other people don't. That happened to me when I was looking for these fields. I remember taking one or two measurements, and then about another three hundred because I wanted to make sure I had all the data I needed on that one lucky day. I loved the challenge of beating nature in that way-getting the answers you need, that you didn't know the day before.

After a postdoc in the US I broke a vow to my Year 12 chemistry teacher to never touch the subject again, and took a position running the Scanning Microscopy Analytical Lab at the University of Melbourne. I had half of my time to do whatever I wanted, which was just fantastic, and the other half doing service work for a lot of different clients with different samples, everything from pieces of videotape to pieces of cheese.

The best stuff often comes from the things that you didn't expect. I was very lucky in my career. I remember sitting in front of a monitor once while a colleague from Sydney and I were scanning a particular optical fibre and we both saw this particular pattern and we looked at each other. Those sorts of moments you remember for the rest of your life, they're incredible.

Moving on from the lab

I was lucky enough to get one of the STI innovation grants to fund a 9.3-million-dollar centre. Even better, one of the conditions of the grant was that I'd be CEO of that centre. I'd done some commercial work with the government, so they knew of my capabilities in the area. It was interesting that it had nothing to do with my physics; it only had to do with my commercial background. I ran that centre between 2005 and 2008. I absolutely love science, but towards the end, I found myself sitting behind a desk the entire time whilst my staff were having fun in the lab, and that wasn't the future I wanted. Then I got an offer I couldn't refuse, which was to become the principal strategy advisor to the Vice-Chancellor of the University of Melbourne.

I loved applying for grants. That's probably easy to say when you get them, but to me it was a bit like gambling; just put your best foot forward. About 80% of getting a grant is communication, 20% is the science.

The Order of Australia

The Order of Australia award was for service to science as a communicator. I do it because I love it. It's such a privilege to be able to communicate science to a very broad audience. When I got the letter from the government, I cried a little bit. It was a pretty emotional moment. It meant that somebody noticed, which sounds odd when so many people listen to the show every week. I have worked in environments where they just don't value it at all, which is disturbing because I think it has great value. It meant a lot to me, also for my kids and for my, parents to see that. I grew up in a part of Melbourne where you didn't go to Government House. It was a big deal.

Communication within science education

There are almost no universities that have communication as a core subject, either undergraduate or postgraduate, during the training program of scientists. There are some masters in science communication designed for people going into a science communication career, not for being scientists that communicate. There is a huge gap in the training requirements as I see them for any scientist. Why do I have to learn so much communication stuff for being a scientist as well? You write grants, write papers, give talks, teach, engage with government and the public. Pretty much every single thing that you do as a scientist involves communication.

Aftermath of the 2009 L'Aquila earthquake. Image credit: TheWiz83/ CC-BY-SA-3.0

I learnt my communication skills in two places. One was working in a retail job when I was a teenager; it taught me a lot real fast. And second was my work on radio, where if you don't learn to communicate really effectively really fast, you just get kicked off.

I suggest that people try and spend as much time learning to communicate as they did English or mathematics. This is a core skill that everyone should learn. But in a very different way to the traditional mechanisms that universities use.

Media training courses, for example, are a very limited scenario. I could teach you every rule needed for you to go into one of our major television channels and be interviewed for the nightly news; what will happen, what the exchange will be like for you, the whole lot. But if you haven't first learned how to be an effective communicator, those rules won't help you. We don't teach that basic level of communication. I run workshops and teach students across the country and internationally. If they want to learn how to do media communication, like being on radio for 30 years, I can teach them that too. But I do that after I teach them how to communicate first.

Advice for aspiring communicators

Find courses and workshops and programs and do as many as possible. Look for opportunities to be part of podcasts. Give talks to school kids. They'll always be honest with you. Give a talk in front of your peers and they will say, "Oh, that was good. Well done." Talk in front of a group of primary school kids and they'll tear you apart. Look for those opportunities to communicate your science and get as much feedback as possible. Make sure you ask for your feedback in an appropriate way. Don't just walk up to someone after the talk or whatever you're doing and say, "what did you think?" Prepare them before that. Tell them what type of feedback you want, because that will get you a lot more information that's useful. Learn by doing; find workshops and programs to teach.

Communication has consequences

Scientists have positions of incredible power. They often don't realise it, but society does listen and change their behaviour based on what scientists say. If we get that wrong, we can cause a lot of damage.

In 2008, there was a very severe earthquake in the small Italian town of L'Aquila and about three hundred people died. Six seismologists and one government official were sent to jail for manslaughter. This is one of the greatest examples of poor communication, because the information that was given out by that committee (as a result of foreshocks) was misleading to the public. About thirty of the people who died in the town didn't do what they'd been trained their entire life to do during an earthquake because they'd been made so comfortable by the science communication that they didn't think there was any danger. I have a picture of the bottle of red wine that the government official recommended everyone drink that night to relax. It led to an outcry all over the world. How could you imprison these scientists? Some of these areas have responsibility and the public makes decisions based on the information that you give them.

I see some extraordinary science communication going on. For example, a professor and researcher at the Royal Children's Hospital, Margie Danchin, whose job is to convince concerned parents to vaccinate their children. She does that by listening to what worries they have about the effects of the vaccines, and then she takes that information and then delivers scientific information to them in a way that is most important to them and has an incredible conversion rate with regards to getting people who otherwise weren't vaccinating their kids to do so. When you take account of what the audience actually cares about, you deliver your science message in a very different way.

We put out too much information. The idea that I'll just keep giving you data and you will somehow take on that data and that will convince you to change your mind about something is flat out wrong. Whenever I talk to people giving a one hour presentation, I'll say "what are the two things you want people to remember?" And they'll look at me like I've just stabbed them in the heart. I can remember two things, and you're going to have to do a pretty good job to make me remember those two.

When we see movies or we listen to music, there are certain things that make us remember. I'm sure you have seen an advertisement on television when you're a child that you still remember today. That's the goal of these companies. We have to start doing that more in science. We put so much out and often it's quantity over quality. When you ask the average person in the public, they just don't remember, they don't care.

Recently there was the first ever demonstration of the flight of a helicopter on Mars. The news channels picked it up. What they didn't tell you is that there's a piece of fabric from the first plane that the Wright brothers flew wrapped inside the helicopter. A piece of the same plane flew on the Apollo 11 mission that landed on the moon. That's a beautiful story. When I tell you these things, you remember these narratives because they have some emotional value to them as well. If I told you the width of the helicopters blades and its weight you’d forget that in thirty seconds.

The amazing work from LIGO as another great example. This is how I told the story to a group of high school kids very differently. Just over 13 billion years ago, something happened in the universe. This ripple in space started traveling across the universe. In just over four billion years ago, the earth was formed. A couple hundred thousand years ago, humans were starting to stand erect and starting to become intelligent. A couple of thousand years ago, we built the pyramids. 100 years ago, Einstein was doing his thing. Six months ago, we started building this LIGO experiment to try and detect gravitational waves. Now you remember that thing from 13 billion years ago, that explosion that occurred, it happened to go past us a month after we built the LIGO experiment after travelling for 13 billion years. When you draw this out and show people physically it's a beautiful story almost of coincidence, you think what is the chance of that ripple going past us just a month after we've got the experiment? We all know now that there's many of these ripples going past; there's plenty to detect. But we didn't know that at the time. We just detected one. And that creates a beautiful narrative around what is otherwise a very technical experiment.

Respect for industry

One of the problems with most universities is a lack of understanding or respect for industry. Sometimes you don't have to be an academic or have a publication record in the traditional sense to be valuable to teaching undergraduate or graduate students. I've been doing radio now for 30 years. I've interviewed thousands of people, hundreds of thousands of listeners, every week. Extraordinary level of knowledge there. Do I publish it in academic journals now? Of course I don't. If you're an undergrad, you wouldn't find a lot of people better at teaching it than me. But I don't have the traditional academic credibility in that space to do that teaching. And this is where universities need to link up more with outside industry. I hold the honorary position at the University of Melbourne in the School of Chemical Engineering, and I'm not an engineer. I'm not a chemist. But I hold that position because I offer them commercialisation expertise. That's a very enlightened attitude that there are things that they need that they can bring in from outside the traditional requirements of academia.

Supporting communicators

I would love to see greater respect and recognition of those in the physics community that are great communicators. If you get a paper in Nature you get a lot of recognition for that as you do if you get a big grant. But if you beautifully communicate a piece of physics to the community, you don't get any recognition for that. There's been some great recognition in the School of Physics at Melbourne University with the July

Shane Huntington

lectures in physics and their value and their continued existence over many, many decades. Beyond that, I don't see a lot of it. I would love to see a lot more recognition of also those who are great teachers of physics. Some of the best teachers of physics are not necessarily the best researchers.

Areas like physics are tough to get across. In medicine, everyone wants to listen because it's about my health. I got the state government to fund my centre in quantum encryption technology. That sounds boring even to me, but we did a fantastic job of communicating that to a government panel that had virtually no science background. You might argue we got some recognition of that with the grant money. But no one said "they got that grant because of the communication." I'd like to see the physics community recognising that and just how much work there is ahead of us in training our next group of physicists in that space, because it really is going to matter a lot more in a world that is so much more connected in a communication sense. Every physics student is on Twitter, I guarantee it. That doesn't mean they're doing good work on Twitter. It just means they're putting out information, sometimes in an uncontrolled way. But there's an incredible power there to communicate what we do if it's done well.

Clara joins the editorial team

The Editors of Australian Physics are delighted to announce that we are joined by Clara Teniswood. She will be helping us with the Young Physicists Page and some special projects. The YPP will return in the next issue.

I am excited to be joining the Australian Physics editorial team. Although my career journey thus far has not been linear, I have been passionate about communication since my school days and this has probably earned me a reputation of being somewhat pedantic by my colleagues!

I have always been interested in climate change – both the physical processes and the impacts on our environment. After my physics Honours year, I was fortunate to find a PhD project with Jodie Bradby on the mechanical properties of pteropod (sea butterfly) shells and how these were affected by ocean acidification. Being able to see the direct link between physics and everyday life is something that I struggled with during my undergraduate degree. This PhD project was ideal for me because the importance of the relationship between a shell's mechanical properties and the organism's ability to withstand an acidifying ocean was clear (they are at the bottom of the food chain!).

When I finished my PhD, I decided to become a secondary school maths and science teacher. Communicating the link between my subject areas and the real world to my students was always at the forefront of my mind. While teaching was certainly fulfilling, I decided last year to pursue my interest in climate change by studying a Master of Climate Change. I am now working at the Department of Agriculture, Water and Environment, where I analyse the impacts of mining and other large developments on water resources and communicate these risks to regulators. In this role, my physics background has paid dividends by assisting me to quickly grasp many geological and hydrological concepts.

During my time as a teacher, Australian Physics kept me up to date with physics news and developments. I am looking forward to building the Young Physicists section as a resource for both young physicists and their teachers. With the number of physics-trained physics teachers in Australia declining, Australian Physics is a valuable resource for new (and experienced) teachers of physics and a source of inspiration for the next generation.

Apep: a new star system confounding our ideas about how massive stars die

Joseph Callingham
Veni Fellow
Leiden Observatory, Leiden University, PO Box 9513, 2300 RA, Leiden, The Netherlands –jcal@strw.leidenuniv.nl

Wolf-Rayet (WR) stars represent the final stage of the evolution of the most massive stars. These stars are often part of a binary system in which the winds of the two stars collide and can produce spectacular dust plumes that encode the parameters of the winds. My colleagues and I recently discovered a new WR system we nicknamed Apep after the Egyptian god of chaos. Apep is adorned with a prominent spiral dust plume that is revealed to be expanding six times slower than the measured stellar wind speed. As the dust should be moving at the stellar wind speed, such an observation is inconsistent with existing models of evolved stellar systems. We propose that this contradiction can be resolved if Apep is capable of launching extremely anisotropic winds. Near-critical stellar rotation is known to drive such winds, suggesting that Apep may be a Galactic progenitor system for long-duration gamma-ray bursts—the most energetic events in the Universe.

