Overlooked: Western Australia's Place in the Universe

[Theme Music: Planets Pianos by Bridget Turner]

Sarah Tout
Hello and welcome to the Geoffrey Bolton Lecture 2023. The Geoffrey Bolton Lecture is an annual celebration of the insight, the stories and the value of archives. This year's lecture comes once again in the form of a podcast, one that explores the theme Western Australia's place in the universe. My name is Sarah Tout and I present you with Overlooked, a story of three parts that each illustrate a different shape of Western Australia's identity.

In these three stories, we will see how, here in WA, our place in the universe is informed as much by how left out we are, and how removed we are from the rest of the universe, as it is by how deeply connected we are to it. It is this tension that unites each of our stories, and gives immense meaning to considering Western Australia's place: literally in our land, our skies, our stars, and our place metaphorically, as we consider our people, their role in WA's contribution to space exploration, and our cultural psyche.

We begin with land. With country. I acknowledge that this podcast has been produced and recorded on Whadjuk Boodjar, the name of this land given to it by a people who have cared for and been its custodian for over 65, 000 years and who have developed an intricate cosmology of the stars above it. As there are myriad First Nations in Western Australia, there is more than one story or understanding of our sky.

From Djinda Dreaming to the Dark Emu, the stars inform so much from navigation and songlines to calendars and seasons. It is important to acknowledge and remember this deep, profound connection to our sky, and indeed the land it overlooks, as we explore the following stories of Western Australia's place in the universe.

We are about to meet Dr. Natasha Hurley-Walker, Senior Lecturer and Radio Astronomer at ICRA (The International Centre for Radio Astronomy Research) at Curtin University. Her work is extraordinary. In a way, she is both looking at, and listening to, the edges of the universe. By looking for and recording information transmitted by slow moving and far travelling light, radio waves, Natasha Hurley-Walker is discovering new and radical truths about our universe.

She works in WA because of where we are in the world and what we have access to, ironically, precisely because we are so far away. Come with us as Natasha Hurley Walker takes us into her world for this lecture story that helps us see what she can see.

Natasha Hurley-Walker
It's summer. You've gone camping with friends and found the perfect remote spot, pitched your tents, stoked a small fire, brought out the camping chairs, and you're enjoying the serenity as the sun sets and the night falls. Amidst the warmth of jokes and chat with your friends, the fire settles and dims. And as the embers fade, the stars above become clear to you. What a sight! Here in Western Australia, we are blessed with one of the most beautiful skies in the world.

The very centre of our Milky Way galaxy passes directly overhead. The Indigenous constellation, the Dark Emu, maps the dust clouds that obscure the light of a hundred billion stars. We might be used

to thinking of those stars as fixed and unchanging, but change they do. You squint at the Pleiades, known by almost all cultures across the world as the Seven Sisters.

You can only just make out six stars. Where's the seventh? Well, the story of the Seven Sisters is older than the language you're asking the question in. Over 10, 000 years ago, there were seven sisters, but motion in that cluster of stars has brought two of them so close together that now we can only make out six.

And yet, the name remains. With a tinny in hand and one of the best views of the sky in the world, you might be thinking, what could beat this? And you'd be right!

Here in WA, we're building one of the largest telescopes in the world. That's because not only do we have a great view in visible light, we also have a brilliant view in radio light.

With the kind and enthusiastic agreement of the Wajarri Yamaji people, radio astronomers have established Inyarrimanha Ilgari Bundara: our Murchison radio-astronomy observatory. This radio-quiet region is one of the best in the world for tuning in to the faintest cosmic signals. I have worked for over 10 years with the Murchison Widefield Array, one of the first telescopes operational at the observatory, making cosmic radio pictures.

And I've picked up some signs of change in our skies. I discovered the remains of an exploded star, a supernova remnant, appearing like a brilliant spherical soap bubble in our southern sky. My calculations suggest it exploded just 9, 000 years ago, so the supernova that caused it would have been visible to the First Australians, and maybe there are still stories out there that reflect that guest star.

Gazing up at that beautiful vista, it might surprise you to know that space can change even faster than over those thousands of years. Well, it certainly surprised me. In 2020, I was awarded an Australian Research Council Future Fellowship, a large national grant that gave me academic freedom to work on the research topics that I found most compelling.

But, as I'm sure you remember, 2020 was a bit of a strange year and we were put through the collective emotional and mental challenge of the COVID 19 pandemic. I decided that rather than write long, focused papers or continue old research projects, I would instead use that year to try many different projects. Throw things at the wall. See what stuck.

One of those ideas was to try looking at observations of our Milky Way in radio light and compare the differences between one month and the next. If I subtracted one observation from another, all the things that stayed constant should disappear and we'd be left with only the things that changed.

Now, this is a bit of a silly idea because the received wisdom is that, at the radio frequencies I was using, nothing would change. There simply isn't expected to be anything out there that would behave like this. I was in a creative mood, so with the help of an enthusiastic final year undergraduate student, Tyrone O'Doherty, we gave the experiment a go. And wouldn't you know, it worked!

Data from 2018 showed the unthinkable. A very bright source, brighter than anything else in that patch of sky, that was on in March and then off in June. And when Tyrone moved to another group to pursue a PhD in something slightly less inexplicable, I started delving deeper into the data.

I found that the source was not only changing between months, it was changing between minutes. Every 18 minutes, the source emitted a burst of radio waves lasting a whole minute, and then repeated this like clockwork. But when we looked at it in current data, we could no longer see it. It seemed we'd missed the fireworks.

For three months in 2018, this cosmic clock was pulsing. But since then it had gone silent. We only found it by searching our archives. So thank goodness we had saved that data. Despite this being an impossible signal, I formulated a plan to find more. In astronomy, there's never just one of anything. Even our own sun is just a star, and there are trillions out there.

We scanned the skies with the Murchison Widefield Array every three days for three months. And within weeks, we'd found another source, this time repeating every 22 minutes. Amazing! And just as inexplicable. Knowing the value of our archives, I searched through older data, and I kept finding the signal all the way back to 2013.

If we'd been looking at the data in just the right way, we would have found this source just two weeks after the observatory was built. At that point, I ran out of data. We simply didn't have the coverage in the Southern Hemisphere. Fortunately, the source is far enough north that it's also visible to my international collaborators.

And with some sleuthing, we found it all the way back to 2002 in data from the Giant Metrewave Radio Telescope in India. And we weren't finished yet. The very first digital radio telescope, the Very Large Array in New Mexico, first started recording data in 1976. We were able to trace our source all the way back to 1988.

And thanks to our careful curation and timing, we know exactly when that pulse arrived, down to the millisecond. When I was just five years old, snug abed in the UK, a burst of radio waves was recorded, and 34 years later I was staring at it in wonder. This phenomenon, incredibly bright radio signals appearing every 22 minutes, lasting 5 minutes each, coming from halfway across our galaxy, has no good physical explanation. We are still working on it.

So, if it's so phenomenal, why had people missed it? Well, our existing theories told us that there simply weren't any signals like this. So why look? It took a change in perspective, an attitude less concerned with what we already know, and instead simply freely exploring the space of possibilities.

This has parallels with the discovery of pulsars. These produce radio bursts on a much shorter timescale of seconds, and were discovered in 1967 by PhD student Jocelyn Bell. No one predicted they would exist, but she found them due to her deep familiarity with the data and her willingness to spend the time to explore it.

Which at the time meant reading literally kilometres of chart recorder paper and keeping an eye out for anything that looked unusual. You'd think that such a discovery would be worth a Nobel Prize or two, and it was. But not for Jocelyn Bell. The award went to her supervisor.

We make assumptions about who does science and whose work is important. Twenty years earlier, on our side of the world, the first female radio astronomer, Ruby Payne-Scott, discovered complex radio bursts from the sun. And she made critical technical advances in Australian radio astronomy, positioning us as a world leader in this new field. She did this while being paid 75 percent of the salaries of the men around her, and was forced to resign when she married. They even revoked her pension. She was a year younger than I am today.

What did we miss by forcing out such a brilliant researcher? Making assumptions, accepting without question the received wisdom and ignoring new possibilities, these things blind us to the underlying reality. Just like missing a new radio signal in space, it's easy to overlook the incredible historical contributions of female scientists who made amazing progress in an environment that was biased against them.

And while things have certainly improved, we keep telling the story that science is done by lone male geniuses. My amazing colleague, Dr. Kat Ross, analysed the curricula of Australian high school syllabuses and found that of the 145 scientists mentioned, only one was female. And yet, just in this short story, I've told you about several amazing female scientists.

Whose other voices are we missing? And how does that change who enters science and who stays? And what directions we explore? So, as you watch the sky wheel overhead and spot the occasional meteor and satellite, I encourage you to keep an open mind, value the contributions of diverse voices, and not to make assumptions.

Gold is waiting to be found in our archives, if only we choose to look.

Sarah Tout
Natasha Hurley-Walker, that was such an incredible description of the work that you do.

Natasha Hurley-Walker
Thank you.

Sarah Tout
I would love to ask you some questions based on the story that you've just shared with us. You mentioned so many interesting things in that ten minutes, but I want to start back with the little girl that you mentioned tucked up in bed in the UK: has space always been a fascination for you? How did that little girl end up a radio astronomer?

Natasha Hurley-Walker
That's a wonderful question. Um, yeah, I even worked out exactly when that radio burst would have appeared. Like I went and did the time conversion and it was about four o'clock in the morning when I was about five years old.

I think that part of the answer there is that when I was six years old we moved to the United States. I was in Houston, as in *Houston, we have a problem*, and I was very lucky to live near the Johnson Space Center where they ran a space camp. And we would like, you know, once a year go with our school as like a little trip, and seeing the space shuttle, and like the Saturn V. And at school – they were designing the International Space Station – so there was this nationwide campaign where all

the students were asked to come up with ideas of what people, astronauts, could explore while they were on the space station.

And I remember designing something out of shoeboxes and Lego. It was surprisingly tangible in the US at that time. Which is, you know, an exciting time to be involved: when you can get involved as a little kid, that does sort of fire up the passion. Of course also, big Star Trek fan. *[laughs]* And I wanted nothing more than to *boldly go*.

But once I got a little bit older I realised space is actually pretty big. I'm not really going to get very far if you go there, try and visit things directly. But we're also actually in this really kind universe. You know, it didn't have to be like this. Light could be really slow or instantaneous. But light travels at such a speed that right here, right now on Earth, we can look back in time to the very earliest moments of the universe, all the way up till now.

It's, it's like being an archaeologist, but every single layer is exposed. Being a palaeontologist and being able to go back, not just to like the Jurassic, but to the Cambrian explosion, right? You can see every single layer and it's all there for you to look at. You just have to look at it in the right way.

And I just think that's so incredibly fortunate. And I can't understand why more people don't go around looking up.

Sarah Tout
Well, indeed. And to break this down into a really granular, fundamental, perhaps – *my* level – understanding: anything that's happened in space that could be seen, that light is still moving through space?

Natasha Hurley-Walker
Yeah, including the moment when the universe began, including the moment when the stars first switched on, including the moment when matter and energy decoupled and the energy started flowing through the universe. That's the cosmic microwave background. And every galaxy and every star since then, somewhere, that light is still moving and you can capture it.

So I just find myself in this incredibly blessed… I'm just so happy to be in this career where I get to explore that. And of course, I don't just want to keep my discoveries to myself. I want to share them with people and I'm incredibly fortunate that I get to do this.

Sarah Tout
And you are exploring space.

Natasha Hurley-Walker
Yeah.

Sarah Tout
And you've found such an interesting way of doing it. Can you break down for us the difference between *looking* for this light with a telescope and what you do, which is a kind of *listening* for radio waves?

Natasha Hurley-Walker

Sure, so light is an electromagnetic spectrum, right? Light that we can see with our eyes is just a particular set of wavelengths between about 400 and 700 nanometers.

Those wavelengths can be longer and then they're in the infrared and we can't see them, or they can be shorter and then they're in the ultraviolet and bees can see them, but we can't. Um, and they can get shorter and shorter still: x rays, gamma rays. Or they can get longer and longer still: microwaves, and eventually radio waves.

So, I am using light to explore the universe. It's just a kind of light that passes harmlessly through you. And here on Earth we use electronic devices to communicate: computers, Wi-Fi, Bluetooth. All of those things work using radio waves.

So that is, of course, why we have to build our telescopes.very far away from people, so that we can pick up the - just unbelievably - faintest signals that come from space. Compared to signals from our mobile phones, which would otherwise completely drown them out.

Um, so this kind of technique of looking at the sky, radio astronomy, I got into it because when I was doing my undergraduate degree there was a summer program at Jodrell Bank Observatory, which is a famous observatory in the UK.

It has one of the largest steerable telescopes in the world. And my supervisor gave me a filing cabinet full of tapes, and those tapes contained all of the times that the Parkes Radio Telescope here in Australia had pointed at a little patch of sky that contained a globular cluster, which is a big dense cluster of stars, and said, *hey, look for something new in here*.

And I found a pulsar. Same as Jocelyn Bell, but of course it wasn't the *discovery* of pulsars, I just found one of several hundred known pulsars by that point. And that really, that really got me going, you know, that discovery was just the best thing I'd ever done. And it's gone from there.

Sarah Tout
And as I watch you describe that, I'm drawn to the idea of… it's like a little girl finding treasure.

Natasha Hurley-Walker
Yeah. Yeah.

Sarah Tout
And it's that exciting.

Natasha Hurley-Walker
It's just phenomenal. And I think, you know, it was one thing to go looking for a kind of object that people knew existed and had known about for, you know, nearly 50 years at that point.

It's unfathomably amazing, an honour and a privilege (and an excitement in my life) to have discovered something that – not only wasn't theoretically predicted to exist – but also we can't actually explain. Our models of how these sources should produce radio emission tell us that, as they slow down, and they emit more slowly, they should just stop, right? But this is *still* emitting radio waves.

Just last night we were observing it with a very powerful radio telescope and it was producing all sorts of exciting structure and polarisation and interesting behaviour. We have never seen anything like this and everyone around the world is just rushing to try and understand what's going on.

So to discover something entirely new, oh my goodness. It's just been the most wonderful experience.

Sarah Tout
And so it sounds like we're really on the brink of a new layer of understanding our universe. Because if we don't yet have a model of what we're observing and what it means, that means we're onto something brand new?

Natasha Hurley-Walker
That's right. That means there's something wrong with our theories. Because we never really get to the underlying reality, right?

In science: you propose a theory that explains your observations (or a hypothesis, more formally) and then you perform experiments. Or you take observations. In my case, I can't actually go and experiment on the universe. I just have to look in different places. And then whatever you see either proves or disproves whether your hypothesis is a good explanation of the data. It doesn't say that that is exactly what's going on.

I mean, Newton, for instance, came up with a very good law of gravitation that explained absolutely everything… until you get into the really subtle way in which mass bends light. And then Newton has nothing. But Einstein came along and refined that and improved that and that's what we use today: General Relativity.

So we have… I guess I find it an incredible quest that humankind is on. That we can get to better and better descriptions of the universe.

And to have found maybe a little oversimplification, a little typo here and there… that maybe we will then be able to take that knowledge and improve how we understand the universe? Yeah, it's, it's incredible. I'm really happy.

Sarah Tout
And I think this is touching again on one of the themes that we're exploring. Which is this idea of what's been overlooked. What hasn't been noticed. Which presupposes that these truths are there if we pay attention.

Natasha Hurley-Walker
Yeah.

Sarah Tout
I want to come back to an amazing astronomer who you've mentioned a few times, Jocelyn Bell. Now, can you tell us a bit more about why discovering pulsars was so incredible?

Natasha Hurley-Walker
Sure.

So I should say – formally now Dame Jocelyn Bell-Burnell, full name. But of course at the time *Jocelyn Bell, the PhD studen*t.

So what was quite incredible about that was: there was this very short time scale that those bursts were occurring on.

And that implies that the object that was making them was incredibly small. Basically, big objects make things that last longer and small objects make things that last only a short time.

But this was very odd because, at the time in the universe, there weren't known to be things that were sort of small *and* energetic. You could have big stars, you could have little planets. But neither of those things made the signal that she was seeing.

So what she had discovered was the signal of neutron stars.

So that's basically when a massive star, but not too massive (too massive stars turn into a black hole) but kind of maybe twice the mass of our sun ends its life, collapses down just like a figure skater kind of bringing in their arms. As all that mass collapses into one tiny little blob, it spins up really, really fast.

So our sun, for instance, rotates, um, oh my goodness I'm not a solar astronomer, once every few days? Oh my goodness, that's not quite right, but it's close enough.

If our sun were to collapse, it would start rotating once every minute. Right? It would just collapse down. So these big stars go from rotating, you know, once a day or once every half a day or something to rotating every second. And all that mass is crushed down into pure neutrons, which is just an incredibly weird state of matter, right?

And that was the only thing that could explain these rapid bursts of energy. So, By finding these, she was finding a new endpoint in stellar evolution, a new state of matter, and opening up an entire new study of particle physics. Just by looking for, you know, a little bit of scruff in some chart recorded data.

So that discovery had a lot of knock-on effects. Which we are still exploring now.

Sarah Tout
That's amazing. And I think that illustration of the figure skater is so comprehensible because yes a figure skater, arms out wide, spins a certain way. And as soon as they pull them in we can imagine them spinning much, much faster.

So that's what's going on with this star collapse. And that fast-spinning figure skater out there in the universe is a pulsar.

Natasha Hurley-Walker
Yeah, exactly.

Sarah Tout
And then what happens?

Natasha Hurley-Walker
Well, and then we expected them to just slowly slow down.
Just like your figure skater on ice, they kind of run out of momentum eventually. They have to, kind of, move their legs. But a pulsar doesn't have legs *[laughs]*…

And so we thought we understood pulsars, and we thought that once they spun once a minute-ish, that would be it. They would cease to produce radio waves. That's why nobody was looking.

And so I have found something that repeats just like a pulsar, very similar signatures in all the other ways, but it's spinning way too slowly and way too brightly.

These things are much more luminous than pulsars as well. So, fascinating.

Sarah Tout
Fascinating.

And what's a neutron star?

Natasha Hurley-Walker
It's a star that has collapsed so much that not only have the atoms been combined and squashed together, the protons and the electrons themselves have been squashed together to make neutrons.

There's just nothing left but neutrons. So no normal chemistry like hydrogen and carbon and oxygen, none of that exists anymore. Just pure neutrons. Typically, a neutron star has a mass of one and a half suns, like our sun, but one and a half times bigger, confined to an area the size of Perth, so about 10 kilometres across.

Sarah Tout
Wow. And yet, I was reading something like, if we took a sugar cube size of a neutron star –

Natasha Hurley-Walker
Yeah Mount Everest, typically. Yeah. You take a teaspoon, it weighs the same as Mount Everest. Something like that. Not that you could take a teaspoon because you'd be immediately squashed flat if you were anywhere near a neutron star, not to mention being also irradiated and fried by all of the radiation and magnetic fields and they're very energetic monsters.

Sarah Tout
Best observed from a distance.

Natasha Hurley-Walker
I agree.

Sarah Tout
And that's what you do. And so, is this one of the reasons you're working in Western Australia because of our distance from all the other things that might interfere with you being able to look and listen to the sky?

Natasha Hurley-Walker
Yeah, that's right. So, the establishment of the observatory here has allowed us to build these really, really sensitive telescopes. And also the telescopes can operate across a very wide range of frequencies.

So all these different electronic devