The Royal Society of Victoria
Promoting science since 1854

Inspiring Australia Victoria

SCIENCE VICTORIA

NOVEMBER 2023

SEEING THE INVISIBLE

How to Detect Dark Matter

pg 15

SLIP, SLOP, SLAP, MAGNETIC FIELD, ALUMINIUM SHIELD

Protecting Astronauts from Space Radiation

pg 18

LOW ON GRAVITY, BIG ON TASTE

Growing Food in Space

pg 37

PLUS

Hunting for Exoplanets
Glaciers in a Warming World
Mr Brown Coal on Coal

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9 772981 866005 10

Star trail over Melbourne.
Photograph: Yong Chuan Tan via Unsplash.

IN THIS ISSUE

SCIENCE VICTORIA

This Edition: Victoria and Space

Studying the night sky has a very long history in Victoria, from First Peoples' use of the stars for meteorology, navigation, and story-telling, through to measuring dark matter in Stawell, and everything in between. This month we look at the ongoing work in Victoria to further understand everything beyond Earth's atmosphere, and how we can use satellites in orbit to better connect and care for our state.

On the Cover: Looking into space from Lake Tyrrell in north-west Victoria. Photograph: Lisa Zhou via Shutterstock


pg 15


pg 18


pg 37

Please note the submission deadline for content to be included in upcoming editions:

December 2023
The Future of Drug Discovery

5pm, Friday 17 November 2023.

February 2024
Artificial Intelligence

5pm, Friday 19 January 2024.

FROM THE EDITOR

Scott Reddiex
Editor, *Science Victoria*

At whatever point in history you find yourself reading this, it will remain a fact that the universe is quite big. Everything we know about space - and we know quite a lot - has come from all of the telescopes we have on the ground, or the ones we have sent out to scan the skies. We have so many questions and we have so far found a few answers - all from our pale blue dot.

With the ever-increasing number of satellites orbiting the Earth, we have never had a greater ability to connect everyone across this continent. We have never been better equipped to observe and monitor our environment, which is proving vital in measuring the impacts of things like climate change and deforestation. But the more satellites we send out, the harder it is for us to look to the stars. Some of the newer satellites are among the brightest objects in the night sky.

This month, things are literally looking up in *Science Victoria*, as we consider some topics in the narrow range of from 'here' to 'the edge of the observable universe'.

We take a look at exoplanets – the planets outside our solar system – and how astronomers can detect their presence in star systems that are light years away. If you've ever considered a career change to become an astronaut, Dr Gail Iles is investigating different ways to shield yourself from the different types of radiation in space that you would be exposed to once you leave the safety of Earth's magnetic field. If you're still keen on making the journey into space, you might like to read what Ben Liu and Tanya Hendy from the Royal Botanic Gardens Victoria have to say about the 'Growing Beyond Earth' program. In this program, school students collect data to help NASA discover new fresh, tasty, and nutritious foods for astronauts to grow and eat on the International Space Station (ISS).

As we look around the universe, whether it be with telescopes or other conventional measures, we are actually not seeing very much of it. Less than 5% of the universe is made up of visible matter – the atoms that make up everything we know. The other 95.1% of the entire universe is made up of dark matter and dark energy, which also happen to be extremely difficult to detect. This month, we hear about the work of Professor Alan Duffy and Dr Grace Lawrence, who are trying to establish ways to detect the elusive dark matter.

Elsewhere in this edition, you will find details of current grant opportunities, upcoming events, and consultations currently open for feedback.

We hope you enjoy this edition of *Science Victoria*.

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Acknowledgement of Country:
The Royal Society of Victoria acknowledges the many First Peoples of our continent, their vast history and connection to the lands and waters within and beyond the State of Victoria, and the valuable cultural and scientific knowledge held by the Elders to care for Country. We acknowledge our headquarters are located on Wurundjeri land, never ceded, and convey our respect to Elders past and present. The RSV welcomes all First Nations people, and seeks to support and celebrate their continued contributions to scientific knowledge.

FROM THE PRESIDENT

Rob Gell AM MRSV
President, The Royal Society of Victoria

As an erstwhile Earth scientist, our *Science Victoria* theme this month takes me into the extra-terrestrial – this is not familiar territory. I must admit I'm more concerned that we don't 'stuff up' planet Earth than whether or not we can inhabit another celestial body.

I pay attention when I know that damage to the stratosphere from ozone depleting gases, the halons, hydrochlorofluorocarbons, carbon tetrachloride, and others was declining and perhaps an 'environmental win'. That was, until smoke from our 2019-2020 Black Summer was transported around the planet and is likely to delay 'Ozone Hole' repair.[1] I'm also very aware of the value of the free energy available from that enormous star at the centre of our solar system supplying anything from photovoltaic panels to life as we know it!

There's no doubt that the explosion of Earth monitoring satellites has provided us with wonderful data and direct information. My first engagement with this technology was with geostationary meteorological satellites in the 1980s. Now we have Google Earth and thousands of low Earth orbit constellations of SpaceX satellites in 'trains', facilitating fast communications to millions of subscribers and particularly for military purposes.

On the flipside, there are companies like Planet Labs, with a fleet of more than 200 earth imaging satellites.[2] These provide global daily Earth data for farmers, businesses, governments, researchers, and journalists enabling them to understand the physical world and make better decisions – hopefully. There is a growing list of Australian companies in the 'space race', developing new support technologies, cameras, and nanosatellites.[3]

Most of these systems look down, or at least point from space, towards Earth. Congestion is no doubt becoming a problem.

NASA holds a particularly large niche in space in exploration and discovery of the 'unknown', but also in monitoring atmospheric pollution, climate science, and natural systems. In 2024, NASA will launch the NISAR radar satellite mission, which will help researchers explore how changes in Earth's forest and wetland ecosystems are affecting the global carbon cycle and influencing climate change.[4]

I recently had the opportunity to be a judge in the 2023 NASA Space Apps Challenge facilitated in Australia by TomorrowX, a new composable software architecture platform that drives the digital circular economy.[5,6] The programme is run by the NASA Earth Science Division and includes Earth and space science and technology alongside arts and humanities challenges.

The annual hackathon now includes more than 57,999 participants in over 500 "local virtual" events, which are run by local leads in countries around the world. It's the largest annual and global hackathon. During the two-day event, participants from around the world form teams that use software development, engineering, art, storytelling, science, and other skills. They use free and open NASA and Space Agency Partner data to create projects that address the most pressing challenges with NASA subject matter experts. Teams have a chance to win one of ten global awards, with different teams from Perth picking up awards in the 2020 and 2021 challenges.[7,8]

The 2023 theme was 'Explore Open Science Together', and celebrated the benefits and successes created through the equitable and open sharing of knowledge and data.

I'm hoping that in 2024 The Royal Society of Victoria can field a team, perhaps from our new Emerging Scientists Network of undergraduate and graduate science students? There'll be information on the 2024 Challenge in *Science Victoria* when details become available next year.

As usual I welcome your email to **president@rsv.org.au** with your thoughts and ideas.

References:
1. The effects of the Black Summer bushfires on the ozone layer. (2023, March 20). Sustainability Matters. sustainabilitymatters.net.au/content/sustainability/news/the-effects-of-the-black-summer-bushfires-on-the-ozone-layer-584045845
2. Planet Labs PBC planet.com/company
3. Top Space companies and startups in Australia | F6S Companies - Australia. (2020). F6S. f6s.com/companies/space/australia/co
4. NASA-ISRO SAR Mission (NISAR). Nisar.jpl.nasa.gov
5. NASA Space Apps Challenge. spaceappschallenge.org/2023/locations/melbourne
6. TomorrowX | Composable Architecture Platform and Network. tomorrowx.com
7. Loud and Clear | Can You Hear Me Now? 2020.spaceappschallenge.org/challenges/connect/can-you-hear-me-now/teams/loud-and-clear/project
8. Landslide Detection Squad. 2021.spaceappschallenge.org/challenges/statements/identifying-risk-with-science-communities/teams/landslide-detection-squad/project

Below: Katelyn Hertel, Community Management Specialist, NASA International Space Apps Challenge. Katelyn is a data engineer working on climate change solutions when she's not organising the hackathon. Photograph: Rob Gell.

Photograph: NASA via Unsplash

EARTH OBSERVATION CAPABILITY MUST BE AUSTRALIAN-OWNED AND OPERATED

Recently, the cancellation of the National Space Mission for Earth Observation has come under scrutiny in parliamentary questions. To my mind, there is no doubt that cancelling this National mission was a wrong turn, but it is a shame that the issue has become such a partisan one, with more attention paid to whether the previous or current government has done more for the "space sector".

We need to move away from talking about space sector investment, or support for the "space sector". We don't talk about the "oceans sector" or the "land sector". This is not a single industry or technology. It's not about being saddened by one government's decisions over another. It's about understanding how these, and other, space-based technologies enable and support our national priorities as critical infrastructure.

Cancelling the National Space Mission for Earth Observation has put Australians and our nation at enormous risk. We now need to understand and assess that risk and move towards decisions to mitigate them.

We depend on foreign commercial and foreign government providers for the data we need to combat climate change, mitigate and prevent bushfires, for our farmers and agritech to operate effectively, for our Indigenous cultural heritage, for urban planning and property insurance, for maritime domain awareness, for national and regional security. We give away information about all these sectors to Earth Observation companies when we buy data from them.

$3.3bn is generated annually into our GDP from Earth Observation Data, and although it is true that we currently get a lot of the data for free, we still spend $100 million per year on purchasing supplementary commercial data and, as a nation, we continue to depend upon other countries and foreign commercial entities, who may sell that same data elsewhere, or may sell us poor quality or compromised data. What's missing in all of the public commentary and parliamentary finger-pointing is that it's not "the space industry" we need to be concerned about. There is no reason why the government should support an industry unto itself. Rather, we should be VERY concerned about the critical dependencies on space technologies that we have as a nation, and that we are now entirely dependent on foreign government and commercial providers. That comes at enormous economic cost and high risks.

There needs to be a better understanding that space technologies support our national priorities:

- Earth observation satellite data for farmers, miners, climate response, Indigenous rights, urban planning and housing, flood insurance, bushfire mitigation and response, maritime surveillance and national security;
- Position, navigation and timing (PNT) satellite data for aviation, shipping, remote mining, agriculture, banking;
- Satellite communications and internet for all of our primary industries, for education, and for connecting remote, regional and rural Australians.

In summary, the government does not need to "support the space industry". It needs to make decisions to fulfil our national priorities, and it needs to make budget-wise decisions. I trust this government entirely to do just that. But if there were a better understanding of how critical space technologies are to enable these two requirements, better decisions would be made.

By axing this programme, we have just added to our taxpayer bill rather than reduced it. And we are at risk of losing access to the Earth observation data we need if a foreign provider decides its own needs trump ours, and at risk of buying unverified or poor-quality data from foreign commercial providers.

The space sector is not about space, it's about supporting other sectors and national needs. This is the message the space sector needs to be sending to our government.

By Dr Cassandra Steer
Deputy Director (Mission Specialists), ANU Institute for Space

SNAPSHOTS OF STEMM

Images from everyday science.

Audience members visit the Moon, watching CAPCOM GO! The Apollo Story in Melbourne Planetarium at Scienceworks.

Photograph: Love Bree Photography/Museums Victoria

Installation view of μ Muography by Jon Butt, in Science Gallery Melbourne's DARK MATTERS exhibition.

Photograph: Gabrielle Capes, 2023.

DARK MATTERS is an exhibition in collaboration with Arts at CERN and the ARC Centre of Excellence for Dark Matter Particle Physics, closing on 2 December.

A growth chamber used by students as part of the 'Growing Beyond Earth' program, that emulates the growth conditions of space. Photograph: Royal Botanic Gardens Victoria.

Learn more about the Growing Beyond Earth program in the Inspiring Victoria section of this edition.

NEW RSV MEMBERS

INDIVIDUAL MEMBERS

Mr Ashley Van Krieken
Director (Digital & Advanced Technologies, Future Skills), Monash College

Mr Craig Bosworth
Executive Director (Strategy, Quality & Improvement), St Vincent's Hospital Melbourne

Mr Samuel Agostino
Chief Operating Officer, Solar Recovery Corporation

Mr Raveen Wijesuriya
Technical Specialist, Materials Characterisation & Fabrication Platform, The University of Melbourne

Dr Shanmuga Sundar Dhanabalan
Electrical Engineer & Materials Scientist, Functional Materials & Microsystem Research Group, RMIT University

ORGANISATIONAL MEMBERS

sciencein public

SCIENCE IN PUBLIC

We are a science communication and public relations business based in Melbourne. We have a core team of seven staff and associates around Australia. That makes us Australia's largest non-government science communication business.

Our team has a passion for science. We encourage and challenge scientists to reach the public, politicians and the media, while staying true to the science.

CALL FOR NOMINATIONS

Nominations for up to five Ordinary Members of Council for 2024 and 2025 are sought. If required due to more nominations being received than places are available, all nominees will be elected by postal ballot closing at **3.30pm on 1st March 2024.** The newly elected Councillors of the Society will take up office from the Annual General Meeting to be held in May 2024 - all current Ordinary Councillors of the Society appointed for the 2022-23 term will continue until that date. All current 2023-24 Councillors continue until the AGM to be held in May 2025.

Download the nomination form for more information: **rsv.org.au/rsv-council-nomination-form-2024-25**

BECOME A MEMBER OF THE RSV

MEMBERSHIP BENEFITS	STUDENT $40/YEAR	FULL $120/YEAR	ORGANISATION $1000/YEAR	SCHOOL $1000/YEAR	AFFILIATE $500/YEAR
Special Membership rates at RSV and affiliate events.	✓	✓			
Networking opportunities – national and local.	✓	✓	✓	✓	✓
Recognition of membership through use of post-nominal affix	MRSV	MRSV			
Science Victoria Digital Edition (Printed copy available for an additional fee).	✓	✓	✓	✓	✓
Free monthly printed copies of *Science Victoria* for school libraries.				✓	
Recognition of achievements through awards programs.	✓	✓			
Discounted advertising in *Science Victoria*			✓	✓	✓
Discounted facility hire at 8 La Trobe Street, Melbourne.			✓	✓	✓
Discounted membership rate for eligible full-time students.	✓				
Discount on purchases from CSIRO Publishing	✓	✓			
'Schools Supporting Schools' Membership Program*				✓	
Listing of membership on the RSV.org.au website.			✓	✓	✓

The Royal Society OF VICTORIA

For more information, visit **rsv.org.au/how-to-join**

* The 'Schools Supporting Schools' membership program allows a school to sponsor the membership of one or more schools at a discounted rate of $750/year, allowing less-resourced schools the same benefits and opportunities of RSV membership.