Introduction

Wolf-Rayet (WR) stars represent the final evolutionary stage of the most massive (>20 solar mass) stars. They are characterised by powerful high-velocity winds that carry large mass-loss, over four orders of magnitude larger than the Sun's solar wind [1]. Such large mass-loss plays a fundamental role in enriching the interstellar medium of the Milky Way in metals; embers that will be used to form the next generation of stars [2].

WR stars are often found in systems with a massive binary companion. When the WR is of a particular evolved sub-type, they can be dust-making factories generating striking spiral patterns via the interaction of its winds with its binary partner. These dust structures surrounding such colliding-wind binary (CWB) systems are rare and powerful astrophysical laboratories for testing our understanding of WR stars. This is because such patterns encode the mass-loss history of the systems and the orbital dynamics of the system.

Since the late 1990s, astronomers have identified a handful of WR systems with "pinwheel" dust-patterns, such as the archetypal WR 104 [3]. These studies have shown that the dust (as traced by its proper motion in the thermal infrared) and the gas (the dominant wind component in the line of sight revealed by spectroscopy) have been shown to be co-moving. Therefore, CWB systems that contain WR stars can be used to robustly test our ideas of how massive stars die.

Furthermore, WR stars are thought to be the immediate precursors to core-collapse supernovae and gamma-ray bursts (GRBs). These GRBs are the most energetic events in our Universe, and it is hypothesised that rapidly rotating WR stars are likely the progenitors of some of these events [4]. Rapid rotation is required by GRB models since a jet formation at the time of supernova is needed to generate the observed high energies [4].

However, for WR stars that have similar chemical abundance to our Sun, they will not be rapidly rotating when they eventually collapse because the strong WR winds will rob the star of angular momentum. One channel to ensure a WR is quickly rotating before undergoing a core-collapse supernova is through binary interaction [5]. Unfortunately, debates over the role of rotation when WR stars die remain largely theoretical, as it has proved extremely difficult to place any observational constraints on the rotation of WR stars [6].

Discovery of Apep and composition

Serendipitously, while conducting a survey of the Galactic plane in radio and X-rays, we identified a source catalogued as 2XMM J160050.7-514245 as a high-luminosity outlier with an exceptional infrared spectrum [7]. The source brightened from an apartment magnitude of 6.4 at 2.2 μm to to –2.4 at 22 μm, making it one of the brightest mid-infrared sources in the sky. Such dramatic brightening indicates the presence of luminous objects embedded within an extremely dusty environment.

To discern the morphology of the dust, and determine the nature of the source, we observed the object with the mid-infrared camera VISIR on the European Southern Observatory's (ESO) Very Large Telescope (VLT). The spectacular dust plume revealed at 8.9 μm is shown in Figure 1, displaying a pattern strongly reminiscent of the Archimedean spirals produced by WR pinwheels. However, the dust plume is sustainably larger and displays intricate features not common to typical pinwheel systems. Based on the beautiful structure present in Figure 1, we nicknamed the system Apep after the Egyptian god of chaos, who is often represented as a serpent in Egyptian mythology. We think this is an apt allusion as the image evokes a star embattled within a serpent's coils.

To identify the stars present in the system, and to search for the expected fast wind in the system, we also observed Apep using the near-infrared NACO camera and integral field spectrometer SINFONI on the VLT. As shown by the blue stars in Figure 1, the 2.24 μm NACO image showed the centre of Apep is composed of an unresolved binary (hereafter the 'central engine') and a northern companion. The northern companion is a mere spectator to the fireworks going on in the central engine, as it is too distant to impact the dynamics of the dust or wind.

With SINFONI and followup optical spectra [8], the central engine displays the characteristic broad Helium and Carbon lines of a WR star, lacking any presence of Hydrogen that is common for the majority of other stars. Closer analysis [8] in fact identified that the central engine of Apep is composed of not one, but two WR stars. This is the first such binary WR system identified in the Milky Way, and implies that the wind momentum balance should be close to even, unlike other CWBs where the wind of the WR dominates due to its faster speed and higher mass loading compared to its companion. Since the WR phase represents <10% of the total life of a massive star, it is surprising to find two in the same system.

Wind speed discrepancy

The infrared spectra of Apep also gave a direct trace of the speed of the gas in the system. The speed of the gas from both stars was found to be 2100 ± 200 kms^{-1} and 3500 ± 100 kms^{-1} [8]. These speeds are exceptional, but within the normal range for the extraordinary WR star class. Such a measurement was possible from the P Cygni profile of the doubly ionized Helium lines, a distinctive profile that shows blue and red shifted absorption and emission that is sensitive to the speed of the gas.

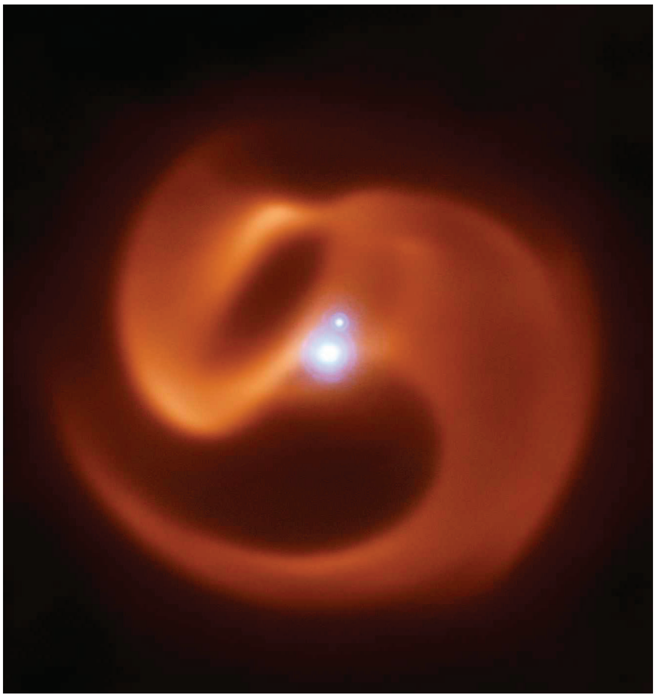


Figure 1: Mid-infrared (8.9 μm) image of Apep displaying the speculator sinuous dust spiral being sculptured by the massive binary located at the centre. The blue stars at the centre are from a 2.24 μm, showing the unresolved central engine binary and a distant northern companion. Credit: ESO/Callingham et al.

As we expected that such fast winds would result in proper motions of the dust pattern shown in Figure 1, as is seen in all other WR pinwheel systems, we took another VISIR observation on the VLT a year after the first epoch. To our surprise, as shown in Figure 2, the dust was only seen to be expanding at 570 ± 70 kms^{-1}, a factor of six slower than the gas in the system. The discrepancy between the gas and the dust in the system was also recently confirmed by a third VISIR epoch [9].

The archetypal pinwheels exhibit no such difference [3]. Angular and spectroscopic expansion speeds are consistent and simply related by the distance. Newly formed dust inherits the motion of the gas in which it formed, in this case the shock-compressed stellar wind. To find such a large discrepancy between the dust and gas is equivalent to finding a feather sitting still in the middle of cyclone.

Anisotropic mass loss

With the disagreement between the dust and gas speeds firmly established, there are only several plausible explanations. Firstly, the speeds can be reconciled if the distance to the star system is incorrect by an order of magnitude. Such an explanation cannot be correct due to the kinematic distance limits from the spectra [7] and the fact that doing so would make Apep the most luminous CWB in the Galaxy by a factor of ten. Furthermore, the smooth and clean form of Figure 1 suggests it is unlikely some unique wind breaking, or pressure confinement is acting, since the plume would be susceptible to Rayleigh–Taylor instabilities.

The dust plume appears to be not stagnant, but expanding at a uniform speed that is different to the gas (Figure 2). Therefore, it is unlikely we are seeing a 'switch in state' from which a previous episode of mass loss was governed by different physics, such as slower winds. Otherwise, we are witnessing a privileged moment where the switch has occurred very recently (within the last decade) as the new faster winds would quickly catch up to the slow dust and accelerate it; a highly suspect coincidence.

With the fast and slow winds occurring simultaneously in the Apep system, we propose that the duality of the wind speeds must be intrinsic to the system. 'The most plausible model that fits the data [7] is one in which one of the WR stars in the central engine of Apep launches both a slow and fast wind. Anisotropic winds, configured as a fast polar and slow equatorial flow, have been established in other non-WR systems, with rapid stellar rotation invoked as the underlying driver [10].

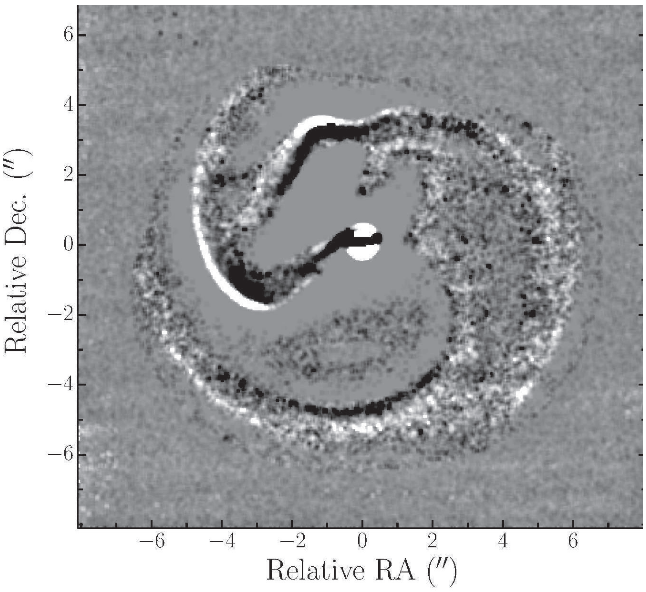


Figure 2: A difference image between the two different VISIR epochs after passing Figure 1 through a high-pass filter to highlight the edges of dust plume. White represents the newer epoch, which is always found exterior to the old epoch (black). Credit: Callingham et al. (2019)

As shown in Figure 3, we suggest that one WR star in Apep is rapidly rotating. This produces a slow, heavy equatorial wind, where dust production occurs when the binary companion passes through the equatorial plane. The gas at the polar region of the star is free to travel at the measured fast speeds, never interacting with the dust. Such a change in dust production state is standard in other WR systems [11].

