Australian Physics

VOLUME 57, NUMBER 1, JAN - MAR 2020

VISUAL BROKERAGE

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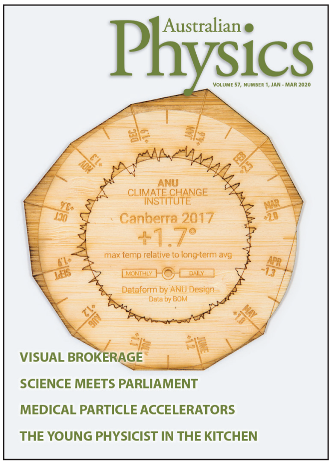

A Climate Coaster as an example of visual brokerage (image courtesy of Mitchell Whitelaw, Australian National University).

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EDITORIAL

Not more to it than meets the eye

To the trained eye, a graph can tell a story, complex or simple. In our profession the storytelling often comes through using our skills in interpreting the visual language of that piece of graphical representation of data and facts. To the uninitiated, there is more to it than meets the eye. What happens when you take visualising scientific content some steps further? Find out in Erin Walsh's article on visual brokerage.

Of course, there are other forms of tangibly connecting science with impacts. This summer's bushfire season was a stark reminder of that, and both as a community and as individuals we feel for the many people who have been, and still are, so terribly affected by the fires.

For physicists the 'call to arms' remains: we must continually remove barriers to accessing physics, and connect what we do to the simple truth of how our work improves the way people live, work, and eat. That is why events like Science Meets Parliament are important platforms for forming those connections. We feature the personal accounts of two physicists, David Gozzard and Tim van der Laan, who spent two days at Parliament House last year, engaging with parliamentarians and their staff. In both cases, they found themselves pleasantly surprised at how engaged the parliamentarians were.

We also feature two pieces approaching how physics connects to everyone from different angles: the grand (accelerator physics in medicine) and the homely (physics in the kitchen). Further on, we continue the hashtag #PhysicsGotMeHere to link physics back to the person and where it can take them. In this episode, Shermiyah Rienecker talks about she moved into medical physics. (Shermiyah has also joined our editorial teams, looking after Samplings. Welcome aboard!) The AIP is a relatively small group in a relatively small country, but that does not mean that the career opportunities for physicists should be limited. Dovetailing with the 'hidden physicists' section in the AIP newsletter, #PhysicsGotMeHere is a good way to talk about those opportunities and personalise physics. This is another form of brokerage.

If you feel physics got you to interesting places, jump on 'the socials' or send us an email.

All the best,

David Hoxley and Peter Kappen

President's Column

Physics and our responsibility to respond to the climate crisis

Like many Australians I am very relieved that the terrible summer of smoke, fire, storms, and floods is almost over. Like thousands of other people, I spent New Year's Eve at the beach in NSW with fires all around us. The smoke was terrible, the information was patchy, and the extent of the fires unprecedented. Luckily the fire didn't arrive reach us that night – it took the catastrophic conditions of Jan 4 for the flames to race up from the Victorian boarder. We made it back to Canberra on Jan 1 but then suffered through terrible smoke for weeks that closed down much of the city including the universities, post-office and many national institutions. It is clear that Australia was not well prepared for these extreme fires despite the climate models predicting exactly these types of scenarios. From a technological standpoint there are many areas where I could see physicists could help. For instance, the air quality data available in most places was patchy. I was delighted to see groups of physicists in Canberra get together to build additional air quality monitors and share the data into open source projects with internet-of-things-enabled systems.

On the Cooma-Canberra Road, Jan 01 2020
Photo: Jodie Bradby

Indeed, I can see many areas where physicists will be key in dealing with such emergencies into the future. Improved geospatial technologies are surely a priority to improve the information on fire location to both the crews fighting the fires and to the general public via real-time fire tracking apps (to name another example).

However, we have other responsibilities too. We also need to add our voices to the call for strong action to address the climate crisis. This comment made last year by astrophysicist Karlie Noon has stayed with me:

Karlie Alinta Noon
@karlie_moon_

If you have a platform and do not use it to discuss climate change in public forums, please step up or step aside.

12:52 PM · Jul 18, 2019 from Canberra, Australian Capital Territory · Twitter Web Client

14 Retweets 58 Likes

I wholeheartedly agree with Karlie. We must all do everything we can around this important issue. We must get behind organisations such as the Australian Academy of Science and Science and Technology Australia as they engage with government and the community over these issues. We must call on our elected leaders to initiate a society-wide mobilisation and implement the strategies proposed by scientists and engineers working on climate solutions. And we must use every opportunity to call for urgent investment in further research and technologies that can contribute to a de-carbonised Australian economy.

We are running out of time. We have only around a decade left to reduce our emissions to avoid warming past the point where we slide into a reality where summers like 2019/2020 are common.

I urge you to not forget the experiences of this terrible summer and use your platform to work towards change. As physicists we have an important role to play in the solutions.

Jodie Bradby

PERSPECTIVES

Editors' Note: We start the Perspectives of 2020 with a retrospective look into the 2019 Nobel Prize in Physics with an article from The Conversation. The perspective comes from US astrophysicist Robert Fisher, reflecting on pivotal contributions to the Big Bang theory and finding exoplanets like 51 Pegasi b by looking at wobbling stars.

Nobel Prize in Physics (2019) for two breakthroughs: Evidence for the Big Bang and a way to find exoplanets

By Robert T. Fisher, University of Massachusetts Dartmouth, USA

Did the universe really begin with a Big Bang? And if so, is there evidence? Are there planets around other stars? Can they support life? The 2019 Nobel Prize in Physics went to three scientists who have provided deep insights into all of these questions.

James Peebles, an emeritus professor of physics at Princeton University, won half the prize for a body of work he completed since the 1960s, when he and a team of physicists at Princeton attempted to detect the remnant radiation of the dense, hot ball of gas at the beginning of the universe: the Bang Bang. The other half went to Michel Mayor, an emeritus professor of physics from the University of Geneva, together with Didier Queloz, also a Swiss astrophysicist at the University of Genevaand the University of Cambridge. Both made breakthroughs with the discovery of the first planets orbiting other stars, also known as exoplanets, beyond our solar system.

I am an astrophysicist and was delighted to hear of the 2019 Nobel recipients, who had a profound impact on scientists' understanding of the universe. A lot of my own work on exploding stars is guided by theories describing the structure of the universe that James Peebles himself laid down. In fact, one might say that Peebles, of all Nobel winners, is the biggest star of the real "Big Bang Theory."

The real Big Bang Theory

As Peebles and his Princeton team rushed to complete their discovery in 1964, they were scooped by two young scientists at nearby Bell Labs, Arno Penzias and Robert Wilson. The remaining radiation from the Big Bang was predicted to be microwave energy, in much the same form used by countertop ovens.

It was a serendipitous finding because Penzias and Wilson had constructed an antenna to detect this microwave radiation which was used in satellite communications. But they were mystified by a persistent source of noise in their measurements, like the fuzz of a radio tuned between stations.

Penzias and Wilson talked to Peebles and his colleagues and learned that this static they were hearing was the radiation left over from the Big Bang itself. Penzias and Wilson won the Nobel Prize in 1978 for their discovery, though Peebles and his team provided the crucial interpretation.

Peebles has also made decades of pivotal contributions to the study of the matter which pervades the cosmos but is invisible to telescopes, known as dark matter, and the equally mysterious energy of empty space, known as dark energy. He has done foundational work on the formation of galaxies, as well as how the Big Bang gave rise to the first elements – hydrogen, helium, lithium – on the periodic table.

Finding planets beyond our solar system

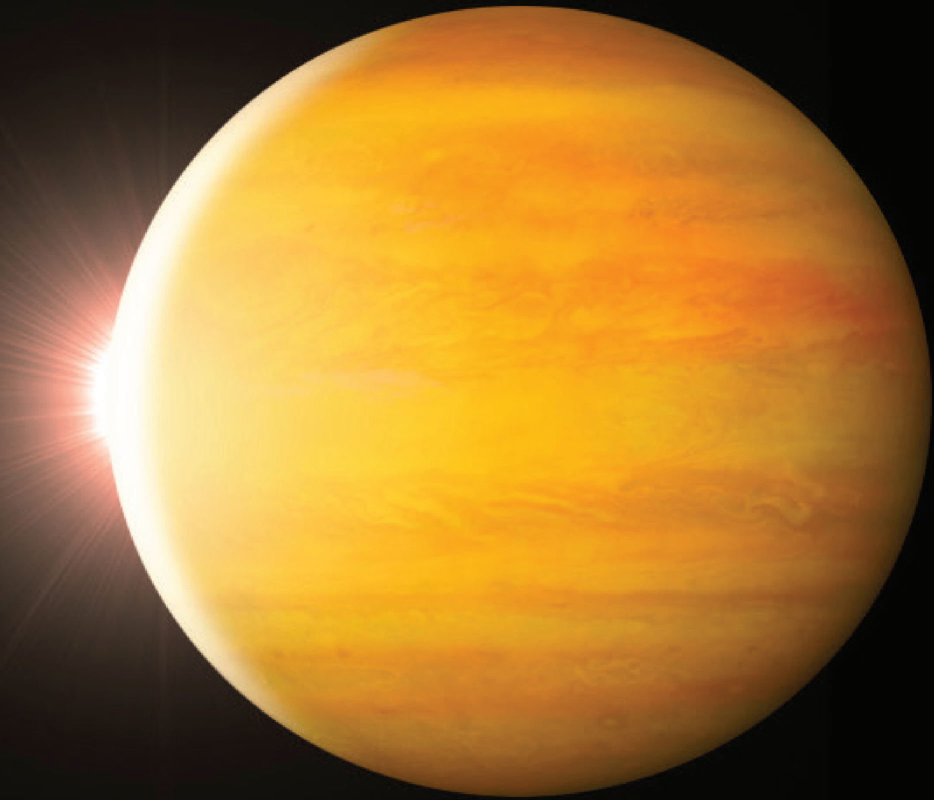
For their Nobel Prize-winning work, Mayor and Queloz carried out a survey of nearby stars using a custom-built instrument. Using this instrument, they could detect the wobble of a star – a sign that it is being tugged by the gravity of an orbiting exoplanet.

In 1995, in a landmark discovery published in the journal Nature, they found a star in the constellation Pegasus rapidly wobbling across the sky, in response to an unseen planet with half the mass of Jupiter. This exoplanet, dubbed 51 Pegasi b, orbits close to its central star, well within the orbit of Mercury in our own solar system, and completes one full orbit in just four days. This surprising discovery of a "hot Jupiter," quite unlike any planet in our own solar system, excited the astrophysical community and inspired many other research groups, including the Kepler space telescope team, to search for exoplanets.

These groups are using both the same wobble detection method as well as new methods, such as looking for light dips caused by exoplanets passing over nearby stars. Thanks to these research efforts, more than 4,000 exoplanets have now been discovered.

Image next page: NASA / JPL-Caltech

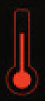
THE **FIRST PLANET** DISCOVERED AROUND A **SUN-LIKE** STAR



51 Pegasi b

Discovered October 6, 1995

This year we celebrate the discovery of 51 Pegasi b in October, 1995. This giant planet is about half the size of Jupiter and orbits its star in about 4 days. '51 Peg' helped launch a whole new field of exploration.



TEMPERATURE

51 Pegasi b has a temperature of **1000C°/1800F°**.

ORBITAL PERIOD

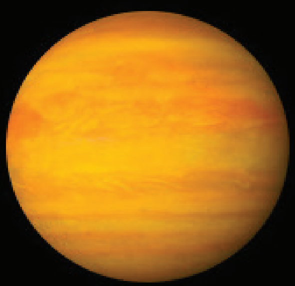
51 Pegasi b orbits its host star **every 4 days.**

DISTANCE FROM EARTH

51 Pegasi b is **50 light-years** from Earth.

PLANET COMPARISON

51 Pegasi b

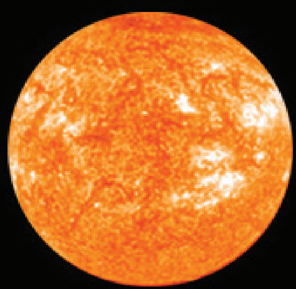


Jupiter

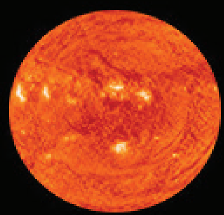
51 Pegasi b is **47% less massive,** but **50% larger** than Jupiter.