FROM SOIL TO SUPPER: THE MICRO- AND NANO-PLASTIC JOURNEY

Have you ever considered that just as much plastic is entering our soil as is making its way into our oceans?

In this public lecture, Associate Professor Suzie Reichman will lead a discussion about micro- and nanoplastics in our agricultural systems and food. She'll investigate how micro- and nano-plastics are entering our soil and food supply, the impacts these plastic particles have on agroecosystems and human health, and consider how concerned we need to be. We'll finish by looking at what we can do to address this growing issue, as both scientists and community members.

This presentation is brought to you as the 2023 G.W. Leeper Memorial Lecture, which is the major event for the Victorian Branch of Soil Science Australia.

ABOUT THE SPEAKER

Associate Professor Suzie Reichman is the Director of the Centre for Anthropogenic Pollution Impact and Management (CAPIM) at the University of Melbourne in Melbourne Australia.

Suzie's research aims to increase our knowledge of the impacts of pollution on the environment and humans. Her research focuses on the effects of contaminants in the terrestrial environment including soil, plants, invertebrates and human health and includes traditional pollutants (e.g. metals (arsenic, lead, etc) and hydrocarbons) as well as emerging chemicals such as per- and poly-fluoroalkyl substances (PFAS).

FROM SOIL TO SUPPER: THE MICRO- AND NANO-PLASTIC JOURNEY

Date/Time:
Friday, 17 November 2023, 6 pm - 7 pm

Price:
Free

Location:
Lower Theatre (B151), Faculty of Veterinary and Agricultural Sciences (142),
The University of Melbourne
142 Royal Parade, Parkville

For more information, visit **events.unimelb.edu.au/science/event/34868-from-soil-to-supper-the-micro-and-nano-plastic**

You can learn more about the impact of plastics and microplastics in the August 2023 edition of *Science Victoria*. Read now for free at **rsv.org.au/science-victoria.**

Microplastics in soil.
Photograph: SIVStockStudio via Shutterstock

Photograph: Jacopo Maia via Unsplash

FOOD FOR THOUGHT: PIONEERING THE FUTURE OF FOOD

Join us for this multidisciplinary two-day event showcasing research from both Australian and global perspectives on food's evolving connections to society, health, and our future.

This conference is designed to bring together and foster dialogue among RMIT researchers, industry leaders, governmental bodies, and other crucial stakeholders, addressing urgent societal challenges around food and charting the pathways for a desirable and sustainable food future.

Activities across the two-day conference include:

- A guided tour of RMIT's state-of-the-art food research facilities
- Innovative presentations and posters on emerging trends and the future of food
- Interactive food demonstrations
- A collaborative ideation (final) session focusing on blueprinting large-scale projects alongside our esteemed partners.

FOOD FOR THOUGHT: PIONEERING THE FUTURE OF FOOD

Date/Time:
Day 1: Monday, 27 November 2023, 9 am - 5 pm
Day 2: Tuesday, 28 November 2023, 9 am - 5 pm

Price:
Free

Location:
Day 1:
RMIT City Campus
Swanston Academic Building, (SAB) Building 80,
435-457 Swanston Street, Melbourne

Day 2:
RMIT Bundoora West Campus
Building 224,
203 McKimmies Road, Bundoora

For more information, visit **rmit.edu.au/events/2023/november/food-for-thought**

You can learn more about Victoria's food systems in the October 2023 edition of *Science Victoria*. Read now for free at **rsv.org.au/science-victoria**.

UPCOMING RSV EVENTS

The RSV hosts many STEMM-related events, public lectures, and meetings throughout the year. These are predominantly held at the RSV Building at 8 La Trobe St, Melbourne (unless otherwise indicated), and simulcast online via YouTube.

Our public lectures comprise the "Scientists in Focus" component of the Inspiring Victoria program in 2023.

2023

10 DECEMBER

GEOGRAPHY VICTORIA'S MELBOURNE CHRISTMAS TREASURE HUNT

Save the date - the Melbourne Christmas Treasure Hunt is back for 2023. Developed by Geography Victoria as part of the City of Melbourne Christmas Festival, there will be three different events tailored for groups and individuals of all ages. You'll be given a map and clues, and begin your hunt for treasure!

More information will become available from mid-November, and shared via Geography Victoria's social media channels.
facebook.com/p/Geography-Victoria-100076161793935

2024

RESCHEDULED

RSV PHILLIP LAW POSTDOCTORAL AWARD LECTURE

Please note that this event has been rescheduled from November 2023 to early 2024.

The winner of the RSV's Phillip Law Postdoctoral Award for 2023 will present their work to a special meeting of the RSV at a public lecture. This will be professionally filmed and shared online.

For more information, visit
rsv.org.au/awards-and-prizes/phillip-law-award/

RESCHEDULED

RSV RESEARCH MEDALLIST LECTURE

Please note that this event has been rescheduled from December 2023 to early 2024.

The winner of the RSV Medal for Excellence in Scientific Research for 2023 will present a lecture to RSV members and guests, at which the Medal will be presented.

For more information, see visit
rsv.org.au/awards-and-prizes/research-medal/

Looking back at Earth from the Cupola module on the International Space Station (ISS).
Photograph: NASA via Unsplash.

ARC FUTURE FELLOWSHIPS

Applications are currently for the Australian Research Council's Future Fellowships scheme, for commencement in 2024.

Future Fellowships provide 4-year fellowships to outstanding Australian mid-career researchers. The ARC may also award the Administering Organisation up to $60,000 of non-salary funding per year to use for personnel, equipment, travel and field research costs directly related to the Future Fellow's research.

Up to 100 four-year Future Fellowships may be awarded each year, providing a salary awarded at one of 3 salary levels and up to $60,000 per annum project funding.

The Future Fellowships scheme encourages applications from researchers working in areas of national priority, listed at **arc.gov.au/funding-research/apply-funding/grant-application/science-and-research-priorities.**

Applications close at **5pm, 23 November 2023.**

For more information, visit: **arc.gov.au/funding-research/funding-schemes/discovery-program/future-fellowships**

DISCOVERY EARLY CAREER RESEARCHER AWARD (DECRA)

Applications are currently for the Australian Research Council's Discovery Early Career Researcher Award (DECRA) scheme, for commencement in 2024.

The DECRA scheme provides focused research support for early career researchers (ECRs) in both teaching and research, and research-only positions.

The objectives of this scheme are to:

- support outstanding ECRs with demonstrated capacity for high-quality research and emerging capability for leadership and supervision
- foster collaboration, with national or international researchers
- support excellent and innovative research that addresses a significant problem or gap in knowledge and represents value for money
- create new or advanced knowledge resulting from the outcomes of the research with economic, commercial, environmental, social and/or cultural benefits for Australia
- advance promising ECRs and promote enhanced opportunities for diverse career pathways in high-quality and supportive environments.

Up to 200 three-year Discovery Early Career Researcher Awards, including up to $50,000 per annum in project funds, may be awarded each year.

Applications close at **5pm, 7 December 2023**.

For more information, visit: **arc.gov.au/funding-research/funding-schemes/discovery-program/discovery-early-career-researcher-award-decra**

NATIONAL SCIENCE WEEK GRANTS 2024

Applications are now open for the 2024 round of National Science Week grants.

These grants are open to individuals and organisations for the purpose of running science engagement activities during National Science Week 2024.

For more information, see the **Inspiring Victoria** section.

The SABRE North experiments are carried out at the Laboratori Nazionali del Gran Sasso (LNGS), underneath Grand Sasso Mountain in Italy. The laboratories on the surface are a fraction of what lies underground. Photograph: TQB1 via Wikimedia Commons (CC BY 3.0).

THE UNIVERSE AND ITS DARK MATERIALS

By Dr Catriona Nguyen-Robertson MSRV, with Professor Alan Duffy

This article revisits a presentation to the Royal Society of Victoria on 12 September 2019 titled "Darkness Visible Down Under" by astrophysicist Professor Alan Duffy from Swinburne University.

> "Beyond the shoreline exists this whole new world out there...how could you not want to explore it?"
> — Professor Alan Duffy.

If you look through the Hubble Space Telescope at a patch of sky the size of your thumb nail, you will find stars, and clouds of gas and dust, distributed across 6,000 individual galaxies. The universe is massive, but what we see is merely the tip of the iceberg. There is an invisible "Dark Universe" that outweighs everything that we can see five times over.

Dark energy makes up approximately 68% of the universe and dark matter makes up another 27%. Despite their dominance in the universe, we still are not sure of what they actually are. The rest – everything we can observe with all our instruments – makes up less than 5%.

Growing up in Northern Ireland, Alan Duffy would often press his face to the window to stare out at the stars. He has always been fascinated by the world around him. After reading Stephen Hawking's A Brief History of Time, he was inspired to channel his curiosity into studying physics. Driven by his desire to want to know more, he undertook a PhD in astrophysics at the University of Manchester. Wanting to explore the unknown, he felt the pull of the Dark Universe. Now, as an astrophysicist at Swinburne University of Technology's Centre for Astrophysics and Supercomputing, he has led a 15-year curiosity-driven research project into uncovering the nature of dark matter and the formation of galaxies, and the acceleration of the universe caused by dark energy.

> "We have never known so little about our universe. Science is not done."
> — Professor Alan Duffy.

For astrophysicists such as Alan, it seems a nearly impossible task to study something currently undetectable, however, we can learn by studying their effects on other things. For example, while we cannot see the air, we can see its effect on the objects it moves, such as swaying tree branches in the wind. Similarly, dark matter is composed of particles that cannot be seen directly, but we know that it exists because of the effect it has on objects that we can see.

SEEING THE INVISIBLE

When we observe the way things move in space, often, our observations do not make sense if we only consider what can be seen. Spinning galaxies that spin at great speeds over time are an excellent example. The Milky Way Galaxy, for example,

Professor Elisabetta Barberio in the Stawell Underground Physics Laboratory (SUPL). Photograph: ARC Centre of Excellence for Dark Matter Particle Physics.

is spinning, taking 250 million years to complete a full turn. But most galaxies spin, particularly their outermost reaches, at speeds that cannot be explained by the gravitational pull from visible matter alone.

When astronomers examined spiral galaxies in the 1970s, they expected to see stars in the centre of the galaxies moving faster than those at the outer edges. You would expect that stars at different distances from the centre of a galaxy would have different orbital speeds, just like Mercury orbits the Sun faster than planets further out in our solar system. Yet inner and outer stars of galaxies appeared to be travelling at the same pace. This hinted that there is more mass within the galaxy than meets the eye.

We do not know much about the vast, invisible clouds of dark matter, but whatever dark matter is, by providing extra mass to galaxies, it generates the extra gravity needed to hold them together. The galaxies are rotating at such high speeds that the gravity generated by their observable matter could not possibly be enough to hold them together – they should have torn themselves apart long ago. Dark matter must be providing extra gravity and holding them together so that they spin without parts being flung off into the cosmos. There must be an enormous amount of dark matter in the universe, pulling on all the things we see. And yet, invisible as it is, dark matter passes through our planet and passes through our bodies, unencumbered by the electric fields that give solid matter its apparent, well, solidness. Entirely imperceptible to us. It is like a cosmic ghost.

Alan investigates how dark matter helps galaxies form and keeps them intact. He uses supercomputers to simulate this process. But the more we learn about the visible parts of the universe, the bigger the gap becomes between what we predict about the unknown and what we see. He and other astrophysicists are hence constantly under pressure to gain a better understanding of dark matter and dark energy. Alan does this by testing his simulations of our galaxy's formation and dark matter theories and comparing these to observations from telescopes to see if they match up.

CAN WE DIRECTLY DETECT ELUSIVE DARK MATTER?

Alan and his team are also devising ways of detecting dark matter in the laboratory. Located one kilometre underground, at the bottom of the Stawell Gold Mine, the Stawell Underground Physics Laboratory will facilitate experiments critical in the global search for dark matter.