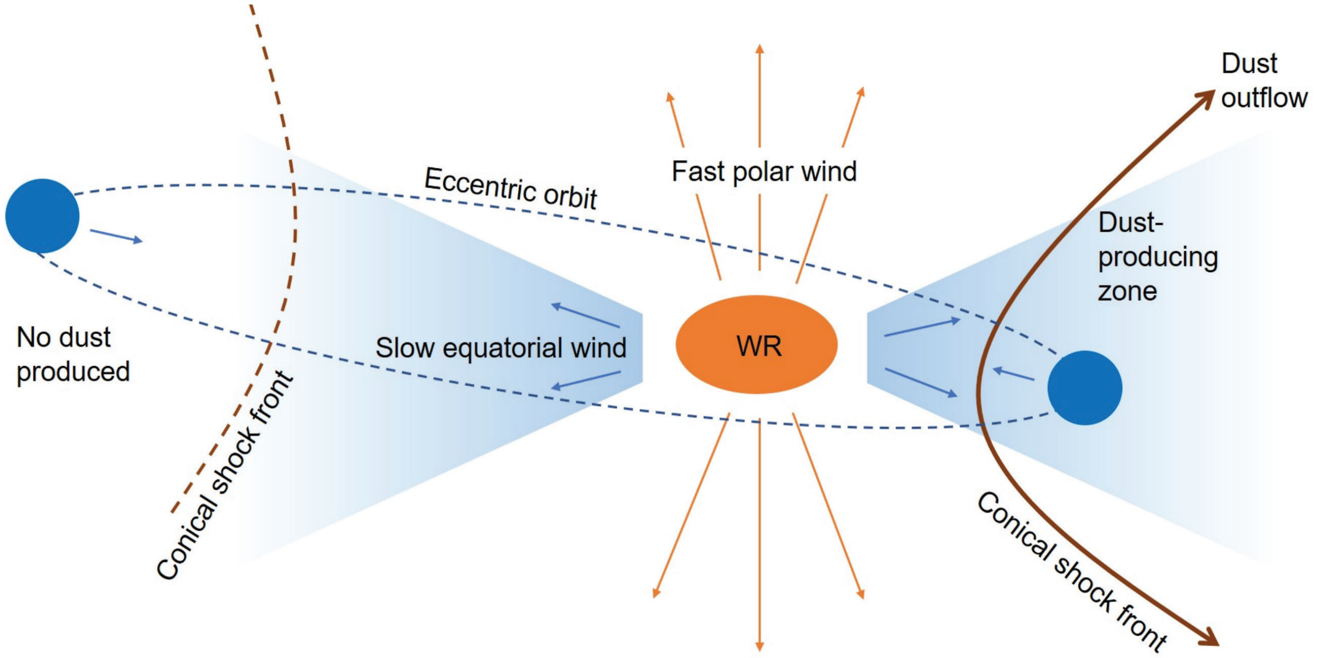


Figure 3: Schematic diagram of the proposed dual wind model that is operating in Apep, orientated on a single WR star in the system. The slow equatorial wind, potentially generated by the critical rotation of a WR star, produces a dust-producing zone around itself. As the binary companion passes in and out of this zone, the dust plume is sculpted.Credit: Han et al. (2020)

With the most likely scenario that Apep is generating anisotropic winds by rapid rotation, Apep potentially represents the first Galactic laboratory to study the progenitors of GRBs. In particular, the progression of angular evolution in the WR phase is poorly understood [12], with the most promising models involving spin up of the WR star via binary interactions. Apep can also serve as a test bed for the type of systems that may eventually lead to gravitational wave signatures.

Conclusions and future outlook

We have detailed the discovery of a new and unique CWB that is composed of two WR stars; the first identified in our Galaxy. While Apep stands out for its extreme luminosity, the discrepancy between the gas and dust speed establishes a system of unorthodox configuration. The model that best explains all the observational signatures is one in which one of the WR stars in Apep is generating anisotropic mass loss via rapid rotation. Such a conclusion identifies Apep as a progenitor to GRBs, also a first for our Galaxy. Apep can be used to test GRB models that have only previously been evaluated at cosmological distances.

While we have presented some answers to the enigmas posed by the discovery of Apep, several remain: how can the X-ray emission stay relatively static over decades, but the radio emission undergoes significant variation? How can the radio emission be so bright? Are there nested shells of colder dust further out than what we see in the mid-infrared, as predicted by our model? Instruments like the Atacama Large Millimeter/submillimeter Array (ALMA) and soon to be launched James Webb Space Telescope (JWST), and more detailed theoretical modelling, will be key in solving some of these problems.

About the author

Dr Joe Callingham is an Australian astrophysicist based at Leiden University, where he is a Veni Fellow. He completed his PhD at the University of Sydney in 2017, and was the de Bruyn Fellow at ASTRON, the Netherlands Institute for Radio Astronomy. He specialises in studying radio stars, exoplanets, and the evolution of galaxies. He also enjoys surfing, independent cinema, running, reading, and pretty much anything to do with science-fiction.

References

[1] H. J. G. L. M. Lamers, A. Maeder, W. Schmutz, and A. P. Cassinelli, *Astrophys. J.*, **368**, 538 (1991).

[2] P. A. Crowther, *Annual Review of Astron. and Astrophys.*, **45**, 177-219 (2007).

[3] P. G. Tuthill, J. D. Monnier, and W. C. Danchi, *Nature,* **398**, 487–489 (1999).

[4] S. E. Woosley and A. Heger, *Astrophys. J.,* **637**, 914–921 (2006).

[5] R. G. Detmers, N. Langer, P. Podsiadlowski, and R. G. Izzard, *Astron. Astrophys.,* **484**, 831–839 (2008).

[6] T. Shenar, W.-R. Hamann, and H. Todt, *Astron. Astrophys.* **562**, A118 (2014).

[7] J. R. Callingham, P. G. Tuthill, B. J. S. Pope, P. M. Williams, P. A. Crowther, M. Edwards, B. Norris, and L. Kedziora-Chudczer, *Nature Astron.*, **3,** 82-87 (2019)

[8] J. R. Callingham, P. A. Crowther, P. M. Williams, P. G. Tuthill, Y. Han, B. J. S. Pope, and B. Marcote, *Mon. Not. R. Astron. Soc.*, **495**, 3323-3331 (2020).

[9] Y. Han, P. G. Tuthill, R. M. Lau, A. Soulain, J. R. Callingham, P. M. Williams, P. A. Crowther, B. J. S. Pope, and B. Marcote, *Mon. Not. R. Astron. Soc.*, **498**, 5604-5619 (2020).

[10] J. H. Groh, D. J . Hillier, and A. Damineli, *Astrophys. J. Lett.*, **638**, L33–L36 (2006).

[11] Williams, P. M. et al. *Mon. Not. R. Astron. Soc.*, **395**, 1749–1767 (2009).

[12] S. E. de Mink, N. Langer, R. G. Izzard, H Sana and A. de Koter, *Astrophys. J.*, **764**, 166 (2013).

Physics labs, then and now

Les Kirkup
Visiting Professor
Faculty of Science
University of Technology Sydney, Les.Kirkup@uts.edu.au

"It is the central place of experimental work in science which makes the teaching laboratory the single most essential part of any science course: the one part without which a course cannot be properly described as science [1]." Driven by challenges posed by COVID 19, some academics are exploring alternatives to face-to-face teaching labs. What do the alternatives have to offer, do they preserve the teaching laboratory as the 'single most essential part of a science course' and so raise the possibility of rendering face-to-face labs obsolete?

Nailing down the role of lab work in the undergraduate physics curriculum has tormented generations of academics, almost as much as the reality of lab programs torment their students. Disheartening lab experiences are a significant factor turning students off physics, especially those not majoring in the discipline [2]. In the words of one student, regarded at the time as a candidate for first class honours in physics: *I don't particularly enjoy laboratory classes at the moment …the experiments rarely work, so there is no real sense of satisfaction… They give you this massive wad of notes. Sometimes it tells you what to do, and sometimes it doesn't. Sometimes when it does it is a load of rubbish… The idea is you plough through these – they eventually go in to theory you haven't done at all, so it is all pretty meaningless*[1].

This example of the student experience of lab work is drawn from a little known (but well worth tracking down) book from the late 1970s sponsored by the Nuffield Foundation. Though quite ancient, much in the book will resonate with today's academics and students. The book is distinguished by having as authors a team of physicists concerned with the quality of undergraduate lab work. Many of the issues are considered that we wrestle with today, including, the role and effectiveness of demonstrators, assessing lab work, the keenness (or lack of it) of senior academics to take on lab development and reasons why undergraduate lab programs evolve only slowly.

Concerns about the role of labs in the undergraduate physics curriculum and student experience of the same stretches back many decades. There are few arguments about which fundamental physical principles should be covered in the undergraduate physics curriculum. By contrast, the role of the laboratory attracts many diverse views. The reality is that the potential scope of lab work is so great that it is hard to reach consensus on its purpose, how practical work should be designed, and how it should be delivered. In fact, it can be argued that unrealistic expectations of the contribution of lab work to the undergraduate curriculum can lead to programs that are too ambitious, as they try to be everything to everybody [3].

Changes to lab provision, and much besides, gathered unprecedented pace in 2020 due to the COVID-19 pandemic, with online options taking centre stage. Given the largely enforced changes in labs that occurred in 2020, it is timely to revisit the purpose(s) of undergraduate labs and the best way that a quality lab experience can be delivered. Indeed, perhaps it is time to ask whether a conventional lab experience remains "the single most essential part of any science course". Institutional responses to this question, post-Covid, could shape university physics education for years to come.

When considering alternatives available to deliver lab programs, it is worth keeping in mind some typical lab learning objectives that have attracted support over many years (see, for example, [4]), including (but not limited to) that a student should *develop useful skills such as record keeping, physical manipulation of equipment, observation and problem solving; design, carry out and refine an experiment or investigation; understand the impact of experimental error on conclusions drawn from data, and; apply appropriate scientific concepts to the interpretation of experimental data, and draw defensible conclusions from that data* [4].

Assuming these objectives retain currency in 2021, to what extent are online laboratory programs able to assist students to achieve them?

Online and remote technologies

Online technologies have become the foremost means of providing many learning experiences during the pandemic, such as those that would normally occur on campus in lectures and tutorials. Declared advantages of studying online include the flexibility to study when, where and how it suits the student.

It is natural to ask, to what extent can (or should) online technologies transform lab work? In fact, can a lab experience be offered to off-campus students of sufficient quality to render the on-campus lab an anachronism?

Online technologies may become the preferred option for those who hold the purse-strings, partly due to belief in the dubious proposition that they are cheaper to deliver and maintain. Online alternatives to face-to-face pracs, sometimes referred to as non-traditional practical work (NTPW), include synchronous and asynchronous remote labs and computer simulated laboratories [5]. These deserve consideration if, as related by Drysdale [6]:

> *NTPW is not simply a low-cost alternative to traditional laboratories, as it offers equal or better outcomes across all educational categories* [7].

Synchronus remote labs

In synchronous remote labs, equipment used to run an experiment is housed in an on-campus laboratory. Students use a computer to connect to that equipment via the internet, making measurements in real time from home or some other location. Data gathered during the experiment are available for download, for example as an Excel file. The student monitors the experiment using one or more cameras situated close to the experiment.

There are many situations (for example in industrial environments) where interaction with remote equipment is the norm. Therefore, to an extent, remote labs offer students an authentic experience, exposing them to situations some will encounter in their careers.

By and large, synchronous remote labs are limited as to the scope the student is given to investigate a phenomenon. The opportunity to meet the learning objective to *Design, carry out and refine where necessary, an experiment or investigation* is denied to the student.

Remote labs present their developers with many technical challenges, including making the experiment "bullet proof" (in the sense that students cannot damage the equipment), reliable, and easily accessible. It could be argued that it is the developers that learn the most through conceiving, creating, delivering and maintaining remote labs [8].

I'd like to relate my first-hand experience of a synchronous remote lab experiment. The aim was to determine the coefficient of friction by investigating the sliding of a block down an inclined plane. An online booking system allowed me to choose the time slot during which I could do the experiment. The apparatus consisted of a smooth metal track that could be inclined at increasing angles until a block on the track started to slide. I could choose the type of block (for example, metal or non-metal) used. A camera was situated so that I could watch the apparatus go through its operating sequence. The data gathered of the motion of the block were available for download as a file which I could analyse.