STAR COMPARISON

51 Pegasi



Our sun



51 Pegasi is **11% more massive** and **23% larger** than our sun.

Particle accelerators from basic science to nuclear medicine

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Particle accelerators might not be the first thing you associate with medical technologies but accelerators have a long history with a strong link to use in medicine. Australia itself has a distinguished record of leading accelerator science and is looking forward to entering a new age of cutting-edge high energy medical accelerators.

Long before Australia had its high energy electron accelerator which Aussies call "the synchrotron", and many years before the Large Hadron Collider was built at CERN, this country produced a number of pioneers in the field of particle accelerators.

Pioneers

One of those was Marcus (Mark) Oliphant. Working in a suit in a cold, dim laboratory with unreliable hand-blown glass apparatus, armed with 'high-tech' tools such as sealing wax and string, Marcus Oliphant was the last of the 'Rutherford boys' who would change the world's view of radioactivity and the nucleus and kick-starting the field of subatomic physics. Luckily he was a cheery, larger than life fellow from Adelaide, who fit right in with Sir Ernest Rutherford at the Cavendish Lab in Cambridge, which he joined in 1927 after winning a scholarship from the 1851 Royal Commission. Oliphant became one of the early pioneers in nuclear physics, remembered for his work bombarding deuterium which led to the discovery of tritium. But he also made a remarkable contribution in the field of particle accelerators [1], as he was the first person to suggest the concept of a synchrotron, where: "Particles should be constrained to move in a circle of constant radius thus enabling the use of an annular ring of magnetic field ... which would be varied in such a way that the radius of curvature remains constant as the particles gain energy through successive accelerations" [2].

Mark Oliphant in 1939

Accelerator physics in Australia

Synchrotrons took off, and Oliphant's vision pushed the world of high energy nuclear physics forward, but it would be many years before Australia would get a synchrotron of its own. During the 1950s and 60s, a drive to be involved in the international particle accelerator community, including investigations to determinate nuclear cross sections and other fundamental research led to the allocation of funding in 1962 for Australia's first particle accelerator, a 3 million volt Van der Graff accelerator. The technology was delivered in 1963 to the AAEC (now ANSTO) and operated from 1964 to 2007. Between then and now, additional heavy ion accelerators available at ANSTO's Centre for Accelerator Science, ANU and The University of Melbourne steadily increased the capacity for Australia to make a contribution to this area of research.

Finally, in the late 80s, Oliphant's invention arrived on our shores leading to the next major leap in accelerator physics in Australia: the development of the Australian

Synchrotron. This 3 GeV electron accelerator is a much more complex beast than the accelerators that had come before it. With over a decade of development, the project was subsequently funded and construction started in 2003. The facility became operational with 'first light' in 2006, a milestone for accelerator science in this country and the beginning of something of an accelerator science renaissance [3].

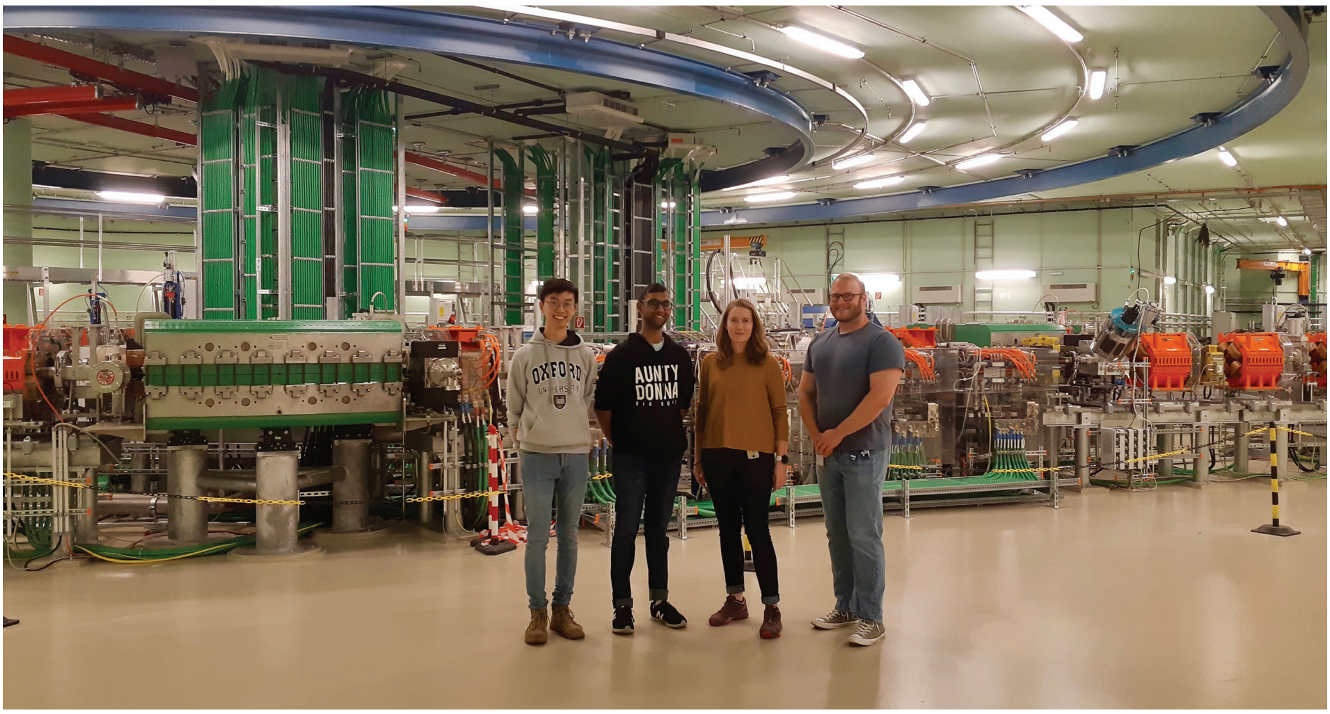
Fast forward to the present

The renaissance continued. In May 2019 over 1500 members of the world's accelerator physics community descended on the Melbourne Exhibition Centre for the International Particle Accelerator Conference, the largest gathering of world experts in particle accelerators. The event was held for the first time in Australia thanks to the dedication and hard work of a number of accelerator experts, including those from ANSTO and the University of Melbourne along with representatives from all over the world including Asia, North America and Europe. It is the premiere conference to share breakthroughs, discoveries, designs and new ideas in the field of particle accelerators—from tabletop-sized experiments to the Large Hadron Collider and beyond.

In the 21st century, knowledge of particle accelerators and the physics behind them is becoming more – rather than less – important. There are over 35,000 particle accelerators in the world today used for everything from making car tires stronger, creating the chips in our smartphones, scanning cargo, through to treating cancer. In fact, around 35% of all particle accelerators in the world are used for medical applications. Many accelerators used for medical applications are not the behemoths we associate with the LHC or even the Australian Synchrotron, but small, roughly 1-meter long electron accelerators. They can generate high energy X-rays by accelerating electrons onto a dense metal target. The entire accelerator is designed to rotate 360 degrees around a patient. This technique is known as radiotherapy. It is an incredibly successful mainstay of cancer treatment, used in approximately half of all curative cancer therapies and also as a support to provide quality of life for patients and complement other cancer therapies.

Particle therapy

While radiotherapy is continuously improving, new options and technologies are emerging. One of the most exciting newer forms of radiotherapy uses heavier charged particles – protons or ions like carbon – to treat cancer. The technology was first proposed in the 1950s; however, only recently has this treatment type become mainstream as a treatment option. Due to the different way that charged particles deposit their energy in tissue (called the dose) when compared to X-rays, it can improve the outcomes for treatment of tumours inside or close to critical organs and cancers which are resistant to conventional treatment with X-rays. We say "mainstream", but you may not have heard of particle therapy because Australia doesn't currently have one of these fa-



Frank Zhang, Greg Peiris, Suzie Sheehy and Dale Prokopovich during a visit of the MedAustron facility

cilities. That's partly because the particle accelerators for proton or carbon ion therapy are much larger and more complex than X-ray radiotherapy accelerators. However, we are catching up and with the growing expertise within this country, we will hopefully be able to move quickly to the forefront of these technologies when they become available in Australia.

The federal and state governments have provided a financial commitment to build the first proton therapy centre in South Australia. This is due to be constructed at SAHMRI in Adelaide in their newly designed SAHMRI II building. A number of other national initiatives are also well underway, including advanced business cases for additional proton therapy centres in Melbourne and Brisbane as well as a combined proton, carbon and other ion facility for Sydney.

Altogether the proposals for particle therapy facilities around Australia would be able to provide treatment coverage for the majority of Australians. This treatment would be complementary to existing cancer treatment modalities and provide support to patients where there would be a significant benefit to treating with particles. In addition to providing the much needed treatment, these proposed facilities would also provide a significant research boost to Australia. Currently Australia doesn't have any accelerators capable of providing the types of high energy particles required for particle therapy, and these facilities can provide the cutting edge research capability that is only available overseas at the moment. The applications for these new research capabilities aren't just limited to medical opportunities but are extremely varied with applications in other areas, such as semiconductors, detectors, space science, materials science, biology, imaging, and much more. Such developments are inherently multidisciplinary, and many areas of expertise are needed. With support from ANSTO, a new group in accelerator physics focused on medical applications has now been started at the University of Melbourne, under the guidance of one of the authors (Dr. Suzie Sheehy) – a Melbourne alumnus who has been working at the University of Oxford from 2007. The group is a new addition to the Australian physics community who have harnessed accelerators to produce outstanding research for many years. In particular, it includes nuclear physics at the ANU, the ion microprobe facility at Melbourne University, various accelerator applications at ANSTO and cyclotrons for radioisotope production, which are used in hospitals for diagnosis. However, what the new group brings is further expertise in the field of accelerator physics – the design and optimisation of accelerators – which until now has been limited in Australia.

The new group will be working on novel accelerator technologies and their applications in medicine, including work to make particle therapy smaller, cheaper and more efficient in future. Bringing this research field to Australia means a lot to Suzie, whose own career in the UK was also (like Rutherford and Oliphant) helped along at one stage by fellowships from the 1851 Royal Commission and the Royal Society. The work is not just interdisciplinary, but also very international – the group are already working with colleagues from Australia and abroad, in particular, with CERN and UK universities including Oxford, Manchester and Imperial College on collaborative projects that will produce the next generation of both hadron therapy and radiotherapy accelerators. They are also working with many developing countries including Indonesia, Botswana and Nigeria, to address technology needs for radiotherapy accelerators in those regions.

Both the authors look forward to seeing the growth of research and collaboration in this exciting area of physics, and encourage other Australian researchers interested in joining in to get in touch with either of them.

About the authors

Dr Suzie Sheehy is an accelerator physicist specialising in the design of novel accelerators for applications including particle therapy and radiotherapy, and in the beam dynamics of high intensity hadron beams. She was trained at Melbourne University (BSc hols 2006) and Oxford University (DPhil 2010) and has held fellowships from the 1851 Royal Commission and the Royal Society. In 2019 she began a new group in Medical Accelerator Physics at Melbourne University. Suzie is also an award-winning science communicator, TEDX speaker and is currently writing her first popular science book due out in 2021.

Dr Dale Prokopovich is a Senior Physicist – Research Infrastructure in the Nuclear Stewardship platform at ANSTO. During his career at ANSTO Dale has been involved in multiple diverse areas utilising particle accelerators for applications including particle therapy for cancer treatment, measurement of space and aviation radiation fields (including measurements at CERN), as well as the use of accelerators to characterise semiconductor materials and device structures for radiation detection. Dale has been actively involved in the Australian particle therapy projects in Australia. In order to support the design and commissioning of potential particle therapy facilities in Australia, Dale has recently undertaken a six-month placement as part of the commissioning team at the MedAustron particle therapy facility in Austria.