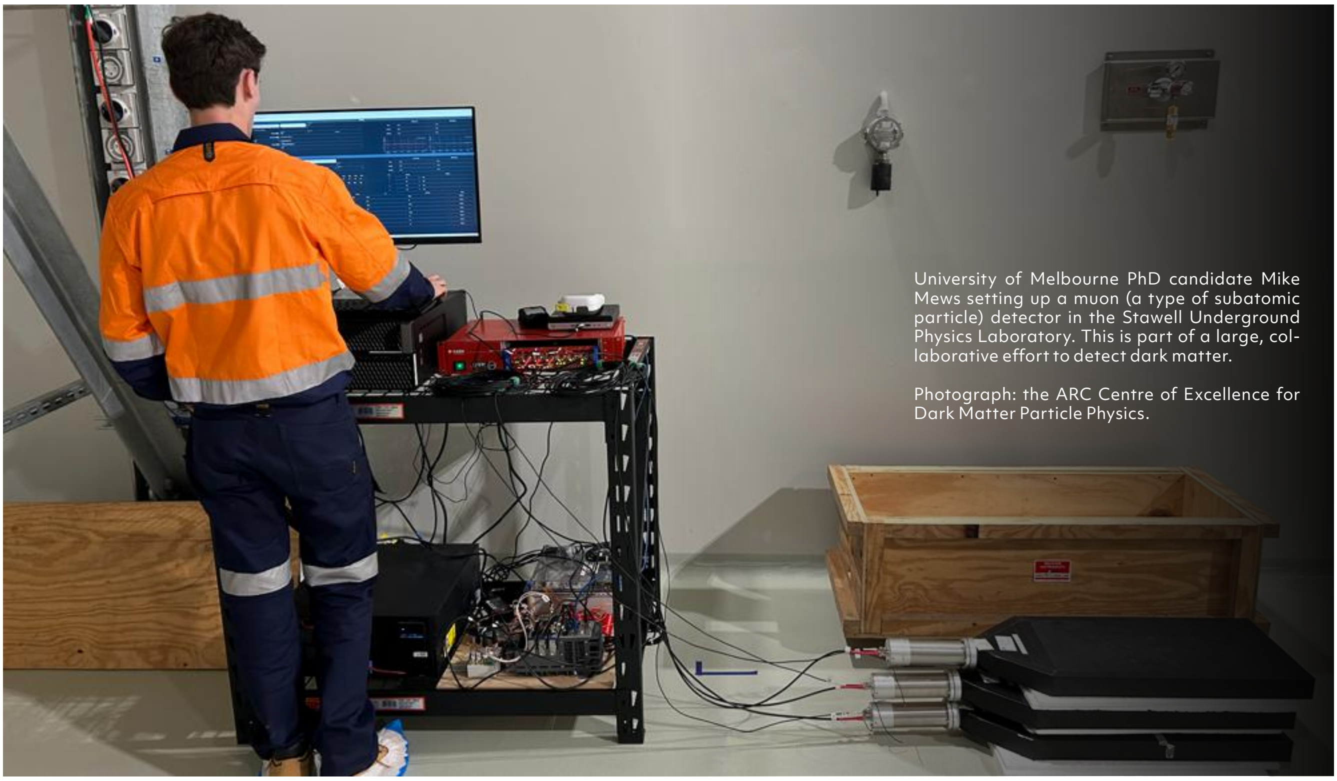
SABRE South, the world's first dark matter detector in the southern hemisphere, is led by the University of Melbourne's Professor Elisabetta Barberio. It is one of a pair of experiments – SABRE South and SABRE North (in the northern hemisphere, under the Gran Sasso Mountain in Italy) – intended to distinguish true signals from possible local or seasonal influences. Essentially, the hope is that dark matter particles are detected in the same way at both sides. The SABRE experiment will be transported into the laboratory, with data collection expected to begin in 2024, a delayed start due to COVID.

Alan is a part of SABRE, attempting to detect dark matter. SABRE, short for Sodium Iodide with Active Background Rejection Experiment, uses sodium iodide crystals to search for proposed dark matter candidate particles. When dark matter particles, or indeed any particles, stream through the gold mine and collide with crystals, they will produce a flash of light (known as a scintillation) that will be picked up by sensitive detectors. Dark matter is thought to rarely interact with 'normal' matter, but occasionally, in a snooker-ball like collision with the nucleus of an atom, they send it recoiling – a reaction that ultimately produces the light that can then be observed.

Particle physicists believe that dark matter exists in the form of a particle - as does the ordinary matter with which we are so familiar (electrons, photons, etc.). Each of the particles in the Standard Model of Particle Physics – the building blocks of the visible universe – have their own properties that define what they are and how they interact with the other particles. The same is true for dark matter, however we do not know what the defining properties of these particles are.

This is what scientists hope to reveal. Alan and a global collaboration of researchers are turning the impossible into something possible. In their endeavour to learn more about our universe, they explore the unknown and the unobservable. There is more dark matter in the universe than all the gas, dust, planets, and stars combined. Consider everything humans have achieved with an understanding of only 5% of the matter in the universe. Imagine what we could do if we unlocked the rest.

Watch Professor Alan Duffy's presentation to the RSV in full at **youtu.be/k-RNnAyaW-4** (or a 10-minute version at **youtu.be/6O7XSLhDy28**).



University of Melbourne PhD candidate Mike Mews setting up a muon (a type of subatomic particle) detector in the Stawell Underground Physics Laboratory. This is part of a large, collaborative effort to detect dark matter.

Photograph: the ARC Centre of Excellence for Dark Matter Particle Physics.

The Bubble Nebula (NGC 7635), viewed by the Hubble Space Telescope, lies ~9000 light years from Earth. Image: Hubble Telescope/NASA via Unsplash.

SURVIVING THE JOURNEY: PROTECTING ASTRONAUTS FROM SPACE RADIATION

By Dr Catriona Nguyen-Robertson MRSV

The vastness of space has beckoned many an adventurer. Yet with the exception of the Apollo astronauts, no human has ever travelled outside of Low Earth Orbit. Remaining reasonably close to Earth, they are protected by its magnetic field. To travel further out would mean facing dangerous cosmic and solar radiation.

Outside the protective cocoon of the Earth's magnetic field is a universe full of damaging radiation. Unlike any of the radiation we encounter on Earth, space radiation consists of solar particles that burst out of the Sun at high speeds, and galactic cosmic rays that come from outside our solar system and are likely produced by explosive phenomena such as supernovae.

NASA's Artemis Mission aims to send the first woman and next man to the Moon in 2024, but a lot of groundwork needs to be done to make this a reality. Experimental physicist Dr Gail Iles works with RMIT University's Space Science program, investigating ways to overcome the radiation barrier so that astronauts can survive long journeys, or even live indefinitely, in space.

Most satellites huddle around our planet in Low Earth Orbit, only reaching 2,000 km from the Earth's surface. Medium Earth Orbit then spans to the ring of geostationary satellites 36,000 km away (so named because they orbit the Earth at the same pace as it spins, meaning that they appear stationary above a spot on the Earth's surface), with GPS satellites at around the 20,000 km mark. Everything is close when compared to the Moon, however, which is 385,000 km away. Even then, a "magnetotail," pushed out behind the Earth's magnetic field by the onslaught of solar particles, can only briefly protect the path to the Moon as the Earth blocks it from the Sun.

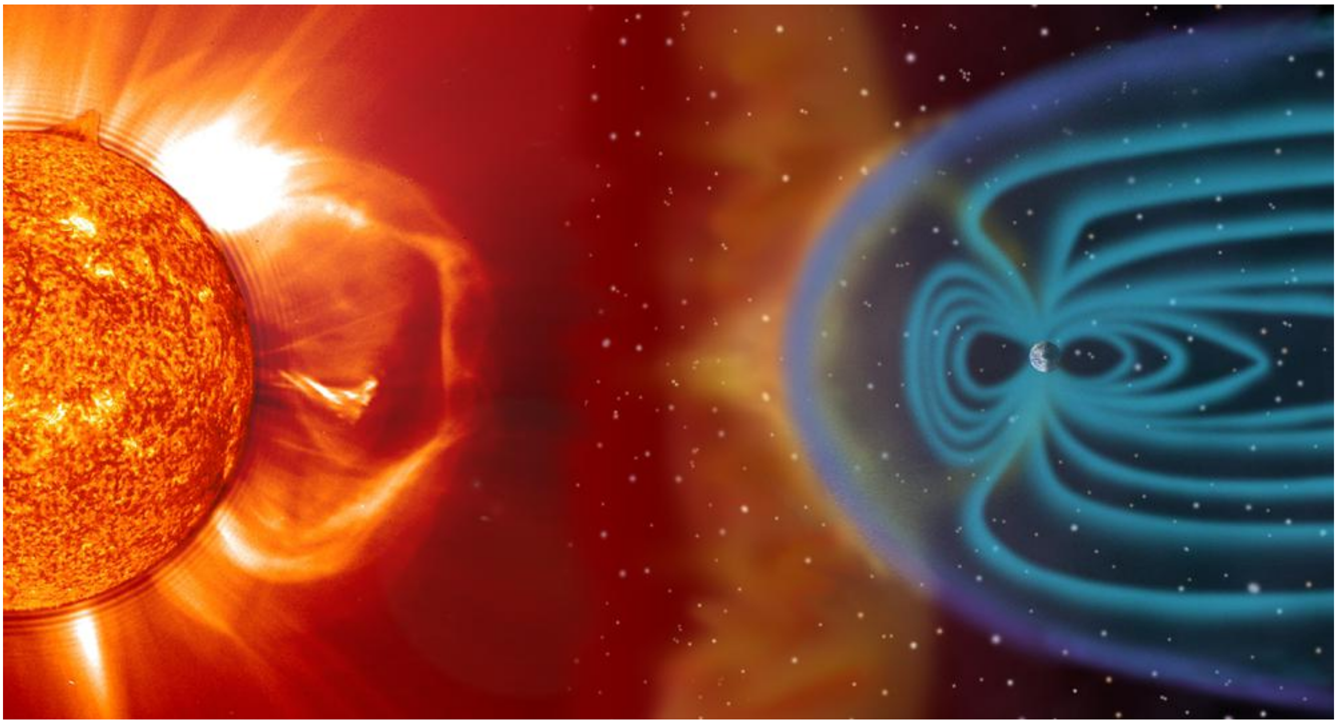
THE NEIGHBOURHOOD NUCLEAR FISSION REACTOR

> 'The power and energy being emitted from the Sun is formidable,' says Gail.

At the core of the Sun, 500 million metric tonnes of hydrogen undergo nuclear fusion every second. This creates tremendous amounts of energy, and every now and then, large eruptions of charged particles burst out. Solar flares are often accompanied by coronal mass ejections – large expulsions of magnetised particles that shoot out at speeds of up to 3,500 km/s. The bulk of these ejections are positively-charged alpha particles and negatively-charged beta particles . These can affect our communication networks and GPS satellites: in 1989, a solar storm caused an electrical blackout across the entire Quebec Province in Canada.

An additional concern for space travel is the galactic cosmic rays that come from the rest of the cosmos. Like solar radiation, these are high-energy, ionising radiation that have enough energy to completely knock electrons from atoms when they cross paths – essentially altering materials as they pass through. These particles are like atomic-scale cannonballs, damaging material as they blast through. They can even create secondary radiation particles, such

An illustration of how the Earth's magnetic field (blue) protects us from solar and cosmic radiation. Particles from the Sun speed towards Earth but are deflected by this shield, our magnetic field. Source: Steele Hill/NASA/GSFC/SOHO/ESA (CC BY 2.0 DEED, creativecommons.org/licenses/by/2.0/)



Dr Gail Iles & Dr Stefan Losch working in a simulated microgravity environment. Photograph: Dr Gail Iles.

as gamma rays (the highest energy particles) and neutrons (neutral) that cause further damage.

Gail's task is to prevent these super-fast, super-charged particles from wreaking havoc on astronauts' bodies. Here on Earth, we are all subject to a natural, background dose of ionising radiation (about 3 mSv per year) from rocks . A full body CT scan would add an additional 10 mSv, a radiation worker would be exposed to less than 50 mSv per year (as per industry regulations), while an astronaut on the International Space Station is exposed to 100 mSv in six months. Higher radiation doses increase the risk of cancer and other illnesses, and the 180-day transit to Mars would push humans well above a limit of radiation that NASA considers acceptable.

PROTECTING AGAINST DIFFERENT TYPES OF RADIATION

On Earth, the solutions to radiation shielding are relatively easy (not to mention, the magnetic field that huddles our planet also provides protection). To protect against alpha particles (if they are travelling slowly), we can use shield materials as thin as paper or our skin. Beta particles are smaller, and therefore more dense materials, such as aluminium, need to be used. Gamma rays have higher penetrating power, therefore requiring thicker materials to be blocked – lead is often used in medical institutions and nuclear power plants. Neutrons are difficult to detect, but hydrogen atoms provide protection because neutrons are absorbed by their light nuclei. Hydrogen-rich materials such as water, concrete, and plastic, can therefore be used as a shield to slow them down.

The challenge with using any of these as protection in space is that shields made from these materials would need to be launched. The heavier a material is, the more fuel is needed and the more expensive it becomes to launch. Spacecraft design is a delicate balance: it needs to be as lightweight as possible, shield against radiation, and be durable against potential meteors and debris. Current spacecraft have multiple bumper shields of thin aluminium sheets, a net of Kevlar and epoxy (materials rich in hydrogen that are also used in military and fire-fighting gear), and air gaps in between these layers to further slow down radiation particles.

But what happens once an astronaut leaves the safety of the spacecraft and goes on a spacewalk? Spacewalks have to be limited in time and frequency to avoid excessive radiation exposure. And to establish a base on the Moon - which is covered in radiation as it has no protective magnetic shield - we would likely have to build underground in channels beneath the surface.

On top of the more passive forms of shielding that simply act as barriers, there are more active forms of shielding that mimic the Earth's magnetic field. Given that they need to be much smaller than the size of our entire planet to be portable while generating the same level of protection, they require an enormous amount of power. Superconducting magnets make this possible and they have been proposed as a lining for spacecraft to deflect radiation particles. The problem, however, is that superconducting magnets are massive in size, heavy, and would require constant cooling with liquid nitrogen (an additional weight). Gail is researching lightweight alternatives for active shielding that utilise the power of the spacecraft itself at RMIT University. She has found that electromagnets provide a lighter weight, alternative shield capable of deflecting charged particles away from spacecraft.

Humans are always exploring and looking for new challenges. After having been an astronaut trainer herself and having felt so comfortable on the "Vomit Comet", a plane for astronauts to train for the microgravity of space, Gail would love to get into space herself one day. Her work is ensuring that astronauts are shielded from radiation from the stars, as they travel to the Moon and beyond.

GLACIERS AND ICE SHEETS IN A WARMING WORLD

By Dr Catriona Nguyen-Robertson MRSV

This article follows the 2023 Howitt Lecture, co-hosted by the Royal Society of Victoria and the Geological Society of Australia (Victoria Division), delivered by Professor Andrew Mackintosh, Head of the School of Earth Atmosphere and Environment at Monash University.

Amidst the frozen landscapes that have been part of Earth's geography for millennia, a transformation is underway as ice sheets and glaciers succumb to climate change. The delicate dance of freezing and melting of these ice formations, once viewed as frozen in time, is yielding to the planet's rising temperatures. From the remote corners of Antarctica to the towering ranges of the Himalayas, the alarming spectacle of accelerating ice loss casts a stark shadow over ecosystems, coastlines, and the equilibrium of our global environment.

The melting ice is a chilling reminder of the urgent need to address the consequences of climate change. Glaciologists like Professor Andrew Mackintosh reconstruct past glacier and ice sheet changes to improve their predictions of the future – and, so long as we do not slow down carbon emissions, the future looks bleak.