Students exploring factors affecting fluid flow through narrow tubes.

Setting aside that an equivalent non-online experiment could be done cheaply and easily with simple equipment; what stood out most to me was that questions immediately came to mind as the experiment ran that I would like to have explored: Would cleaning the block and track before each run affect the data, for example, to what extent would the data be more repeatable? What would be the effect of the motion of the block if it had been turned through 90° (such that there was a different area of contact between block and track)?

Feature	Hands-on lab	Remote Lab (synchronous)
Degree of realism	High	High if camera and audio employed
Perception of control	High	Medium (constraints are evident)
Degree of freedom to experiment	High, but potentially restricted by lab facilities and safety considerations	Inherently low, limited to pre-configured options
Feedback on performance	Potentially immediate, depending on the availability of demonstrators	Likely delayed by hours or days
Access limits to lab	Timetabled lab period only	No real limits, but queuing to access experiments required if classes are large
Supervision	Prompt support due to closeness to instructors/ demonstrators	More *laissez faire* with frustration due to no access to immediate support

Table 1: Comparison of hands-on and synchronous remote labs.

These questions expose three major shortcomings common to most (if not all) online remote labs. First, you can only change parameters that have been preconfigured by the creator(s) of the labs. Second, when the so called 'teachable moment' arrives (which here means you are so engaged with the experiment that you are actively questioning aspects of the experiment and looking to expand and consolidate your understanding), there is no-one with whom to discuss any questions. Third, even small changes to the experimental method (in this example, cleaning the block and track before each run) are impracticable.

Table 1 contains a comparison of hands-on labs with synchronous remote labs which is an edited version of the table contained in Deniz et al. [9].

Asynchronous remote labs

Like synchronous remote labs, an asynchronous remote laboratory experiment is carried out using real equipment held at a distant location, but in this case, the student does not interact with the equipment in real time. The student (typically) submits experimental parameters to the system which remain queued until acted upon on. Data from the experiment are returned to the student some time later in a form suitable for analysis.

It might seem that such labs would do little to endear students to the processes of lab work, especially for students in the first year of their study. However, if students engage in a 'research inspired' project of duration, say half a semester, asynchronous remote labs may be an attractive proposition. As an example, the Center for Authentic Science Practice in Education (CASPiE) recognised that only a few well-placed undergraduates with outstanding academic credentials can normally engage in research [10]. CASPiE wished to broaden access to research experiences by giving first- and second-year undergraduate students the opportunity to carry out (chemistry-related) research. Many of the CASPiE research experiences were based around 'research modules' designed with undergraduate students in mind. The modules were typically six to eight weeks in duration, with one three-hour session per week. Completion of the modules often required the use of research equipment situated in another location (sometimes at another university). To this end, CASPiE formed a remote instrumentation network which provided a 'suite of remotely accessible analytical instruments' accessible by the first- or second-year students. The research modules were developed by a team led by the primary author (who was a researcher). This author was tasked with writing both the educational and research goals for the module.

Computer simulated laboratories (CSLs)

In computer simulated labs (CSLs), students engage in interactive activities that mimic actions they would carry out in a campus-based laboratory. In one type of CSL, students navigate around a virtual environment using a mouse. The student is introduced to physical principles and then asked to apply them. Short quizzes punctuate the exploration of the virtual environment to test understanding.

Several commercial companies have emerged which offer CSLs. One such company is Labster [11] *a growing science education platform focused on high-quality virtual simulations to help students visualize scientific concepts and practice laboratory skills. Our simulations are virtual learning experiences in which students navigate real-world scenarios in a video game-like environment to learn scientific skills and concepts* [12].

Student preparing to operate an atomic force microscope

One appeal of CSLs is that they do not, unlike online synchronous and asynchronous labs, require hardware to be purchased, housed and maintained by an institution. Software development and maintenance are done by the company (usually through the form of a contract).

As technology develops, the virtual environments are increasingly realistic, at least visually. A typical application of CSLs is as part of lab prework. For example, familiarity with instruments such as an oscilloscope can be provided through a CSL.

Another type of lab that generally does not fall within the NTPW definition, but could be considered as "remote", is the home-based lab. Such labs, in which the student carries out an experiment using (for example) a take-home kit supplied by the university, have been around for many decades. Logistical challenges (for example, distributing and collecting kits from many tens to hundreds of students) as well as health and safety issues (who is liable if there is an accident while a student is carrying out a home experiment?) has meant that their use has been limited.

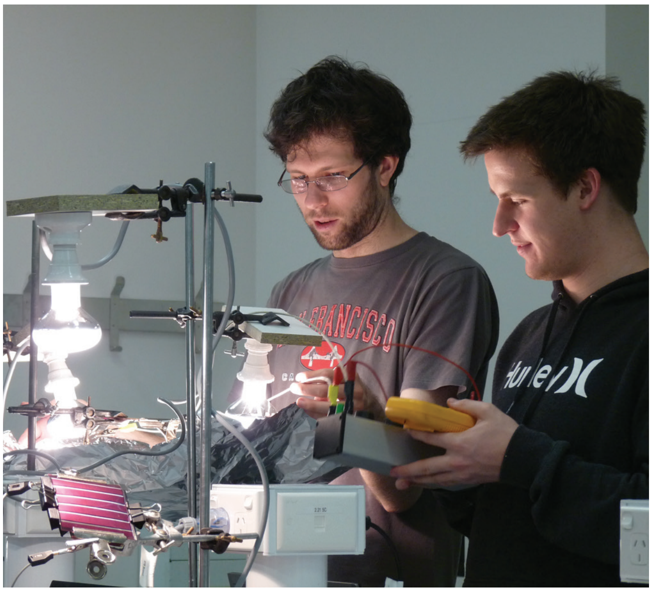
Reflections

COVID-19 demanded universities react quickly to support students to allow them to continue their studies. Some immediate responses to the shutdown of labs that I witnessed included turning lab programs into a series of data analysis-focused exercises, or students watching demonstrators (via a recorded video, or a live Zoom session) carry out experiments on their behalf. The demonstrators sent data from the experiment to the students for analysis. While such approaches were understandable and expedient given the circumstances, they hardly allow students to achieve many of the preferred lab-related learning outcomes.

Here I have tried to give a flavour of some options open to academics, which notionally would assist students to achieve preferred lab learning outcomes. In principle, online education offers the student flexibility in terms of where and when they study. Students can set their own learning pace (which may be a good or bad thing). From a university point of view, there are efficiencies to be had in the use (and reuse) of resources.

Synchronous remote labs seem like an exciting possibility, but the reality is that such labs give students little scope for investigation and have much in common with the recipe type labs that many academics have been trying to move away from for years [13]. Apparent efficiencies that potentially emerge if several universities create a broad network in which 'automated experimental rigs' can be shared disguise the fact that the cost of setting up such networks is high, often needing national funding. Sustaining cross-institutional networks is costly and no doubt contributes to their demise. Many networks that began with high aspirations have faltered. One high profile example that no longer exists is LabShare, which was an Australian initiative funded through a large federal grant that brought together several universities to deliver engineering laboratories to undergraduate students [8].

Asynchronous remote labs can provide students with an authentic research experience, though the students may never get to see the equipment making the measurements. Much input is required from academics to make such experiences a success and is probably one reason why such labs are rare at undergraduate level. Like synchronous labs, there appear to be benefits in setting up a network of equipment so that efficiencies can be gained through the sharing of resources. Also, like synchronous labs, major funding is required to set up such labs and the running costs are likely a contributory factor to their long-term failure. For example, the CASPiE innovation mentioned above attracted National Science Foundation funding in the US. Unfortunately, it no longer operates.



Students investigate the characteristics of organic solar cells

CSLs are being developed by commercial entities, relieving universities of the requirement of having local expertise to create such labs. The virtual worlds they create through simulation are increasingly realistic. While synchronous and asynchronous labs employ real equipment, necessitating that students wait their turn, there is generally no limit to the number of students that can simultaneously carry out a CSL. However, issues may arise if the computer technology the student has access to is not up to the job. The CSL, with its immediate feedback, is a useful tool assisting students to grasp scientific concepts. However, the extent to which a CSL can support students to acquire skills to design, carry out and refine an experiment or investigation, and understand the impact of experimental error on conclusions drawn from data, is moot at best.

There is another aspect of face-to-face laboratories worth emphasising. If online education accomplishes anything, it is that it distances student from student, and student from instructor. Of the many challenges facing new students, one is to gain a sense of belonging to their new institution. The lack of belonging is known to contribute to students giving up on their studies [14]. As universities all but mandate that lectures are online (and tutorials too in some cases), it is possibly in the on-campus laboratory alone where new physics students have the opportunity to interact with their peers one-on-one in an educationally productive (and hopefully stimulating) setting. To restrict labs to online denies students opportunities to build relationships. Such relationships may have many positive consequences beyond the learning of lab techniques or designing and carrying out experiments.

A benefit of online education, from an institutional perspective, is that the pressure (and cost) to support and maintain (for example) large lecture spaces is diminished. The amount they might save if on campus labs for undergraduates could be dispensed with can only be speculated on.

This article began with a comment from a student back in the mid 1970s: 'the experiments rarely work, so there is no real sense of satisfaction…'. This is a sobering reminder that face-to-face labs were (are?) not always a positive learning experience. We should not be hostage to notions that in the "good old days" everything (in the lab) was better. Indeed, I remember struggling with first-year experiments in an environment where the PhD students ostensibly in charge of the lab were in fact preoccupied with their own studies, quite indifferent to problems undergraduates were having.

An enormous amount has been accomplished over the last 30 years to enhance students' face-to-face lab experiences and to improve student learning. This includes innovative work carried out in Australian physics departments, for example by Parappilly et al. [15], Sharma et al. [16] and Wegener et al. [17]. Pivoting to online labs puts at risk much that has been achieved over that time.

COVID-19 has forced universities to reassess the value and costs of all they do. Clearly and convincingly articulating and demonstrating the value of face-to-face labs has never been more vital, otherwise 'Non-Traditional Practical Work' may become common fare for students.

About the author

Les Kirkup joined UTS in 1990. Many of his educational development activities have focused on enhancing the student experience in laboratories. Les' contributions to connecting undergraduates to research at UTS were recognised in 2012 by the award of the UTS Medal for Teaching and Research Integration. His contributions to teaching and learning in science were recognised nationally in 2011 with the award of an ALTC National Teaching Fellowship. In 2014, Les was awarded the Australian Institute of Physics Education Medal for his national contributions to university physics education.

References

[1] Nuffield Foundation Practical Work in Undergraduate Science Editor Ogborn, J Heinemann, London (1977).

[2] R. Cheary, M. V. Gosper, E. Hazel, and L. Kirkup, "Revitalising the first-year physics laboratories at the University of Technology Sydney" A&NZ Physicist vol 32, 119-124 (1995).

[3] D. Boud, J. Dunn, and E. Hegarty-Hazel, Teaching in laboratories. Milton Keynes, Open University Press (1989).

[4] American Association of Physics Teacher, Goals of the introductory physics laboratory, American Journal of Physics vol 66, 483-485 (1998).

[5] S. Mackay and D. Fisher Practical Online Learning and Laboratories, for Engineering, Science and Technology IDC Technologies Pty Ltd, Perth, Australia (2014).

[6] T. D. Drysdale, S. Kelley, A. Scott, V. Dishon, A. Weightman, R. J. Lewis, and S. Watts "Opinion piece: non-traditional practical work for traditional campuses", Higher Education Pedagogies, 5:1, 210-222, DOI: 10.1080/23752696.2020.1816845 (2020).

[7] J. R. Brinson "Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of empirical research". Computers and Education vol. 87, 218-237 (2015).

[8] D. Lowe, S. Murray, L. Weber, & De, M. La Villefromoy, A. Johnston, E. Lindsay, W. Nageswaran, A. Nafalski "LabShare: Towards a National Approach to Laboratory Sharing". 20th Australasian Association for Engineering Education Conference (2009).

[9] D. Z. Deniz, A. Bulancak and G. Ozcan "A Novel Approach to Remote Laboratories" 33rd ASEE/IEEE Frontiers in Education Conference (2003).

[10] C. B. Russell, A. K Bentley, D. J. Wink, and G. C. Weaver "Materials Development for Research-Based Undergraduate Laboratory Curriculum" Chem Educator vol. 14, 55-60 (2009).

[11] Labster https://www.labster.com/ (2021).

[12] Labster https://www.labster.com/faqs/ (2021).

[13] L. Kirkup, J. Pizzica, K. Waite and, L. Srinivasan "Realizing a framework for enhancing the laboratory experiences of non-physics majors: from pilot to large-scale implementation" European Journal of Physics vol 31, 1061-1070 (2010).

[14] C. Stone 'Opportunity Through Online Learning: Improving student access, participation and success in higher education', NCSEHE and The University of Newcastle (2016).

[15] M. Parappilly, C. Hassam, and R. J. Woodman "Race to improve student understanding of uncertainty: Using LEGO race cars in the physics lab." American Journal of Physics vol 86, 68-76 (2017).

[16] M. D. Sharma, A. Mendez, I. M. Sefton, and J. Khachan "Student evaluation of research projects in a first-year physics laboratory" European Journal of Physics vol 35 025004 (2014).

[17] M. J. Wegener, M. Doyle-Pegg, and T. McIntyre, Timothy J. "Heat: an inquiry-based physics laboratory for life sciences students." International Journal of Innovation in Science and Mathematics Education, vol 23, 18-31 (2015).

Highlighting Australia's physics in the AAPPS Bulletin – a call for potential entries

Deb Kane
Personal Chair/Professor
Dept. of Physics and Astronomy, Macquarie University, Sydney, NSW 2109 – deb.kane@mq.edu.au

The Australian Institute of Physics is part of the Association of Asia Pacific Physical Societies (AAPPS). As such, it has the opportunity and responsibility to coordinate profiling and highlighting research that is conducted primarily in Australia via the AAPPS Bulletin. Each year there is a set spot in the calendar of the AAPPS Bulletin for Australia's entry. This article is a call to the Australian physics community to assist in ensuring our physics is profiled in a comprehensive, fair and representative way, each year, in the AAPPS Bulletin, starting in October 2021. It is also an opportunity to produce an annual collation for national use. We aim to start a new habit – one that will benefit Australian physics.

AAPPS Bulletin – Springer Nature

The AAPPS *Bulletin* (AAPPSB) has changed. In February 2021, it was launched as an open access Springer Nature journal [1]. It is aiming to evolve over time into a preferred destination for high impact, highly cited research articles and research reviews. However, it will also still be the publication through which the Asia Pacific Physical Societies share their physics research and other highlights. This initiative is being supported by the Asia Pacific Centre for Theoretical Physics (APCTP) hosted in Korea [2].

Research Highlights and News (RH&N)

Each country has one issue of AAPPSB each year in which the nation's overview of physics research is highlighteds and physics newsis published. This *Australian Physics* (AP) article is primarily calling on the physics community in Australia to contribute to a process whereby the potential items for inclusion are collected and considered in a systematic way to lead to a meaningful overview of Australian physics appearing in the AAPPSB each year. This is also an opportunity for such contributions to become news for AP an alternate destination–if not selected for the AAPPSB. It would be fair to say that the Australian physics community has not made the most of this opportunity in the past, and this is an initiative to address this. It is strategic for Australia to occupy its place in the Asia Pacific region and this is one way forward. Indeed, we have the opportunity to lead by providing a benchmark for reporting national progress in physics in the new context of the AAPPS *Bulletin* as a Springer Nature publication. The future of such an initiative is in the community's hands. It will not be realised unless the community makes it happen.

What is being requested for RH&N?

In order to have the appropriate source material to coordinate Australia's submission for the October issue, two types of contribution are sought. **Research highlights** should be between 150 and 350 words on what is judged to be the most significant new results in research by an identified, team, institutional group, or research centre, published in the year July 2020 to June 2021. Key research publications should be referenced and appended. Please also append a suitable high-quality image that can be published without any copyright issues. If the research involves international collaboration, please be very specific about the contribution to a larger outcome that has been carried out by researchers living and working in Australia. The second type of contribution is **News** capturing the outcomes of key conferences, outreach, or educational events–that have taken place in Australia. Also, tributes to individuals and teams who have marked major anniversaries or received significant awards are noteworthy and welcome.

Please email the contributions for consideration to Deb Kane at deb.kane@mq.edu.au as soon as possble. A consultative process will be implemented to lead to the Australian RH&N content to be forwarded to AAPPSB. Can we as a community produce the outcome sought?

Research reviews and articles for AAPPSB

As noted, AAPPS is aiming to evolve into a high impact publication through publishing research reviews and articles that communicate ground-breaking physics written for a broad physics audience. It is planned that all the Asia Pacific nations will make submissions of such articles. Currently, there are four4 Australian researchers

The Australian editorial team of the AAPPSB on a recent Zoom call, clockwise from top left: Paul Pearce, Deb Kane, Cormac Corr, Murray Batchelor.

on the editorial team at AAPPSB. The current focus is on high-quality, invited research reviews. "Invited" does not mean publication is guaranteed. Publications must pass peer review and meet the publications guidelines of the journal [3]. But, it does mean the publication charges will be met on behalf of the authors for the foreseeable future. Australian teams are encouraged to consider publishing such reviews in the AAPPS Bulletin. To follow up on consideration of such a review, you can contact one of the Australian editorial team listed below with their area of coverage. The team can assist with introductions to other editors in other areas as needed.

The areas of coverage are:

- Applied physics
- Astrophysics & gravitation
- Condensed matter
- Particle & HEP
- Plasma physics
  (Dr Cormac Corr, Cormac.corr@anu.edu.au)
- Accelerator science
- Quantum information
- Optics, photonics, laser
  (Prof. Deb Kane, deb.kane@mq.edu.au)
- AMO
- Nuclear physics
- Statistical physics (Prof. Murray Batchelor, murray.batchelor@anu.edu.au)
- Biological physics & soft matter

In addition, Prof Paul Pearce, paulapearce@me.com, is a Senior Editor and can advise generally. His core expertise is in statistical physics.

Writing for a general physics audience

It is challenging to write for a broad physics audience rather than to assume the specialist knowledge of the field. The AAPPSB aspires to publish reviews that can be appreciated by a broad physics-literate readership. The difficulty in motivating authors to write for this audience reflects, at least in part, the intensification of research and academic work and the priority to do more original research rather than spend time transferring knowledge to a wider audience. As physicists, we should reflect on how, and whether, a focus on communicating research only with other physicists who share our specialist knowledge is part of a wider perception that we are a breed apart from the rest of the community. The suggestion is being made that if we give more priority to communicating physics research to all our physics community, which should include teachers of high school physics, this will be a useful step in the broader issue of the public perception of physics and physicists. We are largely invisible to the public. Practicing writing for a broader audience is one way to improve visibility. A research review for AAPPSB is worth considering in this vein.

References

[1] AAPPS Bulletin https://www.springer.com/journal/43673

[2] APCTP https://www.apctp.org/main/

[3] AAPPS Bulletin Submission Guidelines https://www.springer.com/journal/43673/submission-guidelines

About the author

Deb Kane holds a Personal Chair in physics at Macquarie University, with her research based primarily in photonics. She is a Fellow of the AIP and the Optical Society and chairs the AIP's Accreditation Committee.

#PhysicsGotMeHere

This 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 Phil Burns, Senior Associate Patent Attorney, Wrays

As a senior patent attorney, I assist my clients in establishing and maintaining patents for their innovative work and research. My clients include small start-up companies bootstrapping their first minimum viable product, research organisations and universities looking to commercialise their research output, and large multinational corporations seeking to form a strong intellectual property barrier to competitors entering their product space.

A patent attorney must be able to identify the underlying principle of the innovation and prepare legally enforceable patent claims. These must protect both the innovation itself, and variations on the theme to prevent a competitor from simply copying the principle to develop its own product.

My background as a physicist is invaluable. As each patent application will be in a different field of technology, my technical knowledge enables me to quickly establish an understanding of the client's technology, and provide relevant technical and legal advice.

The best part of my job is the varied technologies that come across my desk every day. On any given day, I work with between five and 10 patent applications across the areas of mechanical engineering, electrical engineering, optics and photonics, and medical devices. I also support other teams in my firm to process engineering and biotechnology applications. It is incredibly interesting to see the new innovations in physics before anyone else, and it is extremely rewarding to assist clients to achieve their business goals.

My career story so far:

I'm a Star Wars kid. I can still vividly remember myself as a 10-year-old watching the original movie (Episode 4: A New Hope, as it is now known) at my friend's house. From Star Wars, my interest in lasers was strong and I devoured anything to do with them in high school, so physics was number one on my subject preferences. My high school physics teacher was instrumental in fostering my love of the subject in general, and optics in particular, and made 'Physics Phun' (his exact spelling!).

I pursued optics at Macquarie University, with a degree in optoelectronics, then went on to an Honours research project in spectroscopic analysis, jointly with the CSIRO and Macquarie's physical chemistry department.

After Honours, I joined the Optical Fibre Technology Centre (OFTC), affiliated with Sydney University, as a research assistant. I was there for six months before deciding that I wanted more than to be working on other people's projects. I chose to return to Macquarie to undertake a PhD in novel laser source engineering.

As it turned out, starting my PhD when I did was very fortunate because it coincided with the tech bust in Australia. Many photonic-based companies collapsed, and many of my friends had been laid off from more than one company while I was sequestered in the university laser labs.

However, this meant that when I completed my PhD, there were not many opportunities for industry employment. Fortunately, an offer suddenly came to join a patent firm in Sydney as a trainee attorney. It allowed me to stay close to family, so I took it initially as a temporary measure until the photonics industry in Australia recovered. A partner in the firm had a photonics client and needed someone who was more familiar with the technology, so it worked out perfectly. Now, I have been working as an attorney for nearly 17 years and have been fortunate to be with Wrays for the last five years.

"Due to the strong technical knowledge required, becoming a patent [...]" Usually, the law degree is done part-time over two or three years while gaining practical experience as a trainee attorney in a patent firm.

I have also been an active member of the AIP, starting as a committee member in 2016, moving up to Treasurer of the NSW Branch since the 2017-18 financial year. I joined the AIP to connect more closely with the physics industry, and to provide the industry with quality support for ongoing education and resources for physics students. I thoroughly enjoy giving something back to the community thatwhich helped me to get where I am now.

Tamara Martin, Education and Training Director, The Naval Shipbuilding College

I am responsible for leading the Sydney office to support the college in educating a targeted, skilled workforce for the construction and maintenance of the Australian Naval Fleet.

My career story so far:

I worked within UNSW's semiconductor nanofabrication facilities as part of my Honours project in quantum physics at the University of Sydney (USyd). I was then offered a role as Process Engineer at the Australian National Fabrication Facility.