References

[1] J. Rotblat, "Mark Oliphant (1901 – 2000), Nature 407, 468 (2000); https://www.nature.com/articles/35035202

[2] M.O. Oliphant, The acceleration of particles to very high energies, Classified memo submitted to DSIR, United Kingdom, Sept. 1943, now in University of Birmingham Archive.

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Bringing out the best in scientific visualisation for reach and impact: visual brokerage

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Population Health Exchange, Research School of Population Health, ANU – erin.walsh@anu.edu.au

Scientific visualisation is a ubiquitous, often necessary component of explaining and sharing research findings. If used thoughtfully, it can engage, inspire, and enhance the communication of ideas and discoveries. While real-world impact has long been central to research, methods of demonstrating impact are moving beyond counting peer-review publications and citations. The way we think about scientific visualisations is changing, in particular how it can be used to creating and enhancing communication throughout the research process. This article outlines the scope, opportunities and challenges of scientific visualisation, and discusses how the concept of visual brokerage can bring out the most from the possibilities offered by visualising scientific content.

Scientific visualisation

Visualising content is an excellent communication tool for promoting understanding, recall and learning of data and research findings [1]. Most people associate scientific visualisation with direct depiction of data, such as micrographs, scatter plots, and diagrams.

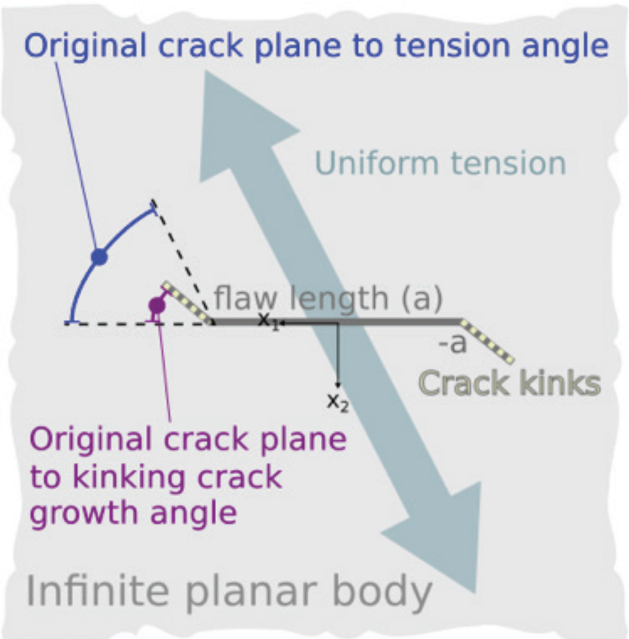


Figure 1: Crack paths under Mode-1 and Mode-11 loading according to maximum hoop stress theory.

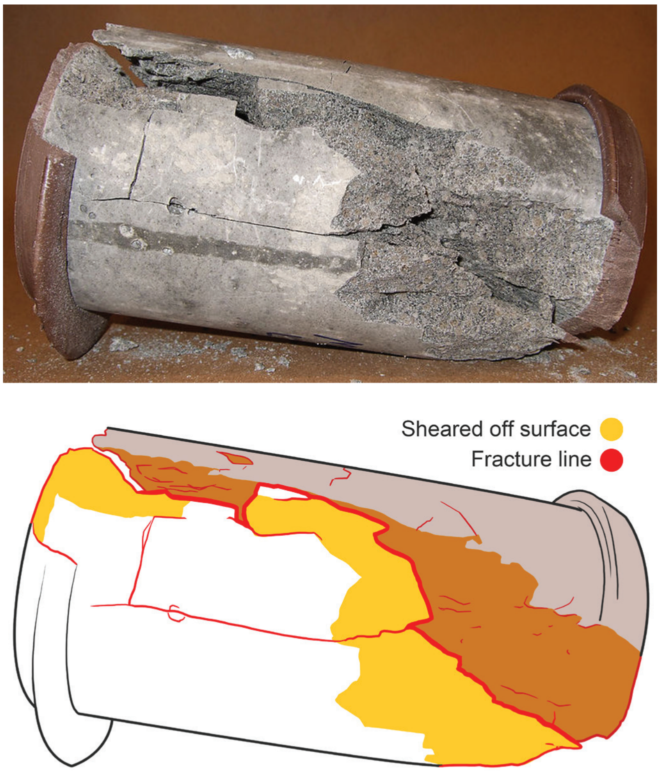


Figure 2: Shear fracture shape in following split failure in a concrete cylinder due to compression forces.

While these visual representations of data are extremely useful, and sometimes incidentally aesthetically appealing, scientific visualisations can go far beyond utilitarian aesthetics which limit legibility beyond a specialist audience (e.g. Figure 1). Although classically used for conveying technical information, they can also capture attention [3], generate emotional responses [4], and persuade [5]. These purposes are not mutually exclusive, especially when visualisations are paired with text. A striking, aesthetically interesting visualisation may serve to capture attention. This attention is referred to text, which then provides information and is supported by the initially attention-grabbing Figure (e.g. Figure 3).

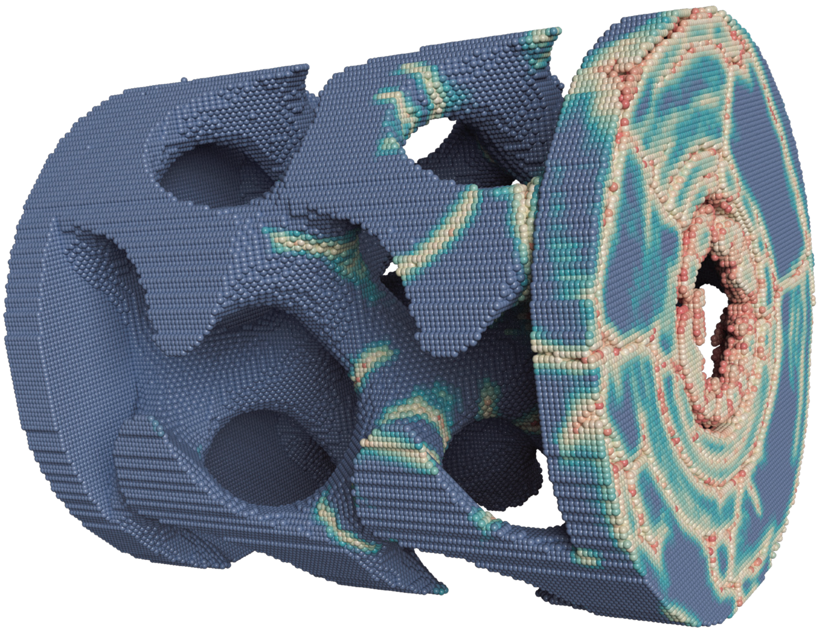


Figure 3: A simulation of fractures propagating through a pair of plates separated by a partially empty middle layer. The structure of this middle layer is called a gyroid. Resembling the spongy structure of trabecular bone, gyroids are attractive in materials engineering because they combine low density with high resilience in every direction. In this calculation performed in the free and open-source LAMMPS physics simulation software [2], the rightmost plate has been hit by a high-velocity impact. Damage (indicated by yellow and red colouring) spreads outwards from the site of the impact. Very highly damaged areas are omitted from the visualisation. This process is modelled using a technique known as peridynamics, pioneered by Dr Stewart Silling. Peridynamic models are used to simulate the fracturing and shattering of rigid solids under high stress.

The key factor that distinguishes scientific visualisations from general visual art is that the technical content (an idea, result, or finding) remains at their core [6]. This leverages the fact that people learn and engage with information more deeply when irrelevant information is excluded [7, 8]. To demonstrate, consider which of the panels in Figure 2 provides the more legible depiction of the fracture shape.

Visual brokerage

Visual brokerage is the process of conceiving, creating, disseminating and interpreting knowledge via visual means [9]. It is the thoughtful, structured application of scientific visualisation in the broader procedure of generating knowledge and subsequent communication. Reflecting the embedded role of scientific visualisation in knowledge discovery, it is a bidirectional process where knowledge is presented, interpreted, and reflected upon. Words hold meaning within themselves but convey much more information in the context of a sentence. Similarly, scientific visualisations are the minimal units of meaning embedded in the syntax and grammar of visual brokerage.

The term 'visual brokerage' is relatively new, but the concept has deep historical roots, where scientific visualisation has been central to the generation and communication of scientific ideas [4]. For example, indigenous Australian cave art maps the land and its resources, some of which are continually updated and re-drawn, through story weaving, discovery and display (e.g. Figure 4). Leonardo DaVinci is an early example of a single individual who embodies the process of visual brokerage. His approach to scientific observation and induction involved drawing from life and concept. These working sketches (e.g. Figure 5) formed part of the undertaking of knowledge discovery [10]. As an artist, alongside more classical art, DaVinci produced polished pieces to convey his technical findings. The visual formed an inextricable part of his scientific process, and the communication of his results.

From the perspective of the artist, illustrator or designer, visual brokerage provides much-needed context, and enhances the meaning of their work beyond the purely aesthetic. The technical accuracy that is core to scientific visualization can be difficult to achieve without a basic

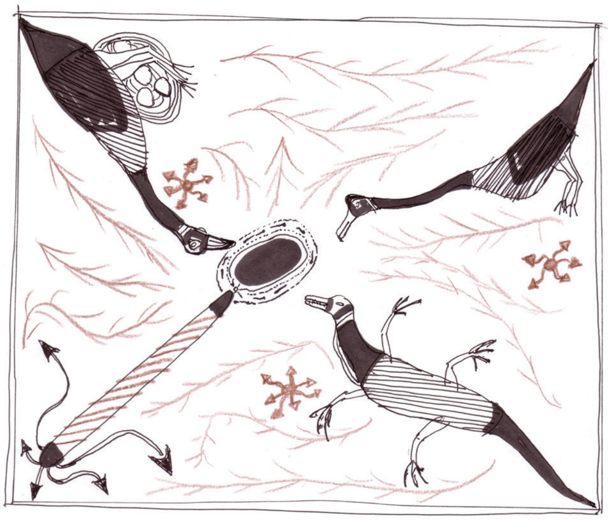


Figure 4: Recreation of an Arnhem Land North Coast Indigenous Australians cosmogony.

understanding of often complex concepts. Accuracy in depiction, and identification of core (versus irrelevant) information is enhanced by watching the research process unfold [11]. Further, it guarantees that the final work will have embedded authority. Visual brokerage produces scientific illustrations of particular credibility, as the viewer is aware that the artist has been creating as part of the research team, and so their depictions of technical information become more trustworthy [9].

From the perspective of the researcher, visual brokerage is the logical extension of scientific visualisation already (or advisably) taking place. In science, visualising data is integral to the research and discovery process [2, 12]. Scientific visualisations can assist with initial data scrutiny and exploration, or codifying ideas in progress [13]. For instance, a glance at a histogram may serve to check feasibility of values, closer inspection of a micrograph can reveal a structure of interest, or a chart may indicate links and relationships between findings as they arise. Visual brokerage enhances the discovery process by more directly connecting those internal work-in-progress visualisations to the eventual external communication of the work. In doing so, it provides the researcher with greater agency and connection with the way their work is portrayed, as opposed to bringing in an external artist, illustrator, or media expert at the end of the project to create the public-facing depiction of their work [14]. This is particularly important in fields such as the humanities and social sciences, where it is common for manuscript text to be completed prior to consideration of visualisations within the manuscript, and visual communication strategies [15, 16].