CHANGING ICE – A DELICATE DANCE NO LONGER SO BALANCED

Glaciers around the world range from ice that is several hundred to several thousand years old. In polar and high-altitude alpine regions, snow accumulates on glaciers and turns into ice over time. As ice builds up, it begins to flow outwards and downwards under the pressure of its own weight, flowing slowly over the land. The glaciers grow, while also moving and melting as part of their natural life cycle. If the accumulation of snow and ice equals or is greater than the amount melting, a glacier will remain in balance or even grow.

But since the early 1900s, many glaciers around the world have been rapidly melting – too quickly to counter. For 17 years, Andrew worked in the Southern Alps of New Zealand, watching the ice retreat. Every year, glacier "watchers" like him take to the skies to photograph snow and ice clinging to high peaks along the length of the Alps following the summer. They know the landscape well and they even have their favourite glaciers – but those glaciers are clearly and irreversibly disappearing.

There is grief among glaciologists as they watch the ice melt. Andrew helped launch the monitoring programme at Brewster glacier in 2004 at a time when the ice was thick and healthy – 20 years on, it 'doesn't have the characteristics of a happy, living glacier', he says. 'It looks like something that is just decaying and won't be with us much longer.'
Two other glaciers close to his heart are the Franz Josef Glacier, or, as it is known in Māori, Kā Roimata-a-Hine Hukatere, and Fox Glacier, or Te Moeka o Tuawe. For much of their history, people – including Andrew – have been able to walk on the glacier, right up to the terminus to see the frozen towers of ice. But now, some glaciers in the Southern Alps

Tourists trek over Franz Josef Glacier/Kā Roimata-a-Hine Hukatere in New Zealand. The Māori name for the glacier translates roughly to 'Tears of the Snow Maiden'. The legend goes that the Māori princess Hine Hukatere climbed the mountains with her lover Wawe. Tragically, he was swept away by a devastating avalanche, leaving Hine shattered by grief and guilt. The gods, witnessing Hine's anguish, froze her tears, transforming them into a colossal river of ice.

The glacier has been in 'retreat' since 2008, with no signs of slowing, and Andrew notes that the melting ice looks like her tears rushing down the slopes as she cries. Photograph: Jackman Chiu via Unsplash have shrunk so much that they are hard to see and cannot be stepped on; many will be gone within decades.

Using computer modelling, Andrew can predict what may remain of New Zealand's glaciers by 2100. With global warming limited to 1.5-2.0°C (RCP 2.6) in a "peak" scenario, the glaciers will have retreated but remained connected and still act functioning entities that follow a cycle of building and shrinking.[1] If we continue along the current trajectory as the worst-case scenario (RCP 8.5), most glacier ice will be gone.[1] The outcome depends on what we do from this point on. Either way, much of the ice will simply vanish in the coming decades.

The outlook is similarly grim for glaciers elsewhere. In fact, there is 'near universal retreat of glaciers all over the world,' Andrew says. 'The scale of retreat is confronting, even to a glaciologist. It's unprecedented – and I don't use that word lightly'.

In the last few decades, there have been extreme glacier melts. When an ice cube is exposed to warm water or air, it melts. It is therefore no surprise that a warming climate is causing glaciers and ice sheets to melt. Andrew has been concerned to see over recent years that ice is not merely retreating up mountains, but the mountain glaciers are being completely stripped of ice both horizontally and vertically. The ice is becoming thinner and breaking apart more easily. Thinning makes the situation worse – the less ice there is, the faster it will melt and the harder it is to build back up. As glaciers decrease in size and become thinner, their slopes become more unstable. Last year, there were two major avalanches as Tian Shan in Kyrgyzstan and the Dolomites in Italy within the space of about a week as glaciers collapsed. The glaciers were there – and then suddenly they were not. Scientists like Andrew are concerned that similar events are likely to become more common as the planet warms.

It can be difficult to disentangle natural and anthropogenic causes of glacier retreat, but human-induced climate warming appears to be the chief factor in their decline. For example, human-caused climate change made the 2018 extreme mass glacier loss in New Zealand's Southern Alps at least 10 times more likely than natural climate variability.[2] As warming and extreme heat events continue and intensify, there will be an increasingly visible human fingerprint on extreme glacier mass-loss years in the coming decades.

CONSEQUENCES WHEN THE ICE MELTS

As temperatures rise and ice melts, more water flows to the seas from glaciers and ice caps, contributing to global sea level rise. Glaciers hold about 2.1% of all of Earth's water, frozen as ice.[3] Excluding the Arctic and Antarctic ice sheets, if all the world's glaciers melted completely, sea levels would rise by 40cm.[4,5] While this may not sound like much, Andrew warns that the two ice sheets hold much more.

The fate of the world's biggest ice sheet is uncertain – it lies in our hands. Antarctica is covered by a vast ice sheet that is nearly twice the size of Australia's land mass. While it is not yet contributing significantly to sea level rise, it is the riskiest. It holds most of the Earth's glacier ice, and if the entire sheet were to melt, sea levels would rise by nearly 60 m.[6] In addition, the Arctic ice sheet has been showing great signs of vulnerability. Over the past 30 years, the oldest and thickest ice in the Arctic has declined by 95%.[7] If emissions continue to rise, the Arctic could be ice-free in the summer by 2040.[7]

It is very difficult to predict the future of ice sheets with modern observations such as satellite imagery because they cover a very short period. Andrew may be equipped with data for the past 40 years, but these ice systems have been in place for millions of years. He uses computer modelling and radar to explore the water and rock underneath. The East Antarctic

ice sheet is thought to be more stable as much of it sits above sea level, meaning that warming oceans cannot reach it and the only melting is from warmer air, which is a much slower process. In contrast, the WAIS sits below sea level and is of greater concern.

While glaciers and the ice sheets of the poles may seem distant here in Australia, the resulting sea level rise when they melt poses a great threat everywhere. A 2014 report by the Climate Council referred to coastal flooding as a "sleeping giant".[8] Over $226 billion dollars of our infrastructure (residential, commercial, industrial, etc.) is potentially exposed to flooding and erosion hazards if sea levels rise 1.1m, which is quite possible by the end of the century.[8] Globally, sea level rise poses an existential risk to low-lying islands and coastal cities.

Snow and ice loss also have immediate consequences for people. Climate change is predicted to drastically reduce the discharge of snow and ice meltwater in the Himalayas, which could have far-reaching consequences for flood risk and for water security. More than 60 million people in Asia live downstream of five major rivers that originate in the Himalayas, and their food security will be threatened by the melting ice in the coming decades.[9] For example, record temperatures in 2022 hastened melting of the Shisper Glacier, creating a lake that swelled and burst through an ice dam. A torrent of water and debris flooded the valley below, damaging fields and houses, wrecking two power plants, and washing away parts of the main highway and a bridge connecting Pakistan and China.

Given current projections, global temperature rise, and inaction by major global political and industry leaders, a sea level rise of 1.5 m is a realistic estimate that will likely occur within the century. Even a few metres of sea level rise will redraw the map of the world, with profound consequences for millions of people. Many island nations will be below the tideline, and much of Amsterdam, Alexandria, Bangkok, Ho Chi Minh City, Kolkata, and Venice, among other highly populated cities will be underwater.[10] If there are to be glaciers and ice anywhere on Earth in the next century, we need to make ambitious cuts to our carbon emissions.

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Melting ice off the Antarctic coast.
Photograph: Cassie Matias via Unsplash.

RSV YOUNG SCIENTIST RESEARCH PRIZE FINALISTS

The Royal Society of Victoria annually awards four competitive prizes to final year PhD students in all areas of the Biomedical & Health Sciences, Biological Sciences (Non-human), Earth Sciences, and Physical Sciences. In September 2023, we heard from this year's eight finalists about their brilliant work in these fields. Over the coming months, they will share a written summary of their presentations in Science Victoria.

For more information about the RSV's Young Scientist Research Prize, visit **rsv.org.au/young-scientist-research-prizes**

2023 RSV YOUNG SCIENTIST RESEARCH PRIZES (EARTH SCIENCES) - 2ND PLACE

LOOKING AT CLOUDS IN THE SKY IS MORE COMPLEX THAN YOU THINK

By Estefania Montoya Duque MRSV

Have you ever caught yourself looking at the sky trying to figure out the cloud shapes? Look there! A hippo… oh that one! A wombat. I always enjoyed looking at the clouds from my home in Medellín, Colombia. While my head was in the clouds, my thoughts started evolving, until I decided to go far away from the Andes and come to Melbourne to study clouds over the Southern Ocean. Since then, I've been learning about clouds in this amazing, yet challenging, region and how they vary upon weather patterns.

IT'S ALL ABOUT BAKING THE PERFECT CAKE

You've probably noticed there are days in Melbourne when rain comes and goes every hour. On those days, it almost feels like you have all four seasons in one day. Other times, the rain seems to persist for days. All these patterns are related to weather conditions that move from west to east, and to some extent, also from the Southern Ocean to Australia. Each weather condition pattern is characterised by different wind, pressure, temperature, and relative humidity. These variables control cloud formation, and are the reason we might see four seasons in one day. Just like following a recipe, depending on the amount of ingredients you put in, the flavours and forms of your final cake will be different.

Imagine you're a baker who's been asked to bake a cake.

Depending on the event (weather pattern), you will need to prepare a different type of cake.

Initially, in my research I had to identify the differences between the cakes. For example, I found that clouds formed behind a cold front are shallow (cupcakes), rarely precipitating, with a high concentration of liquid droplets and ice (chocolate chips).

But these shallow clouds behind cold fronts are a hard cake to bake since they are small, and the smallest bake pan you have is a 10 cm round one – much too big for a cupcake. In addition, it is challenging to understand their ice production as they need to produce just the right amount of ice at a temperature where you would expect the ice to melt. Imagine your cupcakes need a certain number of chocolate chips to not melt, but you are putting them into an oven, where they likely will melt.

Multilayer clouds are different again – like wedding cakes, with cloud tops as high as 6 km. Satellites usually have difficulties in representing precipitation in these clouds. Multilayer clouds typically precipitate heavily in the tropics, but over the Southern Ocean, the precipitation is significantly less intense, and these differences are difficult to include in satellite algorithms. These challenges are still not fully solved in our models, leading to a chain reaction in which our modelling of other weather variables is affected.

We are also working on finding out how to 'bake cupcakes' - determine whether the oven temperature (sea surface temperature), how much baking powder (buoyancy) or chocolate (ice content) you need in the batter, and how important they are in making the perfect cupcake.

Reading clouds is like learning to bake: it takes a lot of trial and error. However, I have found that understanding your ingredients (which ones, how much and in what combination), and having the right tools available (cupcake tins) can go a long way to making the perfect, puffy cloud/cupcake.

Estefania Montoya Duque presenting to the RSV, September 2023. Photograph: Karey Shandler, Verse Photography

2023 RSV YOUNG SCIENTIST RESEARCH PRIZES (PHYSICAL SCIENCES) - 1ST PLACE WINNER

GUSTS IN THE HEADWIND

By Dr Grace Lawrence MRSV

Dark matter. The elusive and non-luminous substance that makes up a quarter of our cosmos, and permeates every corner of our universe. However, despite a plethora of indirect evidence, its true nature remains one of the greatest astrophysical mysteries of the 21st century.

Direct detection, an exciting experimental detection technique, offers researchers the opportunity to directly detect and characterise dark matter through its interactions with particles we can detect. Direct detection experiments search for the signature left when a dark matter particle recoils off the nucleus of a target atom in a process known as nuclear recoil.

While we cannot directly observe them, every galaxy has its own halo of dark matter, on which the ordinary, visible matter hangs. Our solar system circumnavigates the centre of our galaxy, while Earth orbits the Sun. As we do this, our apparent motion through the Milky Way's halo of dark matter creates the Headwind Effect. The Earth's changing velocity over a year with respect to this headwind traces out an oscillating signal called 'annual modulation', peaking in the middle of the year.

Annual modulation and direct detection theory are underpinned by the Standard Halo Model, a simplified way to mathematically model our galaxy and its dark matter content. With annual modulation triggered by the headwind effect, I asked the question, 'what if there were gusts of dark matter buffeting the headwind?'. I investigated how the inherent variation of dark matter across a galaxy can inform and impact dark matter experiments.[1]

In preparation for direct detection of dark matter here on Earth, I first generated predictions of what we would find. I found that, despite clear evidence in the simulations of large variations and structures within the dark matter field, the annual modulation signals showed little variation. In fact, predictions made using the Standard Halo Model, remained consistent compared to supercomputer simulations, giving confidence to the existing theory and infrastructure in this field. Importantly, large variations in the time of year that the signal will peak were recorded, potentially complicating the way that annual modulation signals are interpreted.

Direct detection experiments sit at the intersection of astronomy, particle physics, nuclear physics, and in the case of the Australian SABRE experiment, at the bottom of the active Stawell gold mine. The SABRE (Sodium Iodide with Active Background REjection) experiment is part of a dual-hemisphere effort to detect dark matter on opposite sides of the globe to distinguish between astrophysical and local seasonal effects. As the headwind of dark matter passes through the Earth, a small percentage of the dark matter particles will interact with the experiment, via nuclear recoil, transferring energy into the detector. SABRE uses radio-pure sodium-iodide crystals as their detector target, chosen for their atomic size and ability to convert high percentages of particle energy into light.

Searching the heavens from underground may seem counterintuitive, but an underground physics lair is a key criterion in the potential success of direct detection as cosmic radiation threatens to saturate or contaminate dark matter signals. By quantifying the impact of real dark matter structure, derived from simulations, on the signals expected for SABRE and other Earth-based experiments, we have significantly enhanced the preparedness of direct detection experiments to uncover a dark matter detection and guide the spotlight on this dark phenomenon.