From there, I observed the untapped potential of university research that was sitting, waiting to be shared with industry for application. I was fortunate to be taken under the wing of the CEO and Board members to learn about the business operations. I shifted my focus to an MBA rather than a PhD and took a job setting up Sydney Nano, a multidisciplinary institute, at USyd. During this time, I had started my MBA and was using my workplace as a test bed for my business learnings.

I then moved over to a government role, within the Ministry of Health, where I managed complaints about healthcare professionals. This insight into the health sector was an appropriate segue into my role within the Quality Department at Cochlear. After one year, and well timed with the completion of my MBA, I took the role as Industry and Innovation Manager for the UNSW's Faculty of Engineering. Here I enjoyed building new connections and strengthening earlier relationships to build a dynamic network of like-minded (and not so like-minded) individuals to bounce ideas off and grow an understanding of how to innovate and bring value to industry from the role of a university.

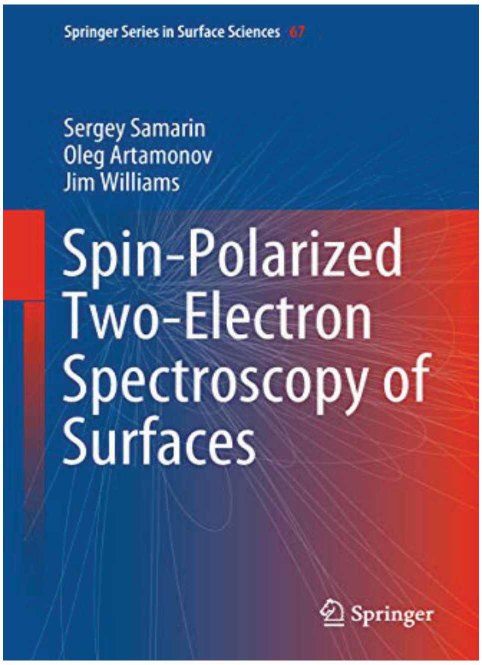
This led me to meeting the Director of the Naval Shipbuilding Institute, where my current role became available.

What I have learned is to always keep an open mind about what may appear as an opportunity, to leverage your network, and to build a strong cohort of mentors.

Tamara Martin

BOOK REVIEWS

Spin-Polarized Two-Electron Spectroscopy of Surfaces



By S. Samarin, O. Artamonov, and J. Williams; Springer (2019), 232 pages, Hardcover ISBN 978-3-030-00655-6, Softcover ISBN 978-3-030-13139-5, eBook ISBN 978-3-030-00657-0. Reviewed by Paul Guagliardo, paul.guagliardo@uwa.edu.au

This monograph outlines the development of spin-polarized two-electron spectroscopy, a unique and novel experimental approach for studying materials through electron interactions at their surfaces. The primary basis of this method is the detection and analysis of correlated electron pairs ejected from a solid. This technique illustrates how electron charge, spin and polarization combine with geometry and topological structures to illuminate the underlying asymmetries of the interactions at the interfaces and surfaces of thin films.

In recent years, interest in new materials has led to the observation of phenomena in which electron spin-dependent interactions and observational geometry play an essential role. Applications of the technique described in this work range from storage media and smart materials of modern nanotechnology, and new branches of physics such as photonics and magneto-plasmonics, to quantum computers and quantum communication. The studies further underpin many applications including, for example, electrical spin current in ferromagnetic materials.

The introductory Chapter 1 describes basic experimental approaches indicating the technique of time-correlated detection of two electrons reflected from a surface. The interpretation of those observations set the direction for the design of new instruments which are capable of extracting information about electron-electron correlations.

In Chapter 2, the reader learns, for instance, about a unique spectrometer for two-electron coincidence spectroscopy of solid surfaces in back-reflection geometry. The chapter describes how combining geometric electron scattering symmetries with coincidence measurements and time-of-flight electron energy measurements have inspired novel presentations of the measured spectra. These ideas are supported by 60 figures with significant detail. The text then goes on to explore the hidden but powerful quantum nature of electron spin at length.

To provide practical context, the principles of operation of a spin-polarised electron source, based on photoemission from a GaAs crystal, are also discussed, as are contributions of single-step and multi-step scattering events leading to the emission of two time-correlated electrons. The text also illustrates, with many references, the great surface sensitivity of the coincidence spectroscopy and its application for studying various types of solid surfaces, as well as the mechanism of electron emission under electron impact.

Chapter 3 describes, with 71 detailed figures, how spin-polarised electrons, and their exchange and spin-orbit interactions in scattering from surfaces, underlie single and two-electron coincidence detection. When applied to thin films and surfaces of high-Z metals (W and Au), and ferromagnetic samples (Fe, Co, Ni), the basic spin and electric charge foundations of electromagnetic interactions become apparent. Subsequent applications of spin-polarised spectroscopy to the study of multi-layered structures of Co/Ni/W(110) and Au/Fe/W(110) samples, show both expected and unexpected behaviour. Visualising an ‘exchange-correlation hole’ confirms fundamental spin-dominated dynamics. The chapter also shows how novel experiments can demonstrate entanglement in electron-electron scattering via spin-entangled states.

The final Chapter 4 discusses experimental examples of correlated electron pair emission from surfaces that have been induced by photons, positrons and ions. The 12 excellent figures highlight the differences of these processes from electron impact dynamics. Of the five typical interactions, fundamental interest centres on pure Coulombic interaction, without the exchange interaction, when the electron is replaced by its antiparticle for positron impact, and observations are made of the outgoing momenta of an electron and positron.

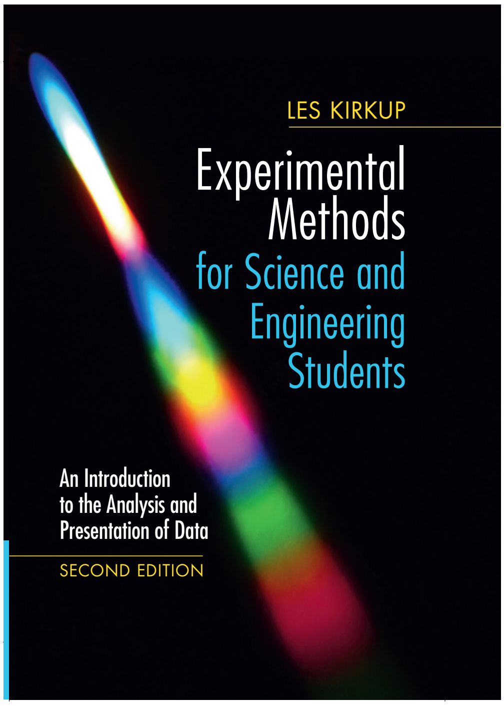
For several materials, a consistent behaviour is that the positron carries away a larger fraction of the available energy, and the positron-electron coupling increases in strongly correlated materials. New features of ion impact excitation, for example, are leading to observations of the time taken by the electrons in a material to respond to external perturbations. The coincidence spectrometry technique shows an experimental way forward at the heart of revealing 'simultaneous' or 'sequential' interactions by photons and ions, and direct interactions for various energy sharing with rearrangements of electronic structures.

Amongst all the studies, both experimental and referenced theoretical ideas, there is a deep understanding of quantum phenomena. Underpinning all aspects of this book are well-directed and implicit questions. What is the quantum definition and expectation for each observable? How does the completely random nature of any single event indicate its meaning and reality? For any single event, is there any way to know the cause or the actual time of occurrence? However, for two seemingly random events in the observed single electron scattering from a surface (and/or from its constituent atoms or molecules), our understanding expands to acknowledge that two-electron coincidence detection shows the degree of correlation of the two electrons under many circumstances. The reader is reminded that the design and construction of an instrument determines the sensitivity of detection and the reality of a quantum system.

Throughout the text, the roles of quantum electron spin-orbit coupling and electron exchange with conservation of total spin are foremost in the quantum interaction processes. The comparisons of the effects of spin-orbit coupling for ferromagnetic and non-ferromagnetic materials are discussed for bulk and layered samples. The introduction of internal and external magnetic fields may change the symmetry constraints for all particles and so emphasise the effects of spin-orbit coupling. Similarly the roles of symmetry and electron transfer have led to the ideas and direction of spin and charge current flow. Such consequences are probably most important for the recent development of electrically driven spin currents.

The multiple spin-polarized spectroscopy described here is an ideal basis for the successful development of spintronics, including quantum computing, quantum communication and for an understanding of the physical mechanisms of quantum spin correlations. This book is strongly recommended for anyone interested in quantum electron phenomena and experimental technique development.

Experimental Methods for Science and Engineering Students-2nd Edition by



Les Kirkup

Reviewed by A/Prof Maria Parappilly OAM, College of Science and Engineering, Flinders University Email: maria.parappilly@flinders.edu.au

The second edition of Experimental Methods for Science and Engineering Students-2nd Edition by Les Kirkup is a very valuable book for physical science and engineering undergraduates, introducing them to the experimental processes of data gathering and analysis, then turning what was found into formal oral or written presentations. The advantage this book lies in its physics context and the level.

Laboratory sessions are an integral element of undergraduate physics and engineering courses. As such, this book is a great resource for academics teaching first year physics and engineering aiming to improve the quality of the scientific and lab reporting skills of their students, and to help them better understand physics through experiments. This book would also be of significant value to science teachers, reminding them of the targets they are inspiring their students to reach before tertiary study to best prepare them for success in attaining scientific lab skills (experimental and analytical) and motivate them to towards experiments.

This book looks at laboratory methodology–a cornerstone of physics education–encompassing the importance of the logbook, the calculations of measurement uncertainties, and features of data. It offers practical and workable advice with the use of excellent examples. The key strengths of this book are: relevance to physics education, highlighting the statistical analysis of the experimental data, and the linking of relevant examples; exercises in basic and derived SI units, significant figures, and uncertainties in measurements. The book also assists in imparting logical thinking to the readers, helping them to acquire core skills (the ability to explain; analytical skills; skills mastery; ability to communicate the findings of an experiment etc.)

The book comprehensively covers the learning of the processes of science as an experimental activity, with many exercises at the end of each chapter. Using known formulae to linearise graphically, the data is covered well across a variety of equation types, from power laws to exponential laws.

The first chapter gives a general introduction plus an overview of the various stages of a typical experiment, reinforcing the importance of learning to keep a laboratory notebook [1]. The second chapter begins with the important features of experimental data. The graphical representation of the data follows immediately from the previous chapter, with graphing and error bars included.

Research [2] shows that students struggle with understanding measurement and the nature of uncertainty. It was very impressive to see that the author has included a special dedicated chapter (Chapter 3) to uncertainty, introducing different types of errors that can occur during an experiment, with great models for reading and measuring uncertainty/error propagation. This chapter no doubt will help students, science teachers and readers to learn about measurement and to develop a deep understanding of uncertainty. The author also cross linked the methods for combining uncertainties with well-matched exercises and examples, allowing the readers to build a conceptual understanding of measurement.

A detailed statistical analysis of experimental data is described in Chapters 5 to 7. These chapters explore fundamental experimental data analysis methods, including both unweighted and weighted least-squares fitting of functions to data. The book emphasises the importance of oral presentations and formal report writing processes, providing clear and explicit guidance on how to organise the content that makes up a report.

Chapter 8 considers the use of Microsoft Excel to analyse data. Chapter 9 introduces the use of computers and smartphones to capture data.

I am sure that this book would also be of value to those teaching in the chemical and biological sciences, depending on the type of data they are acquiring and how they are going to analyse it. In particular, the statistical analysis areas would be relevant to them.

Good year 12 students in science, particularly in the physical sciences, should have some of the skills and techniques handled here when entering tertiary education. This book would give them a head start in this regard. Secondary science teachers would do well to read this book.