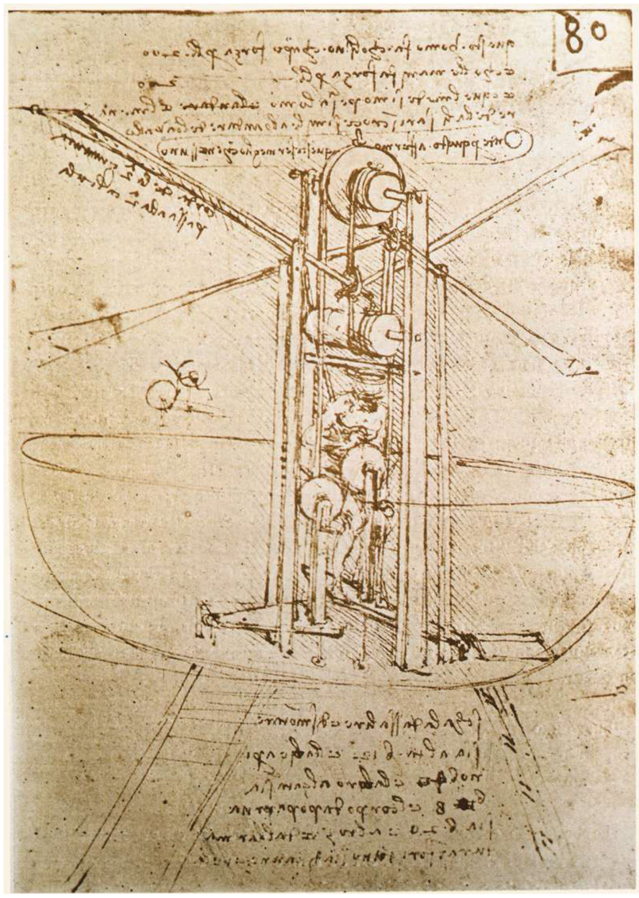


Figure 5: Flying machine sketch, Leonardo Da Vinci.

Challenges to applying visual brokerage

As highlighted, visual brokerage is less of a new paradigm than it is a formalising and "re-convergence" of the historical link between visualisation and science [17]. It is arguably already spontaneously and tacitly occurring throughout the sciences [9]. If the benefits of visual brokerage are to be extended to a more comprehensive approach across multiple fields, researchers may need to be convinced of its viability in both conceptual and pragmatic terms. This may require addressing a number of concerns:

Lack of time and skills / time saved and skills learned

In an era of increasing overwork in academia [18], concerns about what appears to be yet another burdensome task would be understandable. A misperception of visual brokerage as a time sink, rather than time saver, would most likely stem from confusion between media modes (e.g. posters, web, virtual reality), communication platforms (e.g. media releases, social media engagement) and paradigms (e.g. visual brokerage; action research) [16]. Visual brokerage does not expect researchers to craft virtual reality experiences or become media experts, but simply shift their thinking and engage with new collaborators. In reality, visual brokerage is likely to free

Figure 6: A climate coaster

up time and lessen the burden on researchers by providing a collaborative partnership that leverages existing skills. Visual literacy is a useful starting point for effective communication [4], as is scientific literacy on the part of the visualiser [19]. Prior training and experience is neither likely [15] nor necessary because they will develop as part of the visual brokerage process [9].

Lack of resources / making the most of resources

Until granting agencies and research institutions recognise and provide basic resources, it is unrealistic to expect widespread implementation of visual brokerage. There are, however, resources that could allow at least partially implementing visual brokerage into the research stream. In many institutions, support for media releases, infrastructure like web hosting and exhibition spaces, and advice on legalities such as copyright are present, albeit often underutilised [15]. Similarly, artist in residence programs are present but typically limited to single artists embedded in large departments (e.g. University of Sydney Artist in Residence program) or institutions (e.g. Synapse CSIRO residencies). While expansion of these resources would be ideal, raising their visibility to better gauge demand would be a good first step.

Many universities have faculties of arts and sciences. Taking the initiative to form collaborations between these faculties in mini-visual brokerage projects can be an achievable way to demonstrate the utility of this approach. (e.g. 'Climate coasters', a partnership between artists Dr. Whitelaw and Dr. Hinchcliffe and the Climate Change Institute at the Australian National University; Figure 6). Here, the science content around climate data is engraved in an everyday object (a coaster) to bring broker data to the public.

There are also actions researchers can take in their daily work to make the most of what they already produce. This may be as simple as some adaptive habits. For example, a recent review of researchers at the University of Griffith highlighted that researchers were not in the habit of collecting visual or multimedia content that they naturally generated in the normal course of their research [15]. This may be as simple as keeping a folder or file to store visual content as it is generated, thus building a visual archive of a research project. This can then be used as a resource for visual communication.

Poor fit

There are some research projects or findings that are simply not amenable to visualisation. For example, where findings hinge on a clustering of points in an n-dimensional space, 'flattening' them into a necessarily lower dimensional visualisation can be challenging to lay out on the page, and at times impossible to interpret (e.g. as in the canonical force–based model, discussed in [20]). When an artistic interpretation is impossible without misleading or losing the technical core of information, visualisation risks being an ineffective use of resources or, worse, actively harming credibility [21, 22]. In these cases, visual brokerage can help establish whether a visual approach is likely to prove fruitful.

Sometimes, scientists and artists simply do not mix. Problems with communication and substantially different expectations are at the forefront of this concern. For example, attribution and authorship can prove challenging [23]. Should the artist be included in peer-reviewed output as a co-author? How can the scientist include a painting in their CV if it does not have a DOI? Again, visual brokerage can be helpful in establishing fit by allowing the collaborative relationship to develop early in the research progress. This allows the development of shared language and expectations.

Lack of motivation

Few would argue against the goal of bringing science, policy decision makers, and the public closer together to benefit from the knowledge researchers produce. We have established that visual brokerage is a logical step for making the most of scientific visualisations, which could be (and already is being) implemented in current environment of skill, time, and resource limitations. But there remains one key barrier. Universities and granting agencies evaluate researchers based overwhelmingly on their publication output in scholarly journals, particularly in the 'harder' sciences such as physics [24]. In some fields, such as business and economics, researchers have reacted with tunnel vision focus on journal publications rather than presentations or other methods of knowledge communication in a trajectory that has remained pronounced over the recent past [25]. In career terms, it can be argued that a technically informative, aesthetically beautiful visualisation that engages colleagues, media, and lay-audiences remains significantly less beneficial than a publication in a scholarly journal. If visual brokerage is to reach mainstream use, universities and granting agencies need to adjust the metrics used to access researcher output to include a broader sense of research impact.

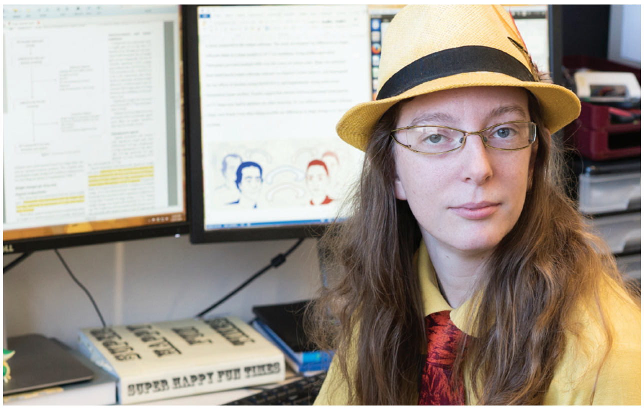
Visual brokerage for impact

'Impact' is a difficult concept to codify. Short of remarkable examples (e.g. Nobel Prize winners), a researcher's impact has historically been characterised in terms of textual output – number and prestige of patents, books, and most importantly peer-reviewed publications [24, 25]. In the past decade, there has been a global push to conceptualise impact more broadly to include attention, engagement and reach of ideas through physical and digital media [26]. This is slowly changing how funding, resources, and consequently research is planned and evaluated.

In Australia, this is demonstrated by initiatives such as the Australian Research Council instantiating a "Research Impact Principles and Framework" working group in 2012, which propose that impact should include peer-reviewed publications alongside national collections, policy briefings and media[27]. This has been reflected in university courses (e.g. "Creating impact", offered by the Australian National University Joint Colleges of Science as of 2014 [28]), and awards (e.g. "Award for Research Impact" at Monash university, as of 2014 [29]).

This shift has been accompanied by modest increases in scientific visualisation and media outreach [22] and the formal codification of the concept of visual brokerage [9]. Publications on the utility of visualisations for enhancing research impact continue to be produced (e.g. [30]). Yet, there remains substantial scope to bring the visual to the forefront. This is an unprecedented opportunity to foster a change in the way research is funded and evaluated, open the door for researchers and visualisers to form value-add partnerships, and in turn, facilitate the integration of visual brokerage into research practice.

About the author



By day, Dr Erin Walsh is a research fellow at the Population Health Exchange, ANU. Drawing on her background in psychology (via morphometrics and structural imaging of the ageing human brain), her primary research focus is using visualisation to maximise knowledge generation, co-production, and implementation in population health. By night Erin is a freelance artist and scientific illustrator who works with academics from a variety of disciplines to bring their work into visual form.

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Figure 1 based on work by JP Mulderring (CC BY-SA 4.0 license) by the author. Figure 2 is based on a photograph uploaded to Wikimedia commons by Xb-70, in the public domain. Figure 3 was created upon request by Dr. R.N.L. Terrett and is used here with permission. Figure 4 is in the public domain, courtesy of Wikimedia Commons and the Ganallingu people. Figure 5 is in the public domain, courtesy of the Web Gallery of Art. Figure 6 is reproduced with permission of the artists.

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Science meets Parliament 2019

Every year, a select group of scientists goes to Canberra to meet and, hopefully, influence members of parliament and their staff. Here, two physicists reflect on their experiences in the most recent iteration. For more information on how to be involved, visit scienceandtechnologyaustralia.org.au/what-we-do/science-meets-parliament/.

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Australia's politicians and scientists share the same goal: to improve the prosperity and quality of life of Australians and people around the globe. However, we can seem to speak different languages and have very different priorities. It is for that reason that I was keen to attend Science meets Parliament, to learn how to bridge the gap between our leaders and researchers. Organized by Science and Technology Australia, with the aid of other institutions and volunteers, Science meets Parliament brings together Australia's leaders, decision makers, and STEM professionals to promote the importance of science, technology, engineering, and mathematics in Australia. 2019 marked the 20th Science meets Parliament, indicating just how successful and strongly supported the event has become.

Spread over two intense days, Science meets Parliament gives researchers the opportunity to learn how our politicians and parliament work, and how to advocate for recognition in Australia's political landscape. Day one focussed on science communication training, and featured keynote presentations from scientists and policy makers working at the coalface of Australian STEM policy and advocacy. Day two featured more presentations from STEM ambassadors and advocates, as well as panel discussions with parliamentarians and senior scientists. But the core of the event was the opportunity to meet and talk with our assigned parliamentarians and their staffers.

Scientists meeting with. From left: Dr Sara Howden (MCRI), David Smith MP, Dr Daniel Rodwell (NCI), Dr David Gozzard (ANU), Dr Michael Tobar (UWA).

We heard from the likes of Chief Defence Scientist Professor Tanya Munro, Australia's Chief Scientist Dr Alan Finkel, and New Zealand's Chief Science Advisor Professor Gary Evans. It was interesting to learn the similarities and differences in science policy and application from the two sides of the ditch, the challenges that our countries are facing, and the priorities for spurring technological development and innovation. Politicians and policy makers are always looking to the future, trying to predict and head off local or global changes that could impact our nation's prosperity. The key challenges in the coming years are how to support our growing, but aging, population; how to maintain a competitive edge for Australian businesses and exports in an ever-changing world; and how to tackle climate change. Professor Fiona Wood, of spray-on skin fame, delivered a fascinating and inspiring opening address that touched on her experiences helping to save lives by changing the way burns patients are treated across Australia,.

The science communication training helped us workshop and refine what we were going to advocate to our assigned parliamentarians. I have been very interested in science communication for a long time, so the techniques and ideas were familiar to me, but not so familiar to many of my fellow delegates. As with all science communication, regardless of your audience, it is imperative that you keep your message clear and concise and jargon free. Understand that effective communication is always a two-way street, be considerate of your audience, and respond to their needs. Find what they are interested in, and use that to guide you in delivering your message.

With limited time to talk to busy politicians, we had to pick one clear idea and communicate it clearly, concisely and persuasively, without getting bogged down in unnecessary details. We learned that in the world of STEM advocacy, communicating the narrative of why we are doing our work is crucial and must not get lost in what we are doing. How does the local community, or Australia as a whole, benefit from what you are doing?

Day one ended with a gala dinner at parliament house attended by some of the politicians and parliamentary staffers we would be meeting the next day. This provided the opportunity to start to advocate, build rapport, and work on our communication techniques in a more relaxed atmosphere.

Science meets Parliament gave delegates the opportunity to meet and network with around 200 STEM professionals from a diverse range of backgrounds, from academia, industry, and even self-employed scientists. I spoke to other physicists, as well as biologists, early-childhood researchers, epidemiologists, and more. I put a neuroscientist in contact with a science journalism group, got a Virtual Reality tour of ANSTO's research reactor, and learned some worrying facts about ticks from an entomologist from Murdoch University. With such diversity, there was a huge variety of goals and agendas, but everyone shared a passion for their field and a desire to raise its visibility in science policy and public debate. Meeting so many passionate scientists was, for me, a highlight of the event.

The most exciting part of Science meets Parliament had to be meeting with our assigned parliamentarians. Each meeting included four STEM professionals from a variety of fields. Some groups worked together to convey a joint message, while others represented the individual challenges of their field. Some delegates were steeling themselves against the prospect of meeting MPs and Senators with more intimidating reputations. I was nervous, but looking forward to my scheduled meeting with David Smith, MP for Bean in Canberra's south, along with his senior staffer Bryce Wilson. The other scientists joining me in the meeting were Michael Tobar from physics at UWA, Daniel Rodwell from Australia's National Computational Infrastructure, and Sara Howden from the Murdoch Children's Research Institute. While we had not worked together beforehand to present a joint message, we found that we were largely united in our concerns for STEM in Australia. We discussed what we felt were the major challenges facing Australian research: tertiary education; funding and job stability; the brain drain of talented scientists out of research in Australia (a widespread concern amongst delegates); and Australia's missed opportunities to capitalize on our nation's expertise and skills.

We found Mr Smith and Mr Wilson to be very receptive to our thoughts on these issues, keen to hear our opinions on how to tackle them, and genuinely curious about our research. Prior to politics Mr Smith had worked in the public service and had experience as a policy officer, so he had been in our position, advocating for the needs and futures of the groups he represented. Mr Smith had also been Director of the ACT branch of Professionals Australia, a body that grew out of the Association of Professional Engineers and Scientists. During his parliamentary career he has served on committees looking into sectors including publics works and electric vehicles. Mr Wilson had been a high school teacher before becoming a political staffer, so had a great deal of experience in the challenges facing secondary education from the classroom to the policy level.

Our meeting had been scheduled for half an hour, but Mr Smith and Mr Wilson gave us more than an hour of their time discussing the issues we had raised (with Mr Smith having to dash to the chamber occasionally for a quick vote). We learned that changes in support and funding for secondary education and TAFE are more immediate priorities than tertiary education for both the government and opposition, and we pushed our argument that tertiary education must not be left behind at this time. We discussed solidifying announcement dates for ARC and other government funding to reduce the employment uncertainty that has caused a recent exodus of brilliant researchers, and changes to visa rules to make it easier to attract and retain top international researchers.

While any single meeting might not have been able to cause immediate policy shift or discussion, this was only one of the nearly 250 meetings the 200 delegates participated in that day. Science meets Parliament has a long-term goal to generate broader and more consistent political support for science and technology in Australia. All of us were encouraged to keep in contact with our MPs, and some delegates left their meetings with further meetings and discussions already scheduled. Many MPs even provided further advice for getting a delegate's proposal onto a state or federal political agenda.

The final day closed with drinks and canapés during which the main topic of conversation between the scientists was their experiences meeting their assigned parliamentarians. Nearly everyone I spoke to reported how engaged and interested their politicians were. Some politicians turned out to be huge nerds, wanting to go into the details about anything from gene editing to dark matter.

Science meets Parliament was a fascinating introduction to the machinations of science and technology policy and advocacy in Australia, and an insight into the life and people on Capital Hill. I'm sure it is an understatement to say that running a country is a hard job, and I'm sure many of us have times when we feel our government should be doing things differently, but Science meets Parliament gives delegates a new perspective on government, and an insight into how to influence discourse and push for change. Politicians' time and attention is in high demand, and they have the daily job of working out how best to use legislation to guide the country and where best to invest the country's limited financial and human resources. I left Science meets Parliament with a lot of notes for ideas to push, things to think about, opportunities to discuss with colleagues, and a plan to make sure I invite David Smith and other MPs to tour our lab.

I strongly encourage anyone who is interested in promoting any and all aspects of STEM in Australia to apply to attend Science meets Parliament in the future. Even if Science meets Parliament is not your sort of thing, take a few minutes to consider what you would say and how you would say it if you went to an event and got a moment to chat with your local MP, or anyone else influential. If you have an event coming up, such as the opening of a new lab, or a press conference about your work, invite your MP down. They will almost certainly be interested in taking a look. Most of them are very interested in anything and everything that is going on in their electorate and want to know what they can do to support it. Science meets Parliament is just one day. Continuing to reach out to and talk with our MPs will help to ensure that the importance and impact of research and evidence-based policy is a part of their everyday decision making.

I am extremely grateful to the AIP for sponsoring my place at the meeting, as well as to Science and Technology Australia, the organizers, volunteers and speakers who made the event a success.

Timothy van der Laan

Researcher
Representing AIP - tim.vanderlaan@csiro.au

First and foremost, I would like to thank the Australian Institute of Physics for providing me the opportunity to attend Science meets Parliament in 2019. I gained a lot from the experience and appreciate the institute's support.

I attended this event with very little idea about what was to occur and how the program would run. Science and Technology Australia did an excellent job of welcoming me and the other delegates to Canberra but also preparing us to handle parliament. My affiliation with CSIRO meant there was an extra afternoon of information beforehand. The role that publicly funded research organisations play in the science sector means the approach to dealing with parliament is a little different. Aspects to this included: being engaging and talking about our passion and excitement for science; speaking where possible to facts and not opinions; and highlighting when something was an opinion. I learned later a lot of attendees were planning on lobbying for areas of science; this does not suit my personality, so I felt more comfortable with the CSIRO's approach to dealing with government.

The first day of the programme was dedicated to preparing delegates for their meetings. For many this involved a lot of pitch practicing which is something not many had done before. Having practiced and delivered many pitches I was quite surprised this is not a more commonly practiced presentation style in the scientific community. I was particularly engaged by the social media session on the first day as I have an interest in science outreach. Professor Fiona Wood's personal and thoroughly engaging address was a highlight on this first day. The gala dinner at the end of the day was excellent. While overall the entire day was a great networking opportunity, I thought the dinner was a particularly good. Parliament's head beekeeper was sitting on my table and a crazy science experiment for 2020 might have been concocted over dinner: think bees, physics and refined natural products!

Day 2 was dedicated to the meetings with members and senators. There was one very good parliamentary panel where we got to hear a little more from three parliamentarians about how STEM research and applications influences them and their parties, particularly regarding policy. Prior to arriving on the second day

I was fortunate enough to be assigned a member of parliament to meet. This allowed me to do a little background research. I met Graham Perret MP, federal member for Moreton. My meeting was rescheduled a few times, however as we were told this is common during a sitting week. Initially I thought I would have to spend time and effort making my work, physics and science in general relevant to the Graham. This however went right out the window as soon as we sat down to chat. Graham had a genuine interest in what me and the other STEM professionals in the meeting were doing. Graham has experience in teaching and was very interested in our thoughts on the teaching of STEM. I'll be very interested to see what he has planned for science week this year.

I left Canberra with a new-found respect and admiration for politicians. Before Science meets Parliament, I didn't realise how difficult their work was. Despite any political orientations of the attendees everyone I engaged with spoke about their assigned parliamentarian's interest in their work and science in general. It was refreshing leaving Canberra knowing that the voices of scientists are heard by our elected representatives. The greatest lesson I have taken from the experience is that, to be relevant in Parliament, we need to make scientific research, process, and funding be more than good policy; also good politics. Scientists, including physicists, have for a long time leaned away from politics desiring to not engage. I suggest that as a community we should be leaning in and becoming more relevant. I would prefer the physics community be a valued advisor, speaking with a measured and steady voice about best evidence and theory rather than sit on the side lines and have minimal impact.

About the authors

Dr David Gozzard is a postdoctoral researcher at the Australian National University working on optical phased arrays, and laser sensors and communications systems. He completed his PhD at the University of Western Australia working on the SKA telescope. He has recently been awarded a Forrest Fellowship and will be returning to western Australia to work on ground-to-space laser links.

Dr Tim van der Laan is currently working with CSIRO to commercialise technology he co-invented. This work is focused on using 2D materials (Graphene) as a membrane for water purification and other applications. He has just finished his first post-doctoral role at Queensland University of Technology (2019) after completing a PhD at the University of Sydney (2016). He is a active member of the AIP's NSW branch and is interested in Physics Outreach.

New Fellows of the AIP in 2018 & 2019

The AIP congratulates the following individuals for becoming Fellows of the AIP, and looks forward to their continuing contributions to physics in Australia:

2018

- Alexander Heger
- Amanda Karakas
- Jennifer Wong Leung
- Maria Parappilly
- Gregory Wilson

2019

- Arti Agrawal
- Jodie Bradby
- Ulrik Egede
- Robin Hill
- Dougal McCulloch
- Frederick Menk
- David Narula
- Jordan Nash
- Jamie Quinton
- Nick Robins

#PhysicsGotMeHere

My name is Shermiyah Rienecker and I am a Medical Physicist at Biomedical Technology Services (BTS).

Describing what I do at BTS begins with what a medical physicist does. In general, a medical physicist is a scientist who applies physics principles to help medical doctors diagnose and treat medical conditions. They are employed in four main areas: academia, industry, hospitals, or government. Academic medical physicists work on cutting-edge healthcare applications and advance our understanding in biomedical science. Industrial medical physicists commercialise the evidence-based healthcare applications which get sold to clinics. Hospital or clinic based medical physicists ensure safe and effective use of the healthcare applications purchased by clinics. Lastly, government medical physicists serve the public and are involved in policy, governance, procurement, and health technology management.

My job at BTS uniquely involves all four main areas of medical physics. The work is industrial in nature (customer service oriented), because BTS is a business enterprise of the Queensland government. The BTS Medical Physics service operates independently of clinics and health technology vendors, in the best interests of every Queenslander. I am currently working towards certification to independently practice in clinical diagnostic radiology (medical imaging).

Physics helps me understand our natural environment, and to be mindful of what we cannot see. I use physics methods and knowledge to physically tell things apart and present this information back into a format we naturally see (images). I like 'seeing' things without destroying them in the process, which is the principle of diagnostic imaging. The physics concepts of diagnostic imaging are very useful in medicine. By understanding the physics behind the intended design and experimentally testing the design of commercial scanners, I am able to help clinicians choose what technology is best suited for their patients; provide day-to-day confidence in using that technology; and support clinical departments in ensuring these scanners are being well maintained.

The greatest challenge about working in hospitals is that it is probably the last place anyone wants to be. However, it is sobering and motivates me to contribute my part to patient care. I was born in a rural hospital myself, so the best part of my job is knowing my work directly helps urban, regional, and rural communities across Queensland.

I completed a Bachelor Honours degree in Medical Physics from Ryerson University (Canada), and a PhD in Biophysics and Physical Chemistry from the University of Queensland (UQ).

Prior to starting my PhD, I worked in Research and Development. My first physics job was at Ryerson working on nanotechnology, and phototherapy under ultrasound guidance. I then worked at Los Alamos National Laboratory commercialising portable NMR and quantitative MRI for the US Department of Homeland Security. That experience helped me secure funding from the German Academic Exchange Service (DAAD) to develop high field quantitative MRI methods for Siemens at Magnetic Resonance Bavaria in Würzburg, Germany.

I received an international PhD scholarship to develop electron spin resonance applications for melanin research, melanoma diagnostic imaging, and biosensor technology. I also worked part-time developing an open-online course in biomedical imaging for UQ. In the middle of my PhD, I took a break to start a family with my husband who is Australian. I was well supported by my colleagues, received paid maternity leave from my scholarship, and flexible arrangements to finish my program. I applied for a job with BTS after submitting my thesis and received a job offer the same day I graduated.

The Young Physicist in the Kitchen

Why in the kitchen? - The Young Physicist series aims to get very early career researchers to look at the world around them through the eyes of a physicist, emphasising hands-on exploration. Professional researchers do this in dedicated laboratories packed with valuable equipment- examples can be found in the product news section of this issue. You likely do not have such a facility-yet there is a natural laboratory in your home, where you can see all sorts of interesting physics: the kitchen. Like most measurements, cooking starts with a literature review; looking up existing recipes and asking other cooks for advice. Then, we attempt to reproduce the result; and then extend, adapt and improve it. We can all be scientists in the kitchen.

Physics kitchen tools

An insanely useful bit of tech is an Infra-Red thermometer. It looks like a gun (see Figure 1), but it's more like a camera. It detects the intensity of Infra-Red light coming from hot objects and uses this to calculate the temperature. We can't see light in the infra-red part of the spectrum with our eyes, but some animals can. It's super fun- point it at a frying pan or saucepan of water, and it tells you how hot it is. If you don't have one, ask for it as a birthday present. Or, see the end of this article for how to get one for free…

Cooking involves measurement of 'how much' stuff. Volumes of flour and water, weights of pasta and beans, temperature of frying chips, and cooking time of cakes. We rely on the measuring cups, jugs and spoons to be correct. But how do we know that the numbers are accurate. These sorts of calibrations, when done by scientists,

Figure 1: Image of a hand-held Infra-red thermometer [1].

are called metrology. Many countries have special labs where teams of scientist define what exactly constitutes a litre, kilogram, or degree Celsius. For further reading, see the article on the standard kilogram ion a previous issue of this magazine.

Microwave ovens

Microwave ovens are an advanced bit of technology that we take for granted. Their ancestors appeared a century ago (Figure 2 has a cute example) and developed alongside military radar technology. The heart of a microwave is a magnetron, which sends electrons in circles which emits 'light' in the form of microwaves- a bit like radio waves. wavelength around 12 cm. (If this sounds a bit like the Australian Synchrotron, it is- they are related, if not exactly brother and sister). Microwaves cook by heating the water. Waves move the water molecules around,

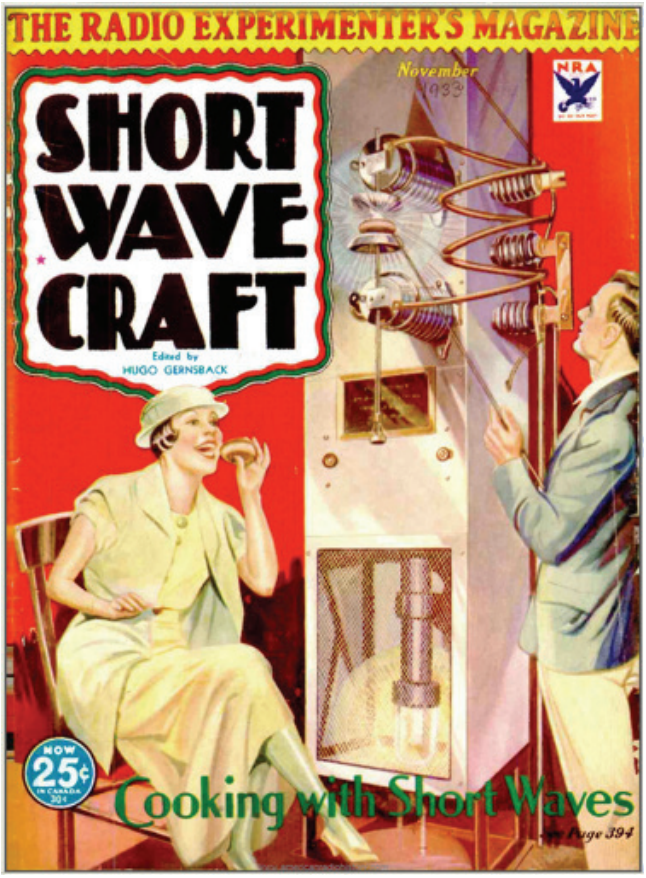


Figure 2: Cover of The Radio Invetors Magazine from 1933, spruiking how to cook with microwaves. This form of cooking was demonstrated at the 1933 Chicago world fair [2].

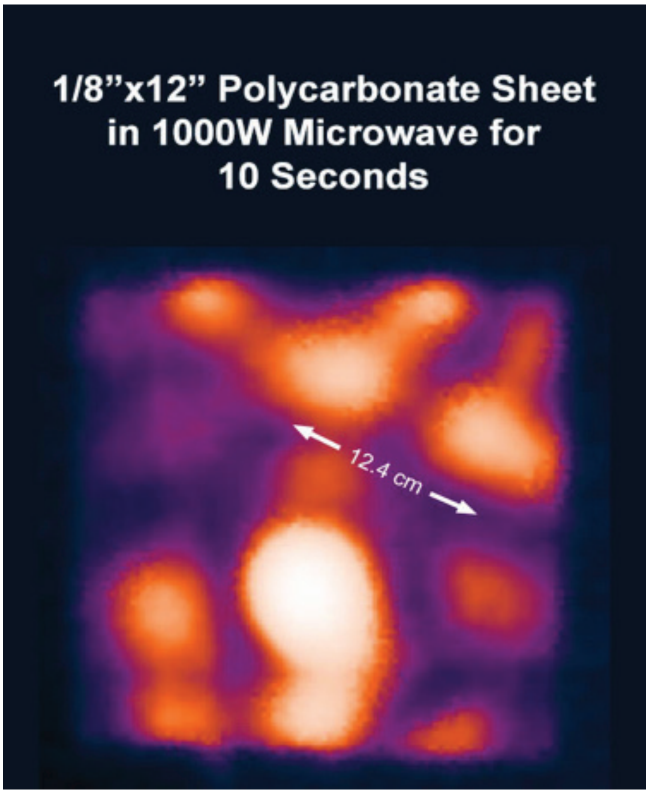


Figure 3: Thermal image of polycarbonate sheet [4].

which is one way of describing heat. Centre and outside heat at same time, but no cooling mechanism inside.

The standing waves can be seen in some ovens by laying down a sheet of chocolate or wet thermal paper (like a supermarket receipt) and watching it melt at the antinodes. An example of the patterns formed is shown in Figure 3. Don't do this at home- some microwaves don't like being run without food inside. The microwave wavelength of 12 cm explains why the door has a screen of metal holes: the holes are smaller than the wavelength of microwaves, and so they are blocked.

Speaking of other things which are dangerous (seriously, don't do this- watch this video instead [3]) is putting metal inside and operating. Metal acts as antenna, absorbing energy from the microwaves which builds up and can then make a lightning strike to the wall of the oven.

In the perspectives section, you can read about the cosmic microwave background, which is a bath of microwaves which fills the universe. They are low energy, so we don't feel them, but we can see them with sensitive antennas.

Baking and roasting in the oven

Heat moves from one place to another all the time, but in the oven it's the main game. It can happen in a few ways. Convection is the hot air moving around, taking the heat with it. Hot air rises naturally, but many ovens have fans to make this faster and get the heat spread out more evenly. Conduction is the heat flowing from the cold parts of a metal to the hot parts. How this happens on the microscopic scale is fascinating- sometimes it's the electrons acting a bit like a gas and carrying heat around inside the metal; other times its cascades of collisions rather like an earthquake. In non-fan-forced ovens, more of the heat transfer occurs by radiation. The light from hot things can pass through the vacuum of space- unlike convection and conduction, there doesn't need to be anything present to carry the heat. This is how we get light and heat from the Sun. Note that the word radiation here is not referring to anything nuclear- that's ionising radiation which can alter the information in cells in your body. The effects of radiated heat in an oven can be dramatic; my oven has a 'browning element' on the top which I use as a super-potent toaster. It will reduce bread to ashes in a few minutes at full blast.

Frying

When frying, hot oil (usually at 160-180°C) makes great thermal contact with food, soaking in and heating it up very quickly. Water boils at 100°C, so the water in the food turns to steam, pushing the oil out. The oil soaks back in after frying stops, as removing the water makes food more oil-loving, and the cracks made by cooking acts like a sponge. By quickly draining the excess oil before it starts soaking in, we can keep the surface light and crispy. The microscopic structure of the material affects the macroscopic taste and texture. These spongy systems are a current hot topic in materials research, and are particularly suited to imaging with X-rays to build up a 3-dimensional model. It's even been done with fried food [5].

A Challenge for you- and a Prize

Make a short video of yourself cooking something in the kitchen, and see if you can identify the processes described in this article. The best entry will win an Infra-red thermometer. Email your videos to aip_editor@aip.org.au. We look forward to seeing them!

References

[1] Image credits: Hedwig Storch, CC BY-SA 3.0

[2] Cover of Short Wave Craft magazine, sourced from https://www.americanradiohistory.com/Archive-Short-Wave-Television/30s/. Public domain licence.

[3] https://www.youtube.com/watch?v=b1MFWbX3Bfc

[4] Image credits: Greg Blonder © 1998- 2020 Genuine Ideas,LLC. From genuineideas.com/ArticlesIndex/wave.html

[5] Tanjila Alam et al. Microstructural Characterization of Fried Potato Disks Using X-Ray Micro Computed Tomography, Journal of Food Science (2016). DOI: 10.1111/1750-3841.13219

(all weblinks accessed February 2020)

SAMPLINGS

Microplastics are turning up everywhere

(Courtesy: iStock/aykuterd)

Tiny plastic particles are showing up in all sorts of places and have become a worldwide problem. Scientists are in the early stages of determining how microplastics, defined as particles smaller than 5 mm, enter the environment and are transported – often up to hundreds of kilometres – into previously pristine ecosystems. Researchers presented several observations on microplastic migration at the annual meeting of the American Geophysical Union (AGU) in San Francisco, California, in December.

Scientists group microplastics into three categories. The first are spherical microbeads, which typically come from facial cleansers and similar pharmaceuti

Fields to mountains

Meredith Sutton, an undergraduate student at the University of Virginia, US, told researchers at the AGU meeting that microplastics are expected to be found downstream of urban centres. However, they are increasingly found downstream of agricultural areas as well. Sutton and her colleagues suspected that fertilizers made from sludge at wastewater treatment facilities might be a source, so they conducted a controlled experiment in the midwestern state of Nebraska. After rainfall, they found that much higher concentrations of microplastics (mainly fragments) ran into streams from fields treated with sludge-based fertilizers than from unfertilized control plots. The sludge treatment process does not screen for or filter out microplastics, Sutton said.

Julia Davidson of the University of Nevada–Reno, US, described finding microplastics on surface snow in remote areas of the Sierra Nevada mountains that straddle the California-Nevada border. Microfibers, especially, showed up 250 to 320 km from the nearest human habitation, and were probably borne there by wind. Davidson, an undergraduate, noted that microplastics do not degrade quickly in the alpine environment and would be difficult to remove due to their tiny size and the vast extent of the mountains. She also pointed out that the Sierra Nevada snowpack is a major source of drinking water for humans and animals. The health effects of microplastics, she said, are not yet known.

According to Davidson, hers is the second study of microplastics in snow. Another, from earlier in 2019, found particles in both the Alps and the Arctic. Both studies suggest that microplastics are widespread and that particles are travelling long distances, Davidson said.

Coming out in the wash

Plastic-based microfibres enter the environment whenever synthetic fabrics are laundered, but especially when detergents are used. According to Emmerline Ragoonath-De Mattos, an undergraduate at Columbia University, US, who conducted a study at Columbia's Lamont-Doherty Earth Observatory, the drying part of the cycle contributes the most microfibres. The Columbia study found both fibres and fragments in zooplankton – a food source for fish – in Long Island Sound, which lies east of New York City and downstream of wastewater treatment facilities.