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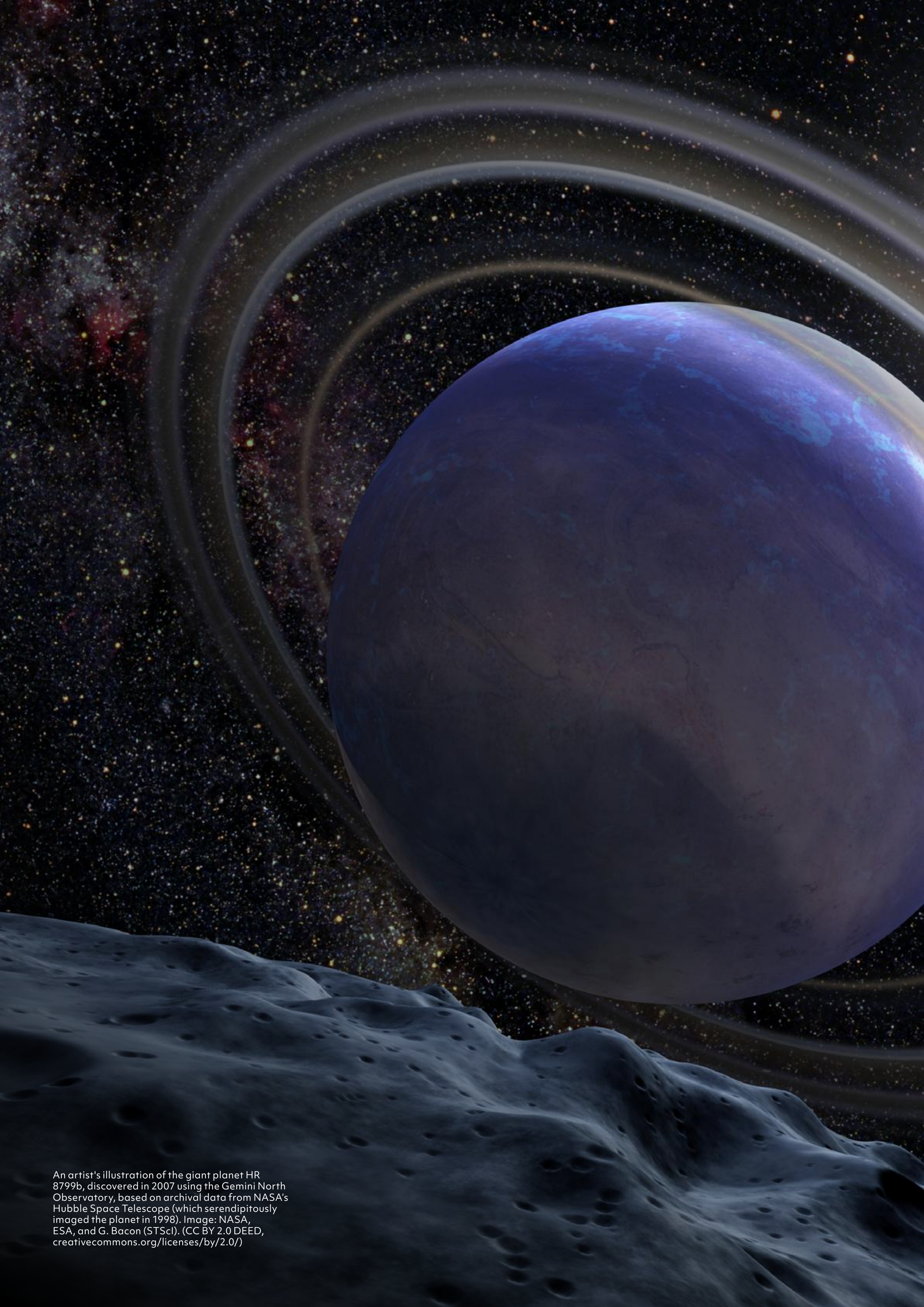
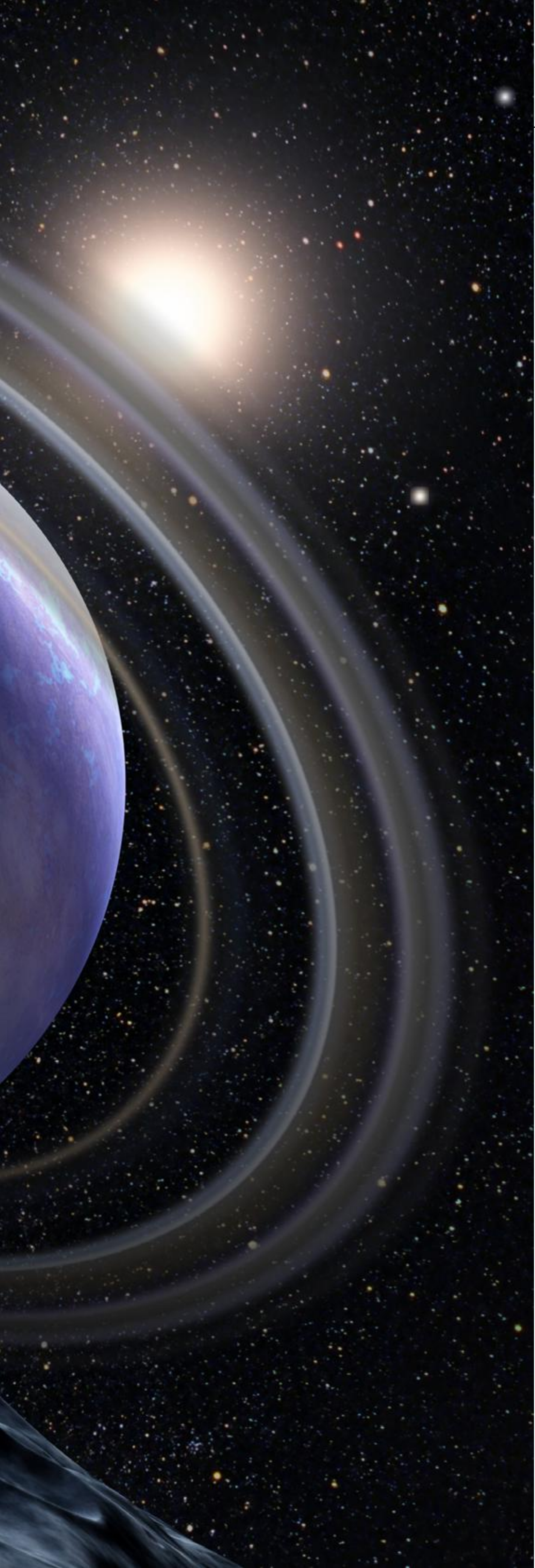
Below: Dr Grace Lawrence is hunting for signs of dark matter. Photograph: Karey Shan, Verse Photography



An artist's illustration of the giant planet HR 8799b, discovered in 2007 using the Gemini North Observatory, based on archival data from NASA's Hubble Space Telescope (which serendipitously imaged the planet in 1998). Image: NASA, ESA, and G. Bacon (STScI). (CC BY 2.0 DEED, creativecommons.org/licenses/by/2.0/)



EXOPLANET HUNTING: A SEARCH FOR NEW WORLDS

By Dr Catriona Nguyen-Robertson MRSV

This article revisits a presentation by Dr Jessie Christiansen at Melbourne Planetarium as part of the Inspiring Victoria Program and National Science Week 2018, and discusses where the search for exoplanets currently stands, five years on.

Eight planets (sorry Pluto) orbit our star, the Sun. But they are not the only planets out there. For years, people have wondered what exists beyond our solar system, and theorised the existence of exoplanets - planets orbiting others stars

The first confirmation of a planet orbiting another sun-like star was in 1992. In the years since, more exoplanets have been found, and we subsequently entered the "exoplanet era". First a trickle, then a flood. As at 2023, more than 5,000 planets beyond our solar system have been discovered.[1]

But it is not easy to find an exoplanet. With few exceptions, we cannot see them directly. Even with the largest, most powerful telescopes, they remain lost in the glare of their host stars. Instead, astronomers search for clues that reveal the presence of unseen worlds as detectives. NASA's "Tomb Raider of exoplanet research", Dr Jessie Christiansen, visited the Melbourne Planetarium during National Science Week 2018 to share her planet hunting missions.

CONVINCING THE WORLD OF OTHER WORLDS

In 600 BC, exoplanets were discussed as we would discuss the idea of alternative universes today. Perhaps they existed, perhaps they did not. But once Aristotle landed on the idea of Earth being unique, that was that, and all speculation was shut down. It was not until the Renaissance that the idea of planets beyond those around our star was revisited. Giordano Bruno claimed that there are 'countless suns and countless Earths rotating around their suns in exactly the same way', and that we only see their suns rather than the planets themselves. His teachings led him to be executed for blasphemy and heresy, his idea resoundingly rejected. Little did he (and everyone) know, he had been right. Isaac Newton also hypothesised that exoplanets exist, but had no means of confirming his hypothesis.

In the 20th century, ideas moved more rapidly. In 1952, astronomer Otto Struve claimed that we only know of our star and solar system, but that there are more beyond. Finally, in 1992, Alexander Wolszczan and Dale Frail published a paper in Nature announcing the discovery of the very first planets outside our solar system, rocky worlds around a dead star. Three years later, Michael Mayor and Didier Queloz observed a Jupiter-sized exoplanet (now termed a "hot Jupiter") that orbits around its star. The idea that exoplanets exist had well and truly sunk in. Rather than being scorned, Mayor and Queloz were celebrated for their discovery, and were awarded the 2019 Nobel Prize in Physics.

THE GREAT EXOPLANET CENSUS

Jessie's hunt for exoplanets began with NASA's Kepler Mission. A one-metre telescope was sent into space in a vessel the size of a school bus to search for Earth-like planets (i.e., rocky planets containing water) orbiting a Sun-like star. At the time of Jessie's presentation in 2018, the total number of known exoplanets was 3,264, with more than two-thirds having been found by this one telescope alone.

The Kepler telescope used the transit method to detect exoplanets: catching planets as they orbited around a star. When the exoplanet would "transit" across the view of the telescope, it would briefly block a patch of light coming from that star (like seeing a black spot on the sun in the sky). Kepler looked in one direction and focused on 200,000 stars, providing enough data to find thousands of planets. It was then the job of people back on Earth, such as Jessie, to sift through this data to detect them. This method provides information on an exoplanet's size and mass (from which density can be derived), and its atmospheric properties. But it also leads to many false positives, as sunspots and other anomalies can appear as transiting exoplanets.

This made it difficult to detect small, Earth-like planets. However, Hot Jupiters were found in abundance, as they block more light and are hence easier to detect. Furthermore, many of the planets that were discovered frequently blocked light, meaning that they orbit closer to their star than Earth does, with each revolution much shorter than 365 days.

The Kepler telescope detected thousands of planets from a small patch of sky – the size of your hand as you look up at it. Imagine if the area we searched were to be extended…

FINDING EXOPLANETS WITH TESS

Knowing that planets that orbit close to their star are common, NASA produced the Transiting Exoplanet Survey Satellite (TESS) to specifically search for them, especially those that are Neptune-sized and smaller.[2] TESS comprises four 10cm cameras, and while this is greatly scaled down from Kepler, the cameras are more targeted, as NASA now knows what to look for.

TESS was designed to scan the southern hemisphere skies for one year, followed by the northern hemisphere, shifting each month to look outwards in each patch of sky, eventually covering the skies of the entire globe. At each patch it points towards, Jessie will look for at least three transits across the star to consider a spot as a planet – therefore meaning that its orbit must be within ten days if it is to pass across three times within a month.

TESS was launched on a SpaceX Falcon 9 rocket in April 2018, and Dr Christiansen was at the launch to cheer it on. As she was delivering her presentation in the Planetarium on 13 August, it was Monday morning in California, where her colleagues had just been beginning to examine the data that had started to download a few days prior.

As its primary mission, TESS imaged about 75% of the starry sky – and it is still going. Within its two-year survey, TESS found 66 new exoplanets as well as nearly 2,100 additional

Dr Jessie Christiansen at the Discovery Science & Technology Centre in Bendigo during National Science Week 2018. Credit: Bendigo Discovery Centre.

candidates that astronomers are working to confirm. Now, around five and a half years since its launch, it is remains active and has found 392 confirmed exoplanets and nearly 7,000 candidates.[3] Jessie believes that it could last a further 20-30 years, during which time it could keep searching for smaller, Earth-like exoplanets or exoplanets further away from their star that may transit (i.e., complete an orbit) less frequently. TESS is finding exoplanets ranging from small, rocky worlds to giant planets, showcasing the diversity of planets in our galaxy.

How long can our search for planets last? NASA predicts TESS will find 16,000 planets, jumping from 70 known exoplanets, to over 3,000 after Kepler, to 16,000 with TESS. NASA is also currently developing a 2.4m infrared telescope as part of the Nancy Grace Roman Space Telescope that will be launched in 2025 or 2026 to search for cold planets, which is predicted to find 100,000 planets. So far, it seems as though the numbers are only going up and up.

Importantly, you do not need to be a professional astronomer to find new worlds orbiting distant stars. We can all be a part of the mission to hunt for exoplanets. Jessie invites everyone to participate in the search as citizen scientists.

Although we can build stunning telescopes that produce vast amounts of valuable data, we can't yet build an algorithm that approaches the extraordinary abilities of the human brain to examine that data. It is easier to train people to find planets from the mission data than it is a computer, and therefore NASA has created citizen science projects (**exoplanetexplorers.org**) for people to search for themselves – and it so far has saved her years of work. You may even discover a planet yourself!

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A satellite in orbit, viewed from the International Space Station (ISS). Photograph: NASA via Unsplash.


Yallourn Open Cut Coal Mine (c.1920-1930).
Source: State Library of Victoria, ID: 2101446 (Public Domain).

1970

MR BROWN COAL ON COAL

By Scott Reddiex MRSV

As we move towards a target of 95% of Victoria's energy coming from renewable sources by 2035,[1] we can reflect on the different approach to energy that has existed in our state over the past two centuries.

As part of the RSV's West Gippsland Symposium in 1970, Claus S. Gloe presented a piece on "The Fuel and Power Resources of the West Gippsland Region". In this presentation and its accompanying article, Gloe describes the past and present fossil fuels and their usage in West Gippsland. He was suitably qualified for the task: dubbed 'Mr Brown Coal', he was 'Geologist-in-Charge' at the State Electricity Commission (SEC) of Victoria, as well as a lecturer at Monash University.