References

[1] C. Wieman and N. Holmes, “Measuring the impact of an instructional laboratory on the learning of introductory physics,” Am. J. Phys. 83, 972–978 (2015).

[2] M. Parappilly and C. Hassam, “Race to improve student understanding of uncertainty: Using LEGO race cars in the physics lab,” Am. J. Phys. 86, 68–76 (2018)

Physics around the world

Physics on Twitter

Scientists and publishers have increasingly taken to Twitter to spread the news on the latest discoveries or their own ground-breaking work. Some scientific journals may use the Twitter platform as an opportunity to reach the broader science community or to engage with the public. Below are some recent tweets from around the world showing just how much can be shared in 280 characters or less!

Really cool mirrors—literally: Using LIGO's suspended mirrors, a new Science study demonstrates the ability to cool a large-scale object—the 10-kilogram optomechanical oscillator the suspended mirrors form—to nearly the motional quantum ground state. doi.org/10.1126/science.abh2634

--Science Magazine (@ScienceMagazine) June 22, 2021

Online this week: Evidence that light pulses can transiently change a metal into an insulator by unveiling a hidden ordered state. Free to read and share with link in bio: rdcu.be/cnoFh

--Nature Physics (@NaturePhysics) June 29, 2021

A new method for direct torque measurements during DNA supercoiling, make possible the determination of torsional parameters previously inaccessible.

Letter: go.aps.org/3hNYPUZ

Viewpoint: go.aps.org/3jNYPUZ

--Physical Review Letters (@PhysRevLett) June 8, 2021

New paper published in Journal of Physics: Condensed Matter. This work shows how ab initio materials modelling can predict the mechanical properties of transmuting tungsten under fusion power-plant conditions. Great team. @VillanovaME @JPhysCM doi.org/10.1088/1361-648X/ac08b8

--David Cereceda (@Prof_DCereceda) July 13, 2021

Sticky baseballs: Explaining the physics of the latest scandal in Major League Baseball

Baseball and catcher's mitt (Courtesy: Plxabay/stanbalik

Cheating in baseball is as old as the game itself, and pitchers' modifying the ball's surface is part of that long history. Adding to the lore of cheating is a new scandal involving pitchers who may be applying sticky substances – what players refer to as "sticky stuff" – to baseballs.

Major League hitters are striking out this season nearly one in every four times they step to the plate, compared with one in six times in 2005.

As a sports physicist and longtime baseball fan, I've been intrigued by news reports that applying sticky substances to balls can make pitches spin faster. And if pitchers can throw their fastballs, curveballs and sliders with more spin than in previous years, their pitches will be tougher to hit. How does science explain all this?

Sticky stuff increases friction and torque

If you want to understand what all the sticky fuss is about, you need to know some friction basics.

You've surely tried to unscrew a lid from a stubborn jar. If there isn't enough friction between your fingers and the lid, you may not be able to exert enough torque – the rotational analog of force – to get the lid to turn. One way to get more torque on the lid is to increase the frictional force. In my home, we keep a circular piece of rubber to increase friction and help open tough jars.

Pitchers want more friction between their fingers and the baseball, and they are supposedly using some interesting substances to accomplish this. According to a recent Sports Illustrated article, "pitchers have begun experimenting with drumstick resin and surfboard wax." "They use Tyrus Sticky Grip, Firm Grip spray, Pelican Grip Dip stick and Spider Tack, a glue intended for use in World's Strongest Man competitions and whose advertisements show someone using it to lift a cinder block with his palm." That article noted one instance of a ball so sticky players could see fingerprints on it, and another story in which a ball could be stuck to a person's open hand with his palm facing the ground. All of these sticky substances would increase friction and thus give pitchers a better grip on the ball.

More spin makes pitches harder to hit

Today's sticky fingers are the latest attempts by players to gain an unfair advantage. But how does sticky stuff make a pitch harder to hit? It helps increase spin rate.

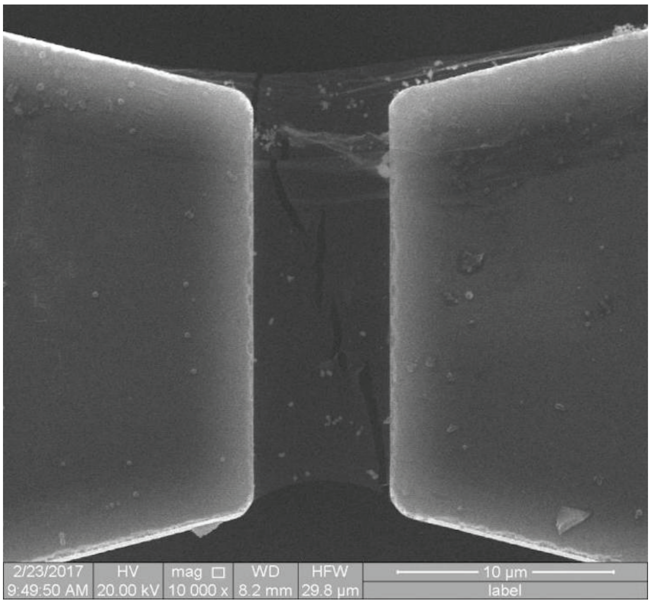
Unless a pitcher throws a knuckleball, which has very little spin, all baseballs are spinning at well over 1,000 revolutions per minute when they leave pitchers' hands. That spin creates a force – let's call it the spin force – that causes baseballs to move and curve in ways that can throw off hitters.

(extracted with permission from an item by John Eric Goff at theconversation.com)

'Iron man of 2D materials' defies century-old description of fracture mechanics

Fracture tests carried out on hexagonal boron nitride (h-BN) show that this 2D material has an intrinsic toughening mechanism, contradicting its reputation for brittleness. This unexpected behaviour, which was observed by Jun Lou, Huajian Gao and colleagues at Rice University in the US, defies a description of fracture mechanics first put forward by the British engineer A A Griffith in 1921 and still employed today to measure material toughness. As with most materials, cracks in 2D materials typically form at sites of concentrated stress. The unique structure of 2D materials, however, means that cracks can propagate straight through, opening up the bonds between individual atoms like a zipper.

To investigate this cracking mechanism in h-BN, the Rice researchers subjected samples of single-crystal monolayers of the material to tensile loads in a micromechanical device. They found that in contrast to graphene – a one-atom-thick sheet of carbon that structurally resembles monolayer h-BN – the growth of cracks in h-BN was surprisingly stable, with cracks forming branches as the tensile load increased. This branching means that additional energy is required to drive the crack further, effectively making the material tougher, Lou explains. Overall, h-BN is 10 times more fracture-resistant than graphene, defying Griffith's formula and leading the Rice University press office to describe it as "the iron man of 2D materials".



Access all areas: The Sakura Samurai group of ethical hackers infiltrated Fermilab's data systems with the knowledge of the lab's managers. (Courtesy: Fermilab/Reidar Hahn))

Good news for flexible electronics

The atoms in both graphene and h-BN are arranged almost identically, in a flat hexagonal lattice structure. However, the researchers say that the slight asymmetries that arise in a material containing two elements (boron and nitrogen) instead of just one (carbon) may contribute to the crack branching behaviour in h-BN.

Regardless of the mechanism, h-BN's newfound toughness is a boon for electronic applications. The material's resistance to heat, stability to chemicals, and dielectric properties all make it ideal as both a supporting base and an insulating layer for placing between electronic components. The discovery that h-BN is also surprisingly tough means that it could be used to add tear resistance to flexible electronics, which Lou observes is one of the niche application areas for 2D-based materials. For flexible devices, he explains, the material needs to mechanically robust before you can bend it around something. "That h-BN is so fracture-resistant is great news for the 2D electronics community," he adds.

(extracted with permission from an item by Isabelle Dumé at physicsworld.com)

LIGO gravitational-wave signal backs up Hawking's area theorem

Stephen Hawking's 40-year-old theorem about the area of a black hole's event horizon has been confirmed thanks to data from the first burst of gravitational waves detected by LIGO. Known as Hawking's area theorem, it states that the entropy of a black hole should not decrease. Because a black hole's entropy is proportional to the area of its event horizon, that means the event horizon area should not decrease if two black holes merge, as they did in the cosmic cataclysm that produced the gravitational-wave signal dubbed GW150914.

To test Hawking's area theorem, astronomers led by Maximiliano Isi of the Massachusetts Institute of Technology (MIT) re-examined the GW150914 signal, which was picked up by LIGO's detectors in 2015 and announced in February of the following year. These ripples in space-time developed when black holes of 36 and 29 solar masses merged to form a new black hole of about 62 solar masses, with the three remaining solar masses converted into gravitational-wave energy.

If Hawking's area theorem holds, the event horizon area of the newly merged "daughter" black hole should not be less than the combined area of the event horizons of the two parent black holes. Instead, Isi explains, "The combined changes in black hole masses and spins should conspire to result in an area increase – or, strictly speaking, to prevent an area decrease."

Putting Hawking to the test

Gravitational-wave signals from merging black holes display a distinct sequence. At first, the in-spiraling black holes produce gravitational waves that increase in frequency and amplitude. A "ring-down" period then follows immediately after the merger, when the daughter black hole is in a distorted state and produces gravitational-wave vibrations somewhat analogous to the sound waves from ringing a bell.

By analysing the in-spiral and ring-down phases of GW150914, Isi's team calculated the area of the two black holes' event horizons based on their masses and rates of spin. They found that the combined area of the parent black holes' event horizons was approximately 235 000 km2, whereas the area of the daughter black hole's event horizon was approximately 367 000 km2. The total area had indeed increased, proving Hawking's theorem to 95% confidence.

Deviations into exotic physics

Gaurav Khanna, a physicist at the University of Rhode Island and the University of Massachusetts, US, who was not involved in the research, calls the MIT study a "truly impressive work" that offers "the clearest such result" that Hawking's theorem is true. "It's really cool when gravitational-wave data is able to help test fundamental theorems of black-hole physics," Khanna says.

Cosmic testbed: A computer simulation of the black-hole collision that produced the first gravitational wave signal to be detected, GW150914. (Courtesy: Simulating eXtreme Spacetimes (SXS) project/LIGO)

Isi's team now plan to study more black-hole mergers, searching for deviations from the theorem that may offer clues to new kinds of object, or even new physics. "Theorists have come up with more or less plausible models that could result in mixed populations of compact objects that could resemble black holes," Isi tells Physics World. As examples, he cites quark stars and gravastars, which are hypothetical alternatives to black holes that contain a gravity-repelling area of space that prevents further collapse. Such extreme forms of matter could, he says, "support very compact objects that look like black holes from afar but have other properties as you get close to where the event horizon would be".

Isi also points out that Einstein's general theory of relativity doesn't mesh well with quantum physics, and may eventually need to be corrected.

(extracted with permission from an item by Keith Cooper at physicsworld.com)

Product News

Coherent Scientific

Optical Cryostats for Spectroscopy

The Optistat range of optical crystats from Andor are optimised for spectroscopy applications in the <3K to 500K temperature range. Dry/Cryofree, liquid nitrogen and helium options are available in both top and bottom loading configurations as well as sample-in-exchange gas or sample-in-vacuum designs. Optistat optical cryostats are ideal for use on optical table based experiments or can be used conjunction with a very broad range of 3rd party spectrometers. Andor also offer a range of optical cryostats for microscopy.