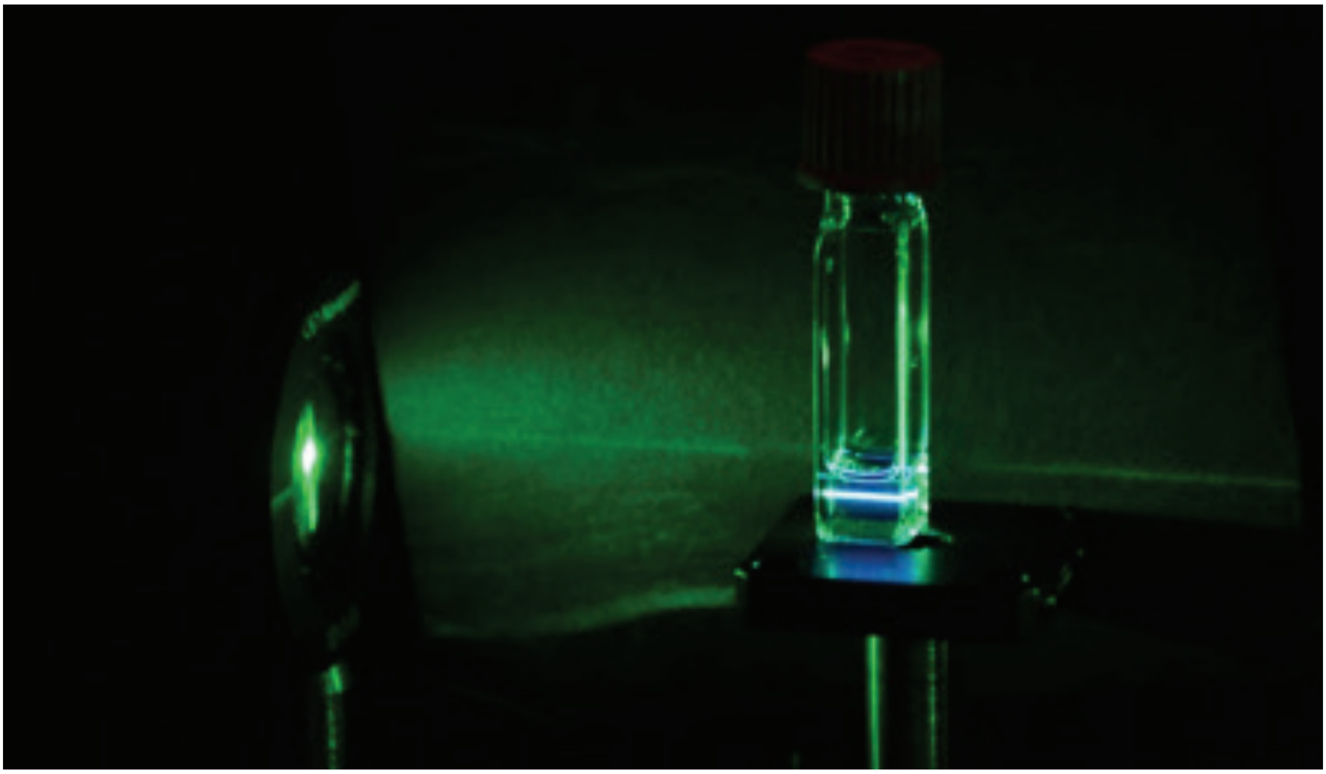
Other research projects described at AGU uncovered large accumulations of microplastics in Virginia floodplains, US; in Chinese mangrove estuaries; in Vietnam's Mekong River and its delta; in almost all Japanese rivers; and in the ocean.

(extracted with permission from an item by Harvey Leifert at physicsworld.com)

Progress in physical chemistry may enhance light-based therapies

Researchers in the US have designed non-toxic silicon nanocrystals functionalized with specialized organic molecules and shown that these materials can readily combine low-energy photons into higher energy ones. This process, known as photon up-conversion, can address several key problems in biology and materials science (Nature Chemistry 10.1038/s41557-019-0385-8).

Recent advances in deep-tissue imaging and phototherapy for cancer treatment have been transformative. Such technologies mainly use near-infrared (NIR) light, which has a higher penetration depth through biolog-



Lower-energy green laser light travels through silicon nanocrystals, which up-convert it into higher-energy blue light (Courtesy: Ming Lee Tang research group/UC Riverside)

ical tissue than ultraviolet or visible light. However, as NIR light contains low-energy photons, it may not have enough energy to generate the free radicals needed to kill nearby abnormal cells.

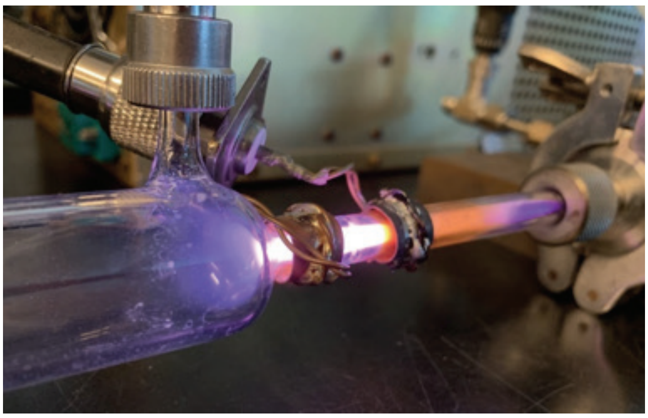
As such, material scientists and chemists have been working to convert low-energy NIR photons to high-energy excited states, using functionalized inorganic nanocrystals (NCs) containing energy-accepting dyes. It is possible to achieve light up-conversion with efficiencies of more than 10% using such materials. However, the NCs employed contain toxic heavy elements, such as lead, which limits how they can be used.

Non-toxic design

To overcome these shortcomings, material scientists at the University of California, Riverside and the University of Texas at Austin – led by Sean Roberts, Lorenzo Mangolini and Ming Lee Tang – replaced the toxic NCs with non-toxic silicon infrared absorbers. Using silicon NCs to upconvert photons holds promise for their application in medicine, to generate light that can penetrate far enough into biological tissue and have high enough energy to generate the therapeutic radicals.

In the new design, the researchers employed nanocrystal-to-molecule triplet energy transfer to achieve photon up-conversion. The silicon NCs absorb 488–640 nm photons and produce excited electron–hole pairs (excitons). These excitons then transfer their energy to 9,10-diphenylanthracene (DPA) molecules in solution. As a result, the DPA molecules are excited to a spin-triplet exciton state (in which one electron is excited to a higher energy level than the ground state and its spin is no longer paired with the ground-state electron).

The newly synthesized silicon NCs are functionalized with organic molecules such as 1-octadecene, or a combination of 1-octadece and 9-vinylanthracene that becomes 9-ethylanthracene (9EA) upon attachment. The researchers chose DPA as it exhibits high (above 97%) fluorescence emission. By carefully studying the surface



The reactor used to produce the silicon nanocrystals. (Courtesy: Lorenzo Mangolini/UC Riverside)

chemistry of the silicon NCs, the researchers learned how to attach surface ligands, enabling them to functionalize the silicon NCs with organic molecules such as 9EA.

(extracted with permission from an item by Rojin Jafari at physicsworld.com)

Ancient art of cheese tapping mimicked by digital signal processing

Cheesy correlations: the new technique could help make cheese like this emmental. (Courtesy: StaraBlazkova/ CC BY-SA 3.0)

Cheesemaking is a complex process, involving many steps that must be precisely executed to ensure the quality of the ultimate product. For semi-hard cheeses like emmental, gouda and maasdam, the final stage is a lengthy period of ripening, during which the cheese develops its various and characteristic sensory properties — such as aroma, colour, flavour and texture. Also created at this stage are "eyes", which are holes within the cheese formed by the bacterial release of carbon dioxide.

Allowing insufficient time to ripen leads to a poor-quality, low-value cheese. On the other hand, excessive ripening can allow the eyes to merge, an outcome that can lead to the cheese collapsing in on itself. At this point, the cheese can no longer be sold as intended and must be repurposed, for example as a grated cheese or an ingredient in other foods. In fact, the international food standards publication the Codex Alimentarius calls for regularly-shaped eyes between 1–5 cm in diameter in cheeses.

To ensure the desired ripening, cheesemakers use various techniques to monitor ripeness and eye formation. Cheeses can be cut and their eyes visually inspected, or samples of the cheese can be subjected to humidity analysis or textural measurements, which determine key properties like hardness, viscosity and chewiness. The drawback of these approaches, however, is that they require a wheel of cheese to be sacrificed for samples each time the tests are run – cutting into potential profits.

Cheese hammer

Some cheesemakers, however, have a non-destructive alternative; they tap the cheese with a special hammer and, from the sound, can determine whether the cheese is ripe enough. An expert can also tell whether the cheese contains defects like slits or "gas blowings" that can cause the wheel to swell. This technique, however, is very difficult to master and requires cheesemakers of considerable experience.

Now, engineers Mariana González and colleagues of the University of the Republic in Montevideo have characterized the tap test so that it could be automatically and reliably performed by machines. The team took eight 8 kg wheels of an emmental-type cheese that had already undergone pre-ripening and ripened them in a temperature and humidity -controlled chamber at around 18 °C and 75% relative humidity, turning each twice weekly.

During this process, the cheeses were acoustically probed daily using an electric hitting device – and every five days the researchers cut open one wheel to observe the extent of eye formation and perform texture and humidity analyses.

Signal cross-correlation

The team explored their acoustic data using two digital signal processing techniques: first order momentum (FOM) and signal cross-correlation.

"FOM of an acoustic signal is related to the tone of the sound and 'summarizes' all changes in the spectrum of the acoustic signal by averaging the distribution of the frequencies of the sound," González explains. She adds: "On the other hand, cross-correlation is a function that indicates how similar two signals are." In this case, the signals compared were those taken during ripening and a baseline signal from the first day of the study.

The researchers found that at low frequencies of 0–50 Hz, FOM was sensitive to the beginning of eye formation at around 10 days of ripening. Meanwhile, medium frequency (50–500 Hz) FOM and cross-correlation both gave indicators when the eyes began to overgrow, which occurred after around 20–25 days. Both transitions are the result of the changing attenuation of the sound waves through the cheese. This is a result of both alterations to the cheese's structure and scattering from eyes. Neither texture nor humidity analysis could indicate when eyes began to form.

“Fast and easy to implement”

González describes the technique as “fast and easy to implement,” although she cautions that the acoustic indicators are unique for each type of cheese and processing conditions. “For each type of cheese and manufacturer, a calibration will be required.”

With their initial study complete, the team is now looking to collaborate with local cheese makers to test how the acoustic monitoring method would integrate with a real-world production site.

(extracted with permission from an item by Ian Randall at physicsworld.com)

European physicists propose huge underground gravitational-wave laboratory

Physicists from across Europe have revealed plans for a huge underground gravitational-wave observatory that, if funded, could be operational by the mid-2030s. The European Laboratory for Gravitational and Atom-interferometric Research (ELGAR) could be located in either France or Italy and would cost around €200m to build. Those involved in the project have now applied for European funding to carry out a detailed design and costing for the facility.

Gravitational waves are ripples in space-time that were predicted over 100 years ago by Albert Einstein. In 2015 the twin Advanced Laser Interferometer Gravitational-wave Observatory (aLIGO) in the US along with the Virgo gravitational-wave detector in Italy detected the first gravitational-wave signal and since then tens of such events have been spotted. The observation and pinpointing of such gravitational waves is expected to be boosted in the coming years by the recent completion of Japan’s KAGRA observatory, which is the world’s first underground gravitational-wave observatory to use cryogenic mirrors.

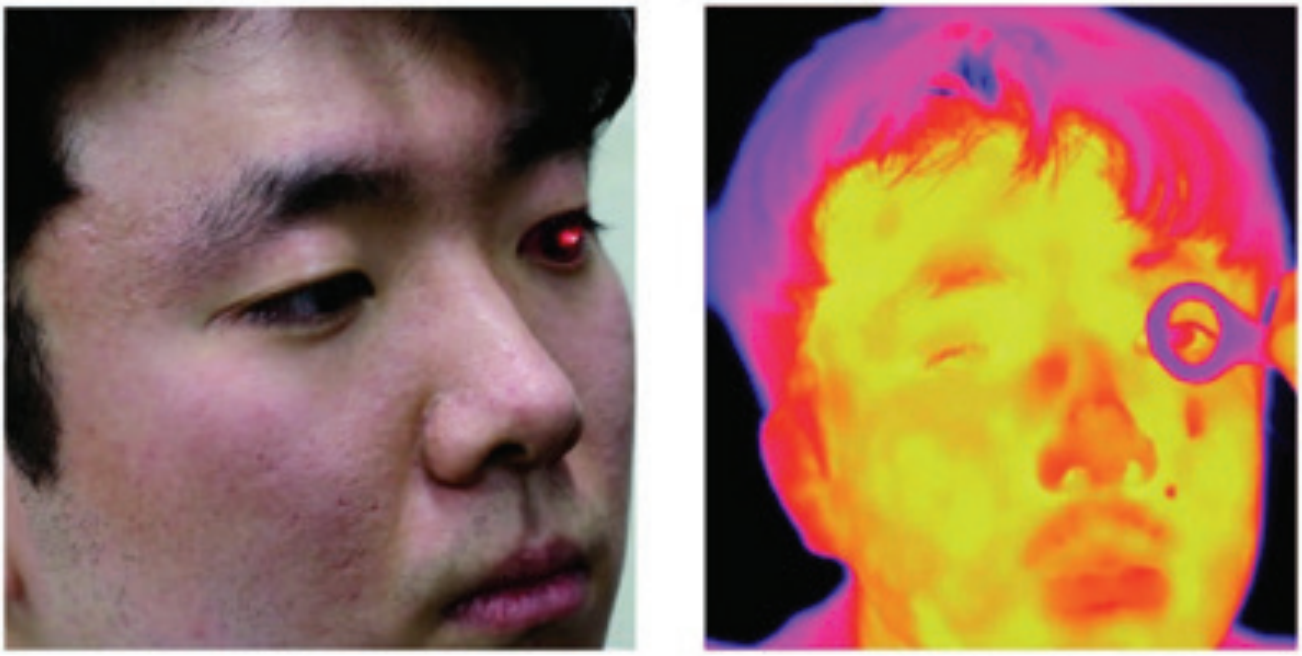
Rather than detecting gravitational waves by bouncing laser beams off mirrors as carried out by aLIGO, Virgo and KAGRA, ELGAR would instead use atom interferometry. This involves splitting an atom beam – rubidium atoms in ELGAR’s case — in half and allowing both halves to travel for a certain distance before being recombined to look for differences in their paths. A slightly longer path would result from a tiny curvature in space-time that could be caused by a passing gravitational wave.

Atom interferometers tend to be more sensitive at low frequency than their laser counterparts as atomic beams travel more slowly. “The technology for ELGAR is already mature,” says Benjamin Canuel from the Photonics, Numerial and Nanosciences Laboratory (LP2N) at the Institut d’Optique Graduate School in Bordeaux, who is coordinating the ELGAR proposal. “Many technological bricks of the ELGAR detector are now available in lab experiments but an ambitious R&D programme is required to benefit from those techniques in a large research infrastructure.”

Plugging the gap

ELGAR would feature two 32 km long arms that each would contain 80 atom “gradiometers” that are separated by 200 m. The gradiometers would measure the

Music to their ears: One site option for the European Laboratory for Gravitational and Atom-interferometric Research (ELGAR) is the Laboratoire Souterrain à Bas Bruit in southern France. (Courtesy: CC BY-SA 4.0/GAllegre)



A soft, smart contact lens worn by a volunteer (left) and undergoing heat tests during operation (right). (Courtesy: Jang-Ung Park, Yonsei University)

relative difference in the positions of the atoms beams as they pass through. This set-up would allow researchers to detect gravitational waves in the 0.1–10 Hz frequency range, which would be emitted, for example, by medium-size black-hole binaries. These black holes have masses between 100 and one million solar masses and are elusive but crucial to explain whether supermassive black holes formed from the expansion of small black holes, from the merger of multiple smaller black holes, or possibly from other scenarios.

This frequency range would allow researchers to plug a gap in observations given that ground-based detectors like LIGO cover the frequency range from around 10 Hz to 10 000 Hz while the LISA space-based observatory, would, if launched in the 2030s, study gravitational waves between 0.1 mHz to 0.1 Hz.

Three possible sites that have been picked for ELGAR – the Laboratoire Souterrain à Bas Bruit (LSBB) in southern France and two former mines in the Mediterranean island of Sardinia. The LSBB is currently the location for the €12m Matter–wave laser Interferometric Gravitation Antenna (MIGA) — a demonstrator atom interferometer being built by a consortium of 17 French institutions and featuring a 150 m-long optical cavity. MIGA will carry out precision measurements of gravity as well as applications in geosciences and fundamental physics·

(extracted with permission from an item by Michael Banks at physicsworld.com\)

Smart contact lenses power up

Flexible contact lenses that incorporate supercapacitors and wireless-charging components are now possible, thanks to newly formulated printable inks that serve as the electrode and electrolyte. Researchers in the Republic of Korea showed that a specific mixture of carbon molecules, polymers and solvent can be used to print a supercapacitor's electrodes onto a lens with micron-scale precision via a technique called direct ink writing. The same process deposits a UV-cured ionic liquid that functions as the supercapacitor's electrolyte. As a proof-of-concept, the work could one day lead to smart contact lenses with sensors for health monitoring, or with integrated displays for augmented reality applications (Science Advances 10.1126/sciadv.aay0764).

While smart glasses have yet to catch on, there might still be a niche for wearable electronics that project information or images directly into the user's field of view. If such a device could be miniaturized to fit into a contact lens, it could offer the added advantage of being able to sample certain biomarkers in the wearer's tears, which can diagnose diseases including diabetes and glaucoma.

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PRODUCT NEWS

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Edinburgh Instruments Launches RM5 Raman Microscope

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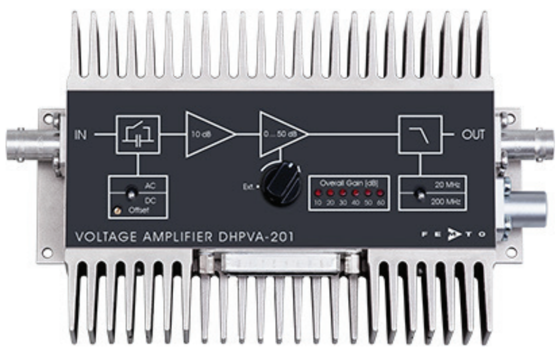

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2.TOPTICA Photonics presents the new FemtoFiber vario 1030, a versatile micro-joule fiber laser

With a centre wavelength of 1030 nm, the laser offers 2 W of output power at a repetition rate of up to 1MHz and a pulse duration of <300 fs. The special features of this laser include variable pulse duration via GDD control, adjustable repetition rate down to pulse-on-demand, and its superior temporal and spatial beam quality.

High Power Ultrafast Fiber Lasers with superior temporal and spatial beam quality

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- Passively-cooled, detachable laser head
- Robust and reliable, all-PM fiber setup
- Turnkey system, compact footprint

One of the main benefits for the user is the unique pulse-on-demand design that is provided with the laser. Unlike any other fibre-laser technology, the unique pulse-on-demand realization of the FemtoFiber vario 1030 allows the user to pick the emitted pulses directly from the fundamental pulse train of the oscillator.

3. SIOS: Laser Vibrometers for high precise measurement of vibrations and length

The design of these devices is based on the proven concept with our SP-series miniature interferometer. The sensor head of the vibrometer is equipped with additional optics, which enables measurements on surfaces of any roughness.

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- Measurement through narrow windows are possible
- Vibration measurement software for Windows

Applications: High precise measurement of vibrations and length

Warsash

Enhanced spectral purity 785nm laser for Raman

HÜBNER Photonics proudly introduces the 08-NLDM 785 nm ESP (enhanced spectral purity) as part of the Cobolt 08-01 Series. The 08-NLDM 785 nm ESP complements the Cobolt 08-01 Series of compact high-performance single frequency and narrow linew-

idth lasers covering a broad range of 405 nm – 1064 nm for the high resolution Raman market.

Enhanced spectral purity is a desired performance specification especially for low frequency Raman applications and defines how well the side modes are suppressed relative to the main laser peak (SMSR) and how close to the main peak the level of side mode suppression is. Thanks to a patent-pending optical design the spectral purity of the 08-NLDM 785 nm ESP is >60 dB as close as 0.3 nm away from the main peak. The multi-transverse mode laser has an output power of <400 mW with fully integrated electronics in a single compact package

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.

V-610 compact PIMag rotation stage

Physik Instrumente, a global leader in the design and manufacture of high precision motion control systems has launched the V-610 compact PIMag rotation stage.

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ASSOCIATION OF ASIA PACIFIC PHYSICAL SOCIETIES

AAPPS Bulletin

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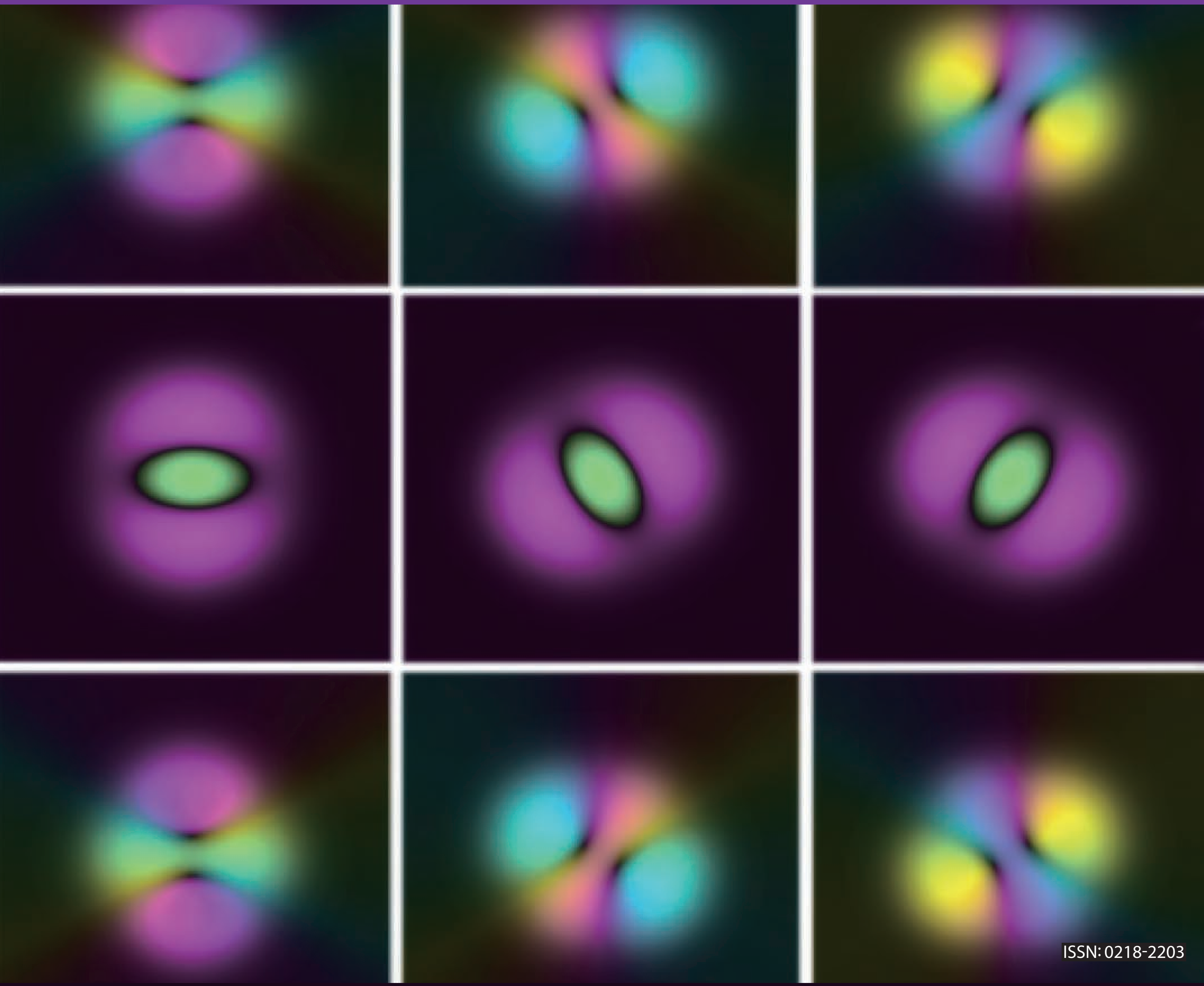
"Shape" of Single Photons May Carry Information



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- Astronomers Receive the 2019 Nobel Prize in Physics

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