Brown coal, black coal, oil, and gas. These four fossil fuels have all been extracted from either in or off the coast of West Gippsland, and used to power the state at different points in the past 200 years.

"*Prior to 1910, local firewood and black coal from New South Wales were the chief fuels used to provide energy for power, heat, transport, etc., in Victoria. Following a prolonged strike of miners in the Newcastle field of New South Wales, the State Coal Mine of Wonthaggi was opened in 1909.*"

Black coal was mined at a range of locations in West Gippsland, including Wonthaggi, Korumburra, Jumbunna, Outtrim, Kileunda, Woolami, Berry's Creek, Boolarra, and the appropriately named Coalville. Most of the black coal in these reserves was mined between 1910 and 1930, before the high production costs saw the closure of these mines in 1968. By that point, there had been a total of 22,338,000 tonnes of black coal mined.

Brown coal (formed 23-66 million years ago) is the younger sibling of black coal (formed 145-299 million years ago). It has a lower carbon content (and consequently less potential energy), higher moisture content, and requires processing before use. In West Gippsland, the deposits of brown coal are predominantly located "*in the Latrobe Valley, and in the Gelliondale-Welshpool area*", and most Victorians would be familiar with the massive open-cut mines at Yallourn and Morwell. Even by 1970, the amount of brown coal mined in Victoria significantly dwarfed its older sibling, with Gloe reporting a total mass of 358.93 million tonnes having been produced.

This amount is in turn dwarfed by the 430 billion tonnes of brown coal estimated to be in Victoria, with 33 billion tonnes classed by the government as 'economically viable'.[2]

It is important to note that plans for a renewable energy future for Victoria don't mean an end toof the continued mining of brown coal in Victoria, as "*there is strong investor interest in using our valuable coal resources to make alternative high value, low emission products for domestic and international markets.*"[3] This means that Victoria's coal will continue to contribute to global greenhouse gas levels for the foreseeable future.

From:
Proceedings of the Royal Society of Victoria, Vol 83 (New Series), 1970. Article 8 - The Fuel and Power Resources of the West Gippsland Region. By Claus S. Gloe.

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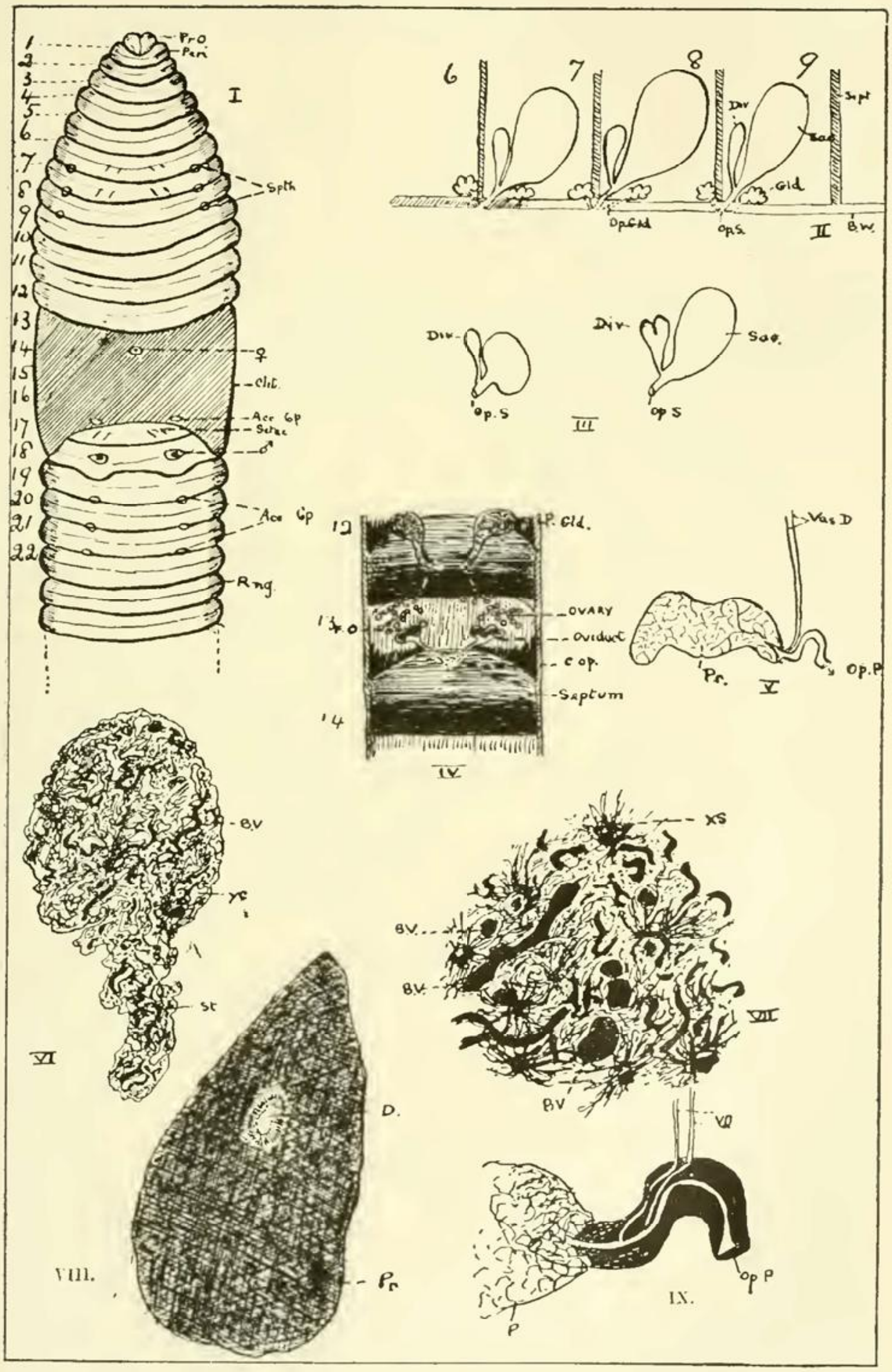
Proc. R.S. Victoria, 1920. Plate XXVIII.



Megascolex Fletcheri

Diagrams from the dissection of Megascolex fletcheri.
Source: *Proceedings of the Royal Society of Victoria*, Vol XXXII. (New Series). 1920.

1920

AN UNLIKELY FAUNAL EMBLEM

By Scott Reddiex MRSV

If you were asked to quickly name an animal native to Australia, your mind would likely go first to the kangaroo or the koala. Maybe an emu, echidna, platypus, or wombat would come to mind. Tasmanians are obligated to respond with Tasmanian devil.

Less likely to spring to mind, and perhaps slightly less glamorous, are animals in the taxonomic family *Megascolecidae*. With neither feathers, fur, nor fins, this family of earthworm species are unlikely to find themselves on a ten-cent coin anytime soon.

While they can be found around the world, Megascolecidae originated in Australia, and there are many species found only in particular parts of the country.[1,2]

On Thursday the 11th of December 1919, a paper by Jean H. Shannon on one of these native species was read to the RSV, titled "*On the Structure of a New Species of Earthworm from South Australia, Megascolex fletcheri*". Over the course of twenty pages, Shannon describes the species' habitat, external and internal anatomy, nervous system, nephridial (excretory) system, vascular system, and reproductive system. She also details an intriguing "*Problematic Gland in the Thirteenth Segment*", found after dissection of the animal, which looked like "*a pair of club-shaped organs, each slightly smaller than the smallest spermatheca* (sperm storage organ)". While this mystery organ featured a very abundant blood supply, Shannon found it difficult to suggest its function.

Shannon had collected the sample of Megascolex fletcheri near Kapunda in South Australia, and had carried out her studies at the Zoological Department of the University of Melbourne. Her paper is one of many similar papers in the history of the *Proceedings of the Royal Society of Victoria* that remain a valuable record of species that have lived in Australia – some of which are now endangered, and others already extinct.

From:
Proceedings of the Royal Society of Victoria, Vol XXXII. (New Series), 1920. XIX - On the Structure of a New Species of Earthworm from South Australia, Megascolex fletcheri. By Jean H. Shannon, B.Sc.

References:
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(Photograph, 1864) Professor Halford with the first two classes of medical students in his makeshift 'dissecting room', located in a converted stable at the back of Halford's rented house in Madeline Street, Carlton. Source: University of Melbourne Medical History Museum (Public Domain).

Professor George Britton Halford (1824-1910) was the first Professor of Medicine at the University of Melbourne, and held lessons in this converted stable until facilities at the university were built.[3]

↑ Back to Contents

1868

CUT IT OUT

By Scott Reddiex MRSV

In some cases, an old or outdated technique may still be the best one to use.

This is not one of those cases.

On Monday the 9th of March 1868, a paper on snake bites by RSV Vice President Professor George Britton Halford was presented to the Society. The title of his piece makes his recommended procedure very clear: "*On a Pair of Scissors for the excision of Snake-bite.*"

Professor Halford had read about "*one or two painful deaths from snake poison in the papers*", and had thought it his duty to help prevent this.

After all his other remedies failed, the treatment he now prescribed for a snake bite was, put simply, to quickly cut out a section of flesh surrounding the site of the bite. To achieve this, he had a pair of scissors made for such a purpose "*under his direction*", so that "*a man could use it himself*".

"*The two blades of the scissors were curved, and they had a point or spike which, when the scissors open, would be driven into the bitten part. As they shut, the scissors pressed this blade, which rose, bringing the flesh and skin with it. The blades of the scissors then severed the piece of flesh, and it was thrown away.*"

His target market for these scissors was "sportsmen, squatters, and others likely to be among snakes", with the suggestion that they could easily hang by the side and be carried.

Venom is, quite literally, a chemical weapon. While the composition of venom varies widely between – and even within – species, it is mostly (>90%) made of proteins and peptides, which act as toxins and enzymes. Generally speaking, the many different toxins and enzymes in snake venom help to immobilise and kill the snake's prey, and make it easier to digest.[1]

Rather than cutting a chunk out of yourself with patented scissors, the current treatments for snake bites in Australia (i.e., from Australian species of snakes) are to immobilise, apply constant pressure, call 000, and get to a hospital as soon as possible for treatment with an antivenom.[2]

From:
Transactions and Proceedings of the Royal Society of Victoria, Volume IX, 1868. Article III. – On a Pair of Scissors for the excision of Snake-bite. By George B. Halford, M.D.

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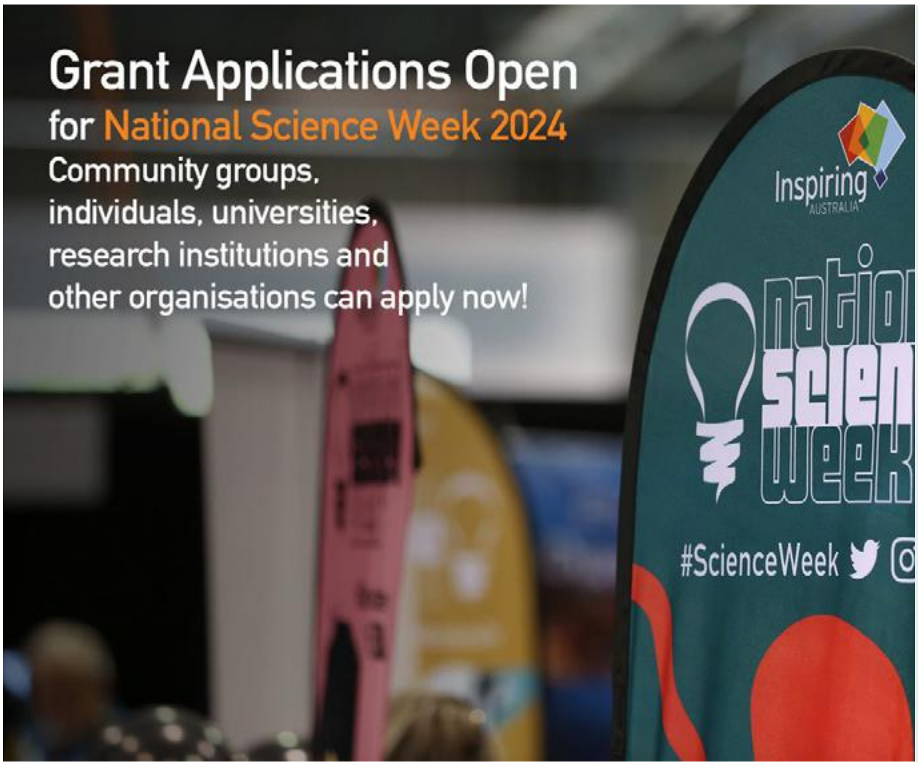

Inspiring Australia Victoria

The **Inspiring Australia strategy** was developed by the Australian Government to increase general engagement and interest in the sciences by Australians. The **Inspiring Victoria** program is jointly funded by the Australian and Victorian governments with the **Royal Society of Victoria (rsv.org.au).**

Inspiring Victoria encourages involvement in STEM through initiatives (such as National Science Week Victoria - **scienceweek.net.au/your-state/vic**) that are governed and delivered by the RSV's program partners:

- **Public Libraries Victoria**
- **Neighbourhood Houses Victoria**
- **Parliament of Victoria**
- **Museums Victoria**
- **Royal Botanic Gardens Victoria**
- The **Commissioner for Environmental Sustainability**
- **Questacon**
- The **Arthur Rylah Institute for Environmental Research**
- **Zoos Victoria**

NATIONAL SCIENCE WEEK GRANTS 2024

Applications for 2024 National Science Week Grants are now open.

These grants provide individuals and organisations with up to $20,000 to support the delivery of science engagement activities during National Science Week 2024, Australia's major national celebration of science.

Closing date:
Monday 11 December 2023 5:00pm AEDT

What do you get?
Grants of between $2,000 and $20,000 for community participation in National Science Week 2024 activities.

Overview
National Science Week is Australia's major national celebration of the sciences, occurring in August each year. National Science Week will be held from 10 to 18 August 2024. National Science Week provides the opportunity for community participation in high profile science engagement activities across the nation.