New AFM Mode – Ringing Mode

Atomic force microscopy (AFM) is a well-established technique for probing the mechanical properties of materials at the nanoscale. For proper quantification of these mechanical measurements, non-resonant AFM modes have several important advantages, including clean separation of modulus versus adhesion. Specifically, Bruker's PeakForce Tapping and AFM-nDMA modes provide quantitative and comprehensive measurements of elastic modulus and viscoelastic behaviour of soft matter.

Developed by Nanosciences Solutions, Inc., Ringing Mode delivers 8 new quantitative compositional imaging channels that expand PeakForce QNM nanomechanical studies and provide unique insights into processes, such as polymer necking or the distribution and length of surface coating molecules. Integrated as a single operational mode on Bruker AFMs, Ringing Mode and PeakForce QNM together provide a comprehensive solution for nanoscale characterisation of soft matter.

Binary Gas Analyser

The BGA244 Binary Gas Analyser from Stanford Research Systems quickly, continuously, and non-invasively determines the ratio of gases in a binary mixture, or checks the purity of a single gas.

It's ideal for a host of applications including binary gas blending, PSA (pressure swing adsorption), helium recovery, ozone purity, dopants and carrier gases, and general research where precise measurements of gas mixtures are necessary.

The BGA244 operates without lasers, filaments, chemical sensors, optical sources, separation columns, reference gases, or reagents, and runs virtually maintenance-free.

For further information please contact:
Coherent Scientific Pty Ltd
sales@coherent.com.au
www.coherent.com.au

Lastek Pty Ltd

Clear space on your optical table:

TOPTICA Photonics introduces Laser Rack Systems for Quantum Technology Applications & Research

Laser Rack Systems for Quantum Technology – Today's applications of high-end laser systems are increasingly complex and demand a short time to market. TOPTICA addresses both of these demands with its highly modular 19" Laser Rack Systems.

The broad product portfolio of tunable diode lasers and frequency combs is all offered in the new form factor. Available laser wavelengths are in the range from 330 nm to 1770 nm, some with output powers of several watts. Whatever your application requires, TOPTICA is committed to find the optimum combination of modular systems. Adding new units is simple.

TOPTICA's Laser Rack Systems have been designed from the very start for high stability, ease of use and maximum versatility. All laser systems achieve the same ultimate optical performance as TOPTICA's established table-top systems: great passive stability, unique locking solutions and narrow linewidth.

All modular laser systems are powered by TOPTICA's proven, versatile and convenient digital laser controller DLC pro. It provides local access via touch screen and complete remote control via Ethernet. The frequency comb is also remotely controlled from a single window. All laser light is available from single-mode polarization-maintaining fibers.

Configure your own T-RACK!

The T-RACK excels with a highly robust mechanical design. Fan-less thermal management, passive vibration isolation and dynamic cable management have been carefully engineered to make it a rack for high-tech precision instruments. The Modular Power Entry Unit (MPE) bundles power supply and laser interlocks.

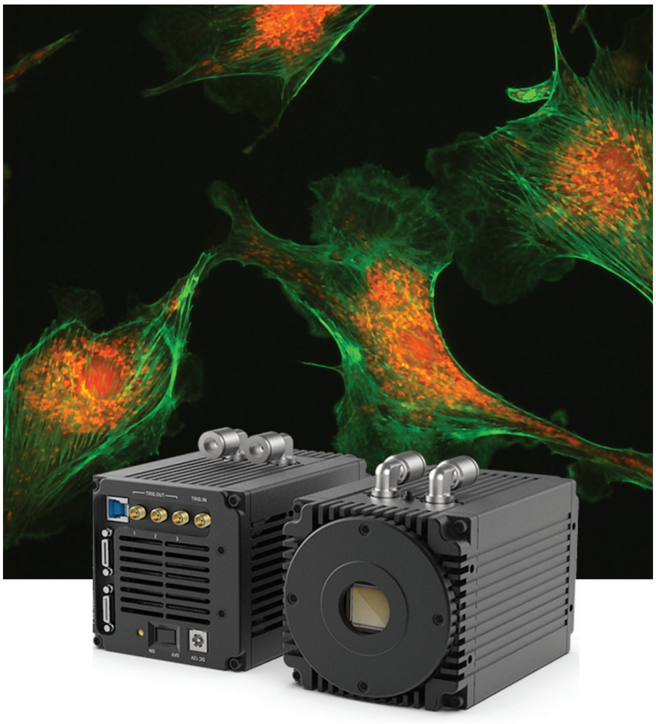
The T-RACK is future proof as it can be retrofitted with any of TOPTICA's Modular Units later, as long as rack space is available.

Key Applications:

- Quantum Computing
- Quantum Simulation
- Quantum Sensing & Metrology
- Optical Clocks
- Quantum Communication
- Quantum Technology Research
- Many other exciting applications

Introducing Tucsen Photonics: Scientific Imaging Cameras

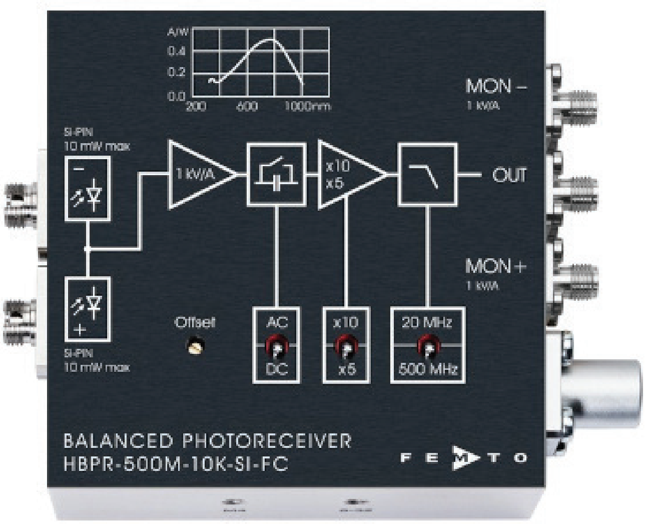
Lastek is pleased to announce that it has been appointed distributor in Australia and New Zealand for the range of innovative scientific imaging cameras designed and manufactured by Tucsen Photonics Co., Ltd, of Fuzhou, China.



Scientific imaging is an application with extreme requirements for image fidelity and accuracy. In this highly specialised field, Tucsen strives to deliver high performance and high quality products, leveraging the spirit of enterprise in efforts to win the market and customers with products tailored to their individual requirements.

Tucsen's core products are the world's first back-illuminated sCMOS cameras (Dhyana95 and Dhyana400BSI) for life science research, astronomical discovery, physical microparticle detection, and cutting-edge medical imaging. In addition, they offer a popular high quality embedded camera (TrueChrome), which is used in industrial inspection, pathology, surgical video, jewellery inspection and other industrial applications. The range is completed by standardised industrial cameras and software (MIchrome camera and Mosaic software) that are one of the most popular product combinations in the field of general microscopy.

FEMTO has raised the bar in the field of low noise balanced photoreceivers to a new level with the new HBPR platform



The newly developed HBPR series enables the differential measurement of optical signals with wavelengths from 320 nm to 1700 nm and bandwidths up to 500 MHz. By taking the exact difference between the two input signals, common-mode noise, such as the intensity noise of the laser source used, is suppressed. This way, smallest optical signals can be extracted from the signal measurement path that would otherwise be buried in the noise.

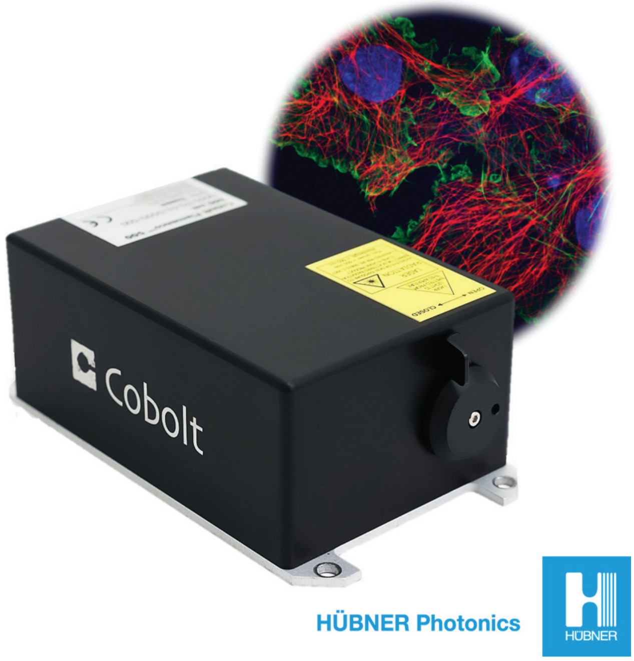
The photoreceivers of the new HBPR series use two photodiodes selected in pairs, which are connected in antiparallel, and a subsequent low-noise transimpedance amplifier to detect the differential signal. The optical inputs are optionally free space or fiber-coupled. The HBPR series is characterized by a very low input noise (NEP) down to 3.7 pW/√Hz and a high common mode rejection (CMRR) of up to 55 dB. Various models with Si or InGaAs photodiodes and bandwidths from 100 MHz to 500 MHz are available. Two monitor outputs with 10 MHz bandwidth enable fast, separate acquisition of the individual input signals. In addition to the outstanding technical data, great emphasis was placed on user-friendly details and versatility: Thanks to switchable gain and bandwidth, switchable AC/DC coupling and broad mechanical compatibility with common optical accessories, the photoreceivers of the HBPR series are among the most versatile balanced photoreceivers on the market.

Typical applications are: optical spectroscopy, coherent heterodyne detection, homodyne detection of optical quantum states, optical coherence tomography (OCT), differential optical front end for oscilloscopes, spectrum analyzers, A/D converters and lock-in amplifiers.

For further information, please contact
Lastek Pty Ltd
(+61) 08 8443 8668
sales@lastek.com.au
www.lastek.com.au

Warsash Scientific

Cobolt Rogue 640nm laser for superresolution microscopy



HÜBNER Photonics proudly introduces the Cobolt Rogue™ 640 nm laser. The Cobolt Rogue™ Series lasers are continuous-wave diode pumped lasers (DPL) and are multi-mode, high power complements to our Cobolt 05-01 Series of single frequency lasers.

The Cobolt Rogue™ 640 nm is multi-longitudinal mode in a perfect TEM00 beam with 1W output power, ideally suited for super resolution microscopy.

All Cobolt lasers are manufactured using proprietary HTCure™ technology and the resulting compact hermetically sealed package provides a very high level of immunity to varying environmental conditions along with exceptional reliability. With demonstrated lifetime capability of >60 000 hours and several thousand units installed in the field, Cobolt lasers have proven to deliver unmatched reliability and performance both in laboratory and industrial environments and are offered with market leading warranty terms.

A-142 PIGlide voice coil linear stage with air bearings

Physik Instrumente, a global leader in the design and manufacture of high precision motion control systems has launched the A-142 compact voice coil linear stage with air bearings.

A-142 is a voice coil miniature linear stage using air bearing guides which offers ultra-precision linear motion for space-confined applications.

This stage features a voice coil motor and air bearings; the frictionless, non-contact design of the stage makes it ideal for high dynamic applications requiring small incremental motion with very good repeatability. High scan frequencies and precision positioning are also possible with these drives, because they are free of the effects of hysteresis.

Typical applications for this stage photonics alignment, laser diode research, optics positioning, scanning, and inspection systems. They are ideal for use in cleanrooms, require no maintenance or lubrication, and have unlimited life.

Key specifications include:-

- Travel range: 10mm
- Velocity: 450mm/s
- Accuracy: +/-0.2um
- Load capacity: 30N

For more information, contact Warsash Scientific on +61 2 9319 0122 or sales@warsash.com.au.