The objectives of the grant opportunity are to:
- inspire wide community participation in STEM
- provide an opportunity to acknowledge and celebrate the contributions of Australian scientists to the world of knowledge
- encourage an interest in science pursuits among the general public
- encourage younger people to become fascinated by the world we live in
- encourage new and innovative ways of engaging with audiences.

The intended outcomes of the grant opportunity are to:
- increase national and international interest in Australian science
- improve critical engagement with key scientific issues by the public
- increase inspiration drawn from science and improve the value of science as perceived by the public.

The grant amount will be up to 100 per cent of eligible project expenditure (grant percentage).

- The minimum grant amount is $2,000.
- The maximum grant amount is $20,000.
- We will only award applications of exceptional merit the maximum grant amount of $20,000.

Eligibility
You can apply if you:
- are an eligible entity
- have an eligible project
- have eligible expenditure.

Full details are available on the grant website, along with links to the application portal: **business.gov.au/grants-and-programs/national-science-week-grants-2024**

Other Grant Programs for National Science Week

National Science Week is part of the Inspiring Australia – Science Engagement Programme.

As the managing organisation for the program in Victoria (Inspiring Victoria), the RSV will be offering small grants (up to $1000) to public libraries, neighbourhood houses, and other community organisations in the first half of 2024.

Please keep an eye out on our communications via *Science Victoria*, and subscribe to receive updates (if you haven't already) at **http://eepurl.com/bg-fjH**

NASA astronauts Jessica Watkins and Bob Hines work on the XROOTS investigation. Photograph: NASA

GROWING BEYOND EARTH

By Ben Liu, Tanya Hendy, and Dr Catriona Nguyen-Robertson

Royal Botanic Gardens Victoria is leading the "Growing Beyond Earth" Australian pilot, where schools collect data to help NASA discover new fresh, tasty, and nutritious foods for astronauts to grow and eat on the International Space Station (ISS).

As humans increasingly explore space, we will want - and need - to bring plants with us. Plants are critical for keeping space travellers healthy on long missions: exploring deep space, on long stints on the ISS, or setting up a base on the Moon or Mars. Researchers are therefore exploring the idea of crews growing some of their food during a mission, testing various crops and equipment to figure out how to do this without a lot of extra hardware or power.

WHY GROW PLANTS IN SPACE?

Plants can provide many benefits, being consumed as food and creating a refreshing atmosphere for spaceflight and space exploration. Plants take in carbon dioxide in the air to produce valuable oxygen and can also help to control cabin humidity.[1] In addition, the growth of fresh flowers and mini gardens can be good for the mental wellbeing of astronauts, and those aboard the ISS appreciate tending to a garden so far away from the greenery of Earth.[2]

As plant growth becomes more feasible in space, there is also hope that astronauts can be supplied with fresh food. Currently, astronauts on the ISS receive regular shipments of pre-packaged meals, but the quality and nutrition of this food degrade over time. As we plan to venture further out into space, people may travel for months or even years without resupply shipments. A lack of vitamin C was all it took to give sailors scurvy back in the day, and vitamin defic iencies cause several health problems. Simply packing multi-vitamin tablets will not be enough to keep astronauts healthy - they will need fresh produce.

It's not all about space. Overcoming the challenges of growing plants in space will also help us grow plants more efficiently on Earth.

BUT GROWING PLANTS IN SPACE IS NO EASY FEAT

One of the most immediate challenges for plant growth is the lack of sunlight in a contained environment of a space station or future base. Without light, photosynthesis comes to a halt and respiration becomes the dominant process in plants - meaning that they consume more oxygen than they produce. As on Earth, artificial lighting can be added to make up for the lack of natural sunlight. Plants typically use red and blue wavelengths of light to grow - they absorb those parts of the light spectrum, which is why they appear green, not red and blue. In addition, chemical engineer Professor Robert Jinkerson, aims to grow plants and mushrooms in complete darkness with specific nutrients that "reawaken" the chemical processes of photosynthesis.[3]

Another challenge is the microgravity environment. Plants are adapted to Earth's gravity; they send their roots downwards towards water and nutrients, and their shoots upwards towards light. An early experiment on the ISS found that microgravity alters wheat plant leaf development, plant cells, and chloroplasts, the green component of leaves used in photosynthesis, but did not seem to be detrimental to plant growth overall.[4] In fact, the wheat plants grew 10% taller compared to those on Earth.[4] In contrast, two generations of mustard plants grown in microgravity produced smaller seeds, but their germination rates were near normal.[5] Perhaps part of the reason for these differences is that seedings acclimatise to the low gravity environment by modulating expression of certain genes,[6] and different plants will respond differently.

Fluids in space tend to form bubbles as, without gravity to tug downward, drops form the shape with the least amount of surface area, which is a sphere. One significant challenge for growing plants in microgravity is therefore providing enough water to keep them healthy without drowning them in water bubbles. Water must therefore be carefully distributed along with nutrients and air in a healthy balance around roots.

WHAT PLANTS CURRENTLY GROW IN SPACE AND HOW?

NASA has a luggage-sized space garden on the ISS known as the Vegetable Production System, or Veggie. The garden is home to six plants, each growing in a "pillow" filled with a clay-based media and fertiliser. The crew members look after the plants and water them by hand, similar to caring for a window garden on Earth. Another system, the Passive Orbital Nutrient Delivery System, or Veggie PONDS, works with the Veggie platform but has a holder that automatically feeds and waters the plants.

In the microgravity environment, plants use light and other environmental factors to orient and guide their growth. LEDs above the Veggie chamber glow magenta pink, shine light that is best suited for the plants' growth - red and blue. Veggie has so far successfully grown three types of lettuce, Chinese cabbage, mizuna mustard, red Russian kale, and zinnia

Dr Meg Hirst, Postdoctoral Fellow - Seed Science, Royal Botanic Gardens Victoria with Catholic Regional College Students. Photograph: RBGV

Catholic Regional College Student examining a plant under a microscope. Photograph: RBGV

flowers, some of which have already been harvested and eaten by crew members.

Another "garden" on the station is the Advanced Plant Habitat, which also uses LED lights and a porous clay medium for plant growth. Unlike Veggie, it is in an enclosed chamber and automated so that it does not require much day-to-day care from the crew. APH has already grown *Arabidopsis thaliana* (thale cress), a plant typically used as a model species in botany, and dwarf wheat. With over 180 sensors, its water distribution, atmosphere content, moisture levels, and temperature are automatically controlled and even send information to a team on the ground at the Kennedy Space Centre.

HOW DOES THE GROWING BEYOND EARTH PROGRAM HELP US GROW PLANTS IN SPACE?

The program is a collaboration between Royal Botanic Gardens Victoria, Fairchild Tropical Botanic Garden, The La Trobe Institute for Agriculture and Food and Melbourne Archdiocese of Catholic Schools and NASA, which will extend the successful Growing Beyond Earth® (GBE) program that has been running for six years in the United States.

Growing Beyond Earth originated with Fairchild Botanic Garden in Florida, USA and is now in 350 middle and high schools across the US. More than 40,000 students have tested how well more than 180 varieties of edible plant seeds grow in a habitat similar to one on the space station. Seeds that grow well in the classrooms are then tested in a chamber at the Kennedy Space Centre, and ones that grow well there, are subsequently sent to the ISS. Students in the USA have successfully identified foods such as "Dragoon Lettuce" and "Extra Dwarf Pak Choi" that have gone on to become a part of the Veggie program.

HOW DOES THE PROGRAM WORK IN AUSTRALIA?

Following the initial trial and pilot programs that have occurred across 2023, we are hopeful that the Australian version of the GBE program could take on an Australian flavour. That is, given the high nutritional content of many Australian Bush Foods, students could identify, grow and test Bush Foods in a specially designed Growth Chamber that replicates growth systems on the ISS, with support from scientists and Aboriginal Learning Facilitators at Royal Botanic Gardens Victoria.

Some Bush Foods are sclerophyllous plants, which means they can grow on impoverished soils and where water is in short supply. For example, *Microseris walteri* (Murnong) has been used as a staple food for millions of years and is eight times more nutritious than a potato. Other potential candidates include *Carpobrotus rossii* (Pigface) and *Tetragonia tetragonioides* (Warrigal Greens).

HOW DO STUDENTS CONTRIBUTE TO THE PROGRAM?

Students test the potential of various plants in specially designed growth chambers that replicate those on the ISS. The chambers are fitted with lights and a fan, and will collect data around germination rate, plant size, edible mass, humidity, light and other variables.

In 2023, two Victorian schools, Catholic Regional College, Caroline Springs, and Mount Lilydale Mercy College took part in the pilot program. Students from Catholic Regional College visited the Gardens in March 2023 to collect their special Growth Chambers and attended education sessions by Gardens experts about plant data collection and Aboriginal Bush Foods.

WHAT IS THE HOPE FOR THE FUTURE GROWTH OF THE PROGRAM?

Broadly, the program aims to attract and engage students in plant science through the unique connection between growing plants for space travel and the ever-emerging field of protected cropping.

Whilst we're hopeful that Australian students may help to identify the next crop to be tested on the international space station an even longer-term outcome would simply be more students engaging in the field of plant science and positively contributing to sustainable food production in the future.

In the short-term, we're hopeful that beyond this initial 2023 pilot we can continue to offer the program to schools across Australia.

HOW CAN SCHOOLS BECOME INVOLVED?

Interested schools can subscribe to Royal Botanic Gardens Victoria's Learning E-news at **rbg.vic.gov.au** to keep up to date with the program.

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Below: NASA astronauts Shannon Walker and Michael Hopkins collect leaf samples from plants growing inside the European Columbus laboratory for the Veg-03 experiment during Expedition 64. Photgraph: NASA

A Mountain Pygmy Possum and (below) a Bogong Moth. Photographs: Zoos Victoria.

MOTH TRACKER

A CITIZEN SCIENCE PROJECT WITH ZOOS VICTORIA

Help scientists at Zoos Victoria track the migration of Bogong Moths to help them and the Critically Endangered Mountain Pygmy-possum!

Beginning in spring each year, Bogong Moths make an epic migration towards alpine regions in Victoria and New South Wales, where Critically Endangered Mountain Pygmy-possums are waking from their hibernation. Bogong Moths are a crucial spring food source for Mountain Pygmy-possums and declines in Bogong Moth numbers are an urgent threat to the possums' survival. After Bogong Moth numbers crashed by an estimated 99.5% in 2017-18, these small but mighty moths were sadly listed as Endangered by the IUCN in 2021.

Moth Tracker is a citizen science initiative which aims to gather open-source real time data on the dates, locations and numbers of Bogong Moths travelling during the annual migration period.

If you see a Bogong Moth, or a moth you think could be a Bogong Moth, take a photo and upload it to Moth Tracker. It's quick and easy, and will help scientists better understand how to help the moths and if they will make it to the mountains this year.

*Learn more about the moths, the possums who eat them, and the Moth Tracker project at **zoo.org.au/possums/***

CALL FOR SCIENTIFIC PAPERS

The Proceedings of the Royal Society of Victoria is our refereed journal, published twice annually by CSIRO Publishing. Current and recent editions are available online in open access format from **publish.csiro.au/rs**.

The Society invites contributions for the *Proceedings* from authors across the various disciplines of biological, physical and earth sciences, including multidisciplinary research, and on issues concerning technology and the applied sciences.

Contributions on topics that are relevant to Victoria and the south-eastern Australian region are encouraged. The journal also publishes Special Issues and themed collections of papers commissioned by the Council of the Royal Society of Victoria. It is published online in May and November, with two issues constituting a volume.

The *Proceedings* is one of Australia's oldest and longest-running science journals, a terrific platform for establishing an individual research presence, grouping papers derived from symposia on specific subjects, or simply joining a distinguished tradition of science published in or about our region that stretches back to the 1850s.

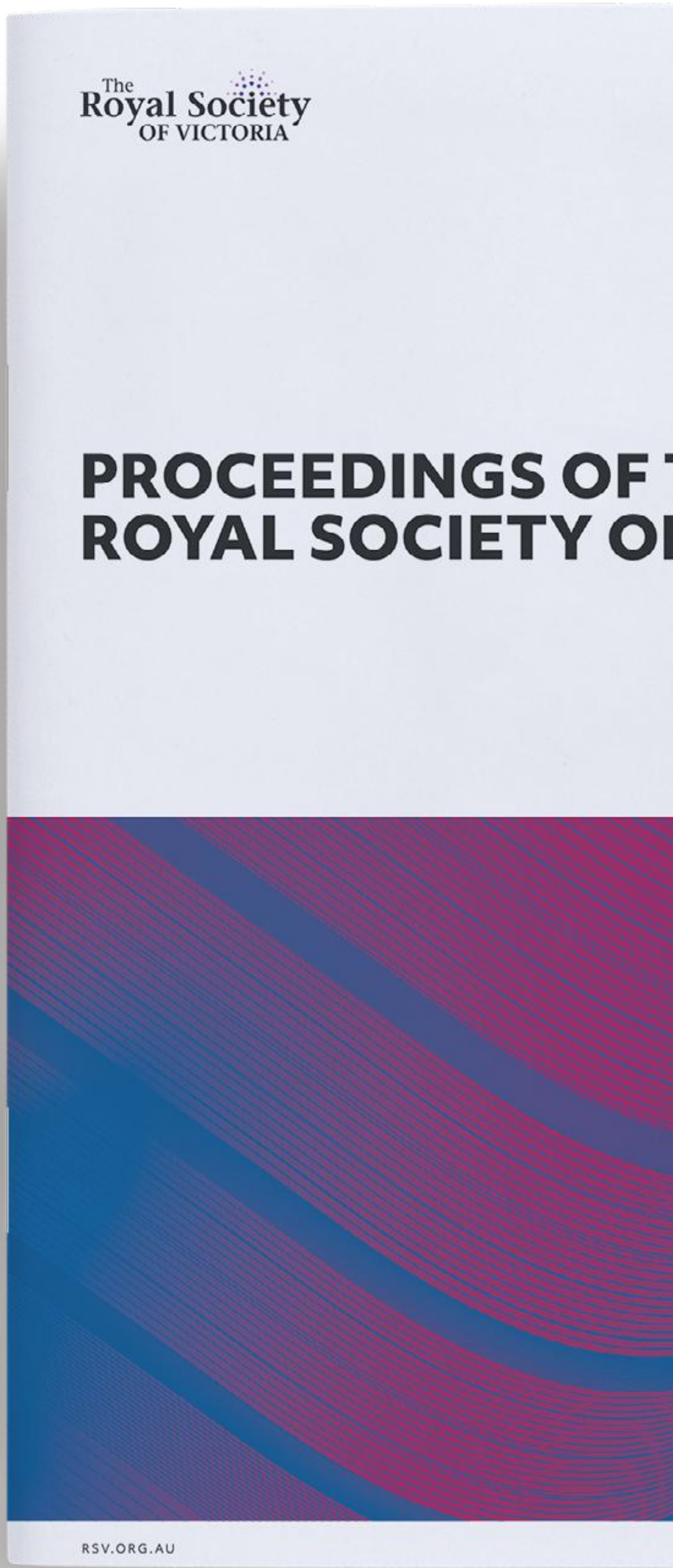
The journal began in 1855 as an irregular publication under the title *Transactions of the Philosophical Society of Victoria,* with the present name adopted in 1889. Since then, volumes of the journal have been published annually, often across one or more parts.

The online content published by CSIRO Publishing extends back to Volume 118, 2006, and is available at **publish.csiro.au/rs**.

All volumes of the *Proceedings* and its predecessors from 1854 to 2006 are also available free online at **biodiversitylibrary.org/creator/6984**.

SUBMISSIONS

Those interested in submitting papers should review the Author Instructions at **publish.csiro.au/rs/forauthors/AuthorInstructions**. Manuscript submissions for the *Proceedings* are now made using the ScholarOne platform. Any enquiries regarding submission can be made to **editor@rsv.org.au**.



CURRENT GOVERNMENT CONSULTATIONS OF INTEREST TO VICTORIA'S SCIENCE COMMUNITY

Projects open for consultation from ***engage.vic.gov.au/project***

Victorian Murray Floodplain Restoration Inquiry and Advisory Committee

Learn about the Standing Inquiry and Advisory Committee appointed to advise on the proposed Victorian Murray Floodplain Restoration Projects and their potential effects

Ongoing:
engage.vic.gov.au/VMFRP-SIAC

Victorian Cancer Plan 2024-2028

Have your say about priorities for the next Victorian cancer plan to help improve cancer outcomes for all Victorians.

Consultation closes 12 November 2023:
engage.vic.gov.au/victorian-cancer-plan-2024-2028

Ministerial Review: Victorian Public Sector Medical Staff

Have your say about workplace systems and employment arrangements impacting public hospital medical staff and delivery of health services.

Consultation closes 15 December 2023:
engage.vic.gov.au/min-review-vic-pub-sector-med-staff

Barwon Women's and Children's Hospital

Have your say on the new Barwon Women's and Children's Hospital, which will be built within the University Hospital Geelong precinct and will provide a new children's inpatient unit, new neonatal and parent care unit, specialist (outpatient) clinics, and more operating theatres.

Consultation closes 24 December 2023:
engage.vic.gov.au/barwon-womens-and-childrens

PITCHING AND WRITING FOR SCIENCE VICTORIA

Science Victoria seeks the discussion and promotion of scientific topics of relevance to people living in the State of Victoria. We are particularly interested in new research, in-depth articles, or exploration of subjects where scientific work and thinking can directly address or deepen our understanding of environmental and socioeconomic challenges.

We welcome your pitches and pieces for news, features, opinion, and analysis articles on current scientific research in Victoria, recent scientific discoveries, related social and policy issues, technical innovations, and overviews of impactful research. We cover a broad range of topics around Science, Technology, Engineering, Mathematics, Medicine/health (STEMM) under an overarching theme of "science and society."

Science Victoria's articles are written in plain, non-academic language, pitched at an intelligent and naturally curious audience that does not necessarily hold subject-matter expertise. This is not a platform for scientific journal articles nor media pieces. For more information on what we're looking for, please read our article submission guidelines below.

HAVE AN IDEA FOR AN ARTICLE?
PITCH YOUR IDEA TO US!
Send your idea to **editor@sciencevictoria.org.au,** along with any questions you have regarding your pitch.

In your email, please outline:

- In one sentence, what is your key message? (No more than 50 words)
- Why should this key message be shared with the readers of *Science Victoria*? (No more than 100 words)
- Which style of article are you proposing to write? (See below for a guide to article types)

Article pitches can be submitted at any time, but please keep in mind the article submission deadlines for the next month's issue. Note that we may accept your pitch, but suggest it is more suitable for another style of article.

ARTICLE SUBMISSION
Once your pitch has been accepted, you can submit completed pieces that comply with the style guide below. Completed articles to be published in the next issue of *Science Victoria* must typically be submitted 2 weeks prior to the beginning of the next month.

All pieces will be reviewed prior to publishing and may be edited for length and clarity (although we will be sure not to alter the message or context of your work). We will also endeavour to fact-check and confirm any grey areas with you ahead of publishing in the interests of accuracy.

All published pieces will be accompanied by a by-line, and a short (<50 word) biography of the author (title, institution, qualifications, current projects, contact email) to be submitted with your piece.

Images and figures to accompany your piece are strongly encouraged, however please ensure that you only provide original images produced by yourself or those that already exist in the Public Domain. Images must include details of the source and any relevant descriptions. If you do not provide any images, we may include Public Domain or stock images that we deem suitable for visual communication of your content.

REFERENCES
References for all articles should use a modified APA 7th edition format: reference list in author-year format, with numbered in-text citations. Refer to articles in previous editions for examples, or contact **editor@ScienceVictoria.org.au**.

WRITING FOR SCIENCE VICTORIA: ARTICLE FORMATS

STYLE GUIDE
To successfully engage the largest audience, all pieces should have readability in mind.

Readability can be determined using a Flesch-Kincaid readability test, aiming for a score between 50-60. This score means that your piece should be easily understood by an educated 16-year-old (a year 10 student).

If drafting your piece in Microsoft Word, **you can easily view your document's readability statistics** at Home>Editor>Document Stats. Alternatively, you can use one of the many free online calculators.

FEATURE ARTICLES
Recommended word count (600 - 1,800)
Feature articles are more in-depth pieces on a specific topic related to STEMM. A key aspect of feature articles is the narrative – this isn't a journal article, so think about the story that your article is trying to tell.

Your audience is intelligent members of the general public, who share an enthusiasm for scientific topics, or who are members of the scientific community outside of your particular field.

Avoid using jargon, as it will quickly alienate anyone who isn't an expert in that field. Explaining one or two otherwise irreplaceable terms is fine.

Please reference primary sources/journal articles for any non-trivial scientific claims, or for publications that prompted your writing of the article.

Feature articles typically run between 600 and 1,800 words (including references). Use of sub-headings and figures to break up longer pieces is strongly encouraged.

Not quite sure about the tone for your piece? Have a look at articles published in previous editions of *Science Victoria*, or in other scientific magazines for a general audience, like *The Conversation, Cosmos, New Scientist* or *Scientific American*. A good litmus test is knowing that most of us have read a piece or been to a presentation that managed to make the most interesting topics incredibly boring. This is what you want to avoid.

LETTERS
Recommended word count (400 - 1,000)
Letters have minimal restrictions on style, structure, or subject matter. You are encouraged to submit your thoughts/questions/comments that broadly relate to STEMM in Victoria and/or the Royal Society of Victoria. Potential subject areas include responses to articles in previous editions of *Science Victoria*, seminars at scientific events, science-related issues and policies, or topics you'd like to see in future editions.

Where a specific question is asked, we will endeavour to have the appropriate person respond to your letter.

WHAT I'VE BEEN READING
Recommended word count (400 - 1,000)
This is a column for you to tell us about a book broadly relating to science that you've read. These pieces are typically between 400 – 1,000 words and include a summary of the book and its ideas, as well as your interpretations or conclusions.

Possible questions to consider when writing this column:

- Do you think the author was correct in any assumptions?
- Was the author's style of writing approachable?
- Did they do the subject matter justice?
- Who would you recommend this particular book to?
- What did it mean to you?
- What did you learn?

OPINION ARTICLES
Recommended word count (600 - 1,000)
In contrast to an unbiased news or feature article, an opinion piece conveys your informed opinion on, or experiences with a particular topic. This is where your expertise on a subject can shine. Clearly state your argument, outlining the details of the problem you are addressing, and build to a strong conclusion.

For greatest impact, your choice of topic should be one that is broadly relevant to STEMM-related fields in Victoria. Examples of possible topics include:

- how to address a climate-change related problem in Victoria,
  successes and failures common to STEMM engagement initiatives,
- changes in your particular field of expertise
- your experiences of a career in STEMM and thoughts on how to better support the next generation of researchers,
- existing STEMM-related studies or approaches that you believe could be applied in Victoria,
- ethical problems related to scientific projects or careers in STEMM.

Please reference primary sources/journal articles for any non-trivial scientific claims, or for publications that prompted your writing of the article.

Opinion pieces should aim to be 600-1000 words. For anything shorter, consider submitting it as a Letter instead. We welcome well-informed opinion articles from all authors, particularly from those with significant expertise in a given area. Articles may reference your own work; however these are not promotional fluff pieces.

NEWS ARTICLES
Recommended word count (400 - 1,000)
News Articles are for the discussion of current or recent news relating to science, with an emphasis on science in Victoria or news that impacts Victoria's scientific community.

These articles should be concise, avoid use of jargon and personal opinion, and be referenced as appropriate. News pieces should be between 400-1,000 words in length.

Reports could relate to funding announcements/grant outcomes, new STEMM-related projects, high-impact publications relevant to Victoria, successes of Victorian scientists, or relevant STEMM-related policy news.


SOCIETY OF VICTORIA
THE ROYAL SOCIETY OF VICTORIA
Promotion and Advancement of Science

HOLD YOUR NEXT EVENT AT THE ROYAL SOCIETY OF VICTORIA

The RSV engages communities with scientific knowledge through aligned partnerships, special events, festivals, conferences, and education programs. Email **rsv@rsv.org.au** to discuss your needs and ideas!

FACILITIES FOR HIRE

The Royal Society of Victoria's facilities are available for hire to organisations, companies, or private groups. This heritage-listed building opposite the Carlton Gardens is suitable for a wide range of events, including conferences, seminars, meetings, and private functions.

Limited parking is available on-site and a commercial parking operator is adjacent on La Trobe Street.

The RSV has audio visual and seminar equipment available for use, including videoconferencing facilities. There is a commercial kitchen on the ground floor, suitable for your own use or by a caterer.

SERVICES AVAILABLE

We provide a number of services to ensure your event is a success. Some of the services we provide are:

- Event management
- Meeting venues
- Grants and awards administration
- Social media campaign management
- Broadcasting and video production
- Campaign management
- Recruitment of scientific panels
- Convening community engagement and deliberation processes where scientific work contributes to social, environmental, and economic impacts and benefits.

The Burke and Wills Room

Multi-functional space with adjoining kitchen.

Capacity:

Workshops	≤30 people
Dinners	≤60 people
Seminars, functions, catering, etc	≤80 people

The Von Mueller Room

Seminar room great for smaller meetings and seminars.

Capacity:

Meetings, seminars, etc	≤15 people

The Ellery Lecture Theatre

Raked seating great for lectures, presentations, and conferences.

Capacity:

Raked seating	≤110 people.

The Cudmore Library

A picturesque room great for larger meetings and seminars.

Capacity:

Meetings, seminars, etc	≤24 people

We are registered as a Certified Social Trader working for the benefit of Victorian communities, which makes our services eligible under the Victorian Government's Social Procurement Framework, as well as the social procurement guidelines of the governments of New South Wales and Queensland. Our certification also assures industries of our authenticity in building social procurement into services and supply chains. For more information and bookings please contact our Business Manager at **james@rsv.org.au** or on +61 3 9663 5259

SUPPORT VICTORIA'S SCIENCE SOCIETY

Founded in 1854, the Royal Society of Victoria (RSV) is our state's science society. We are a membership based, non-government organisation, advocating for the importance of science, technology, innovation, and building the skills for Victoria's future industries, governments, community leaders, and research superstars.

We manage the Inspiring Australia program in Victoria, meaningfully engaging communities with science. We encourage, profile, and celebrate the achievements of Victorian scientists through public lectures, awards, and prizes, which are supported by the donations and bequests to the RSV Science Foundation. Your donations allow us to continue the work we have been doing for Victoria for more than 160 years.

To make a donation, please fill in the form below and return to the Royal Society of Victoria, 8 La Trobe St, Melbourne VIC 3000. Alternatively, you can donate online at **rsv.org.au/support-the-rsv**

RSV 2023 FUNDRAISING CAMPAIGNS

The area of greatest need, as identified by the Society's Council	$
Inspiring Victoria – Community Science Engagement Program	$
Science Awards & Prizes	$
Science History & Heritage	$
Science for All - Citizen Science Programs	$
BioQuisitive Community Lab	$
The Phoenix School Program	$
The BrainSTEM Innovation Challenge	$
Australian Indigenous Astronomy	$
Science Victoria - Magazine and Web Content Production	$
TOTAL	**$**

Personal Details

Title: ____________ **Family Name:** ____________________

Given Names: (In Full) ____________________

Method of Payment (Select one below)

By submitting this form I acknowledge that the amount entered against 'TOTAL' donations above will be charged to my credit card.

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Card No. ____________________ **Expiry Date** ___ / _____

Name on Card: ____________________ **Signature:** ____________________

☐ **Cheque or Money Order**

I enclose my cheque or money order made out to The Royal Society of Victoria.

☐ **Electronic Funds Transfer (EFT)**

I have transferred my donation to the Royal Society of Victoria as follows:
BSB: 083-019 **Account No:** 51-515-2492
Account Name: The Royal Society of Victoria **Reference:** Your Surname and "donation"

Science Victoria
The Royal Society of Victoria
Wurundjeri Country
8 La Trobe Street, Melbourne, VIC 3000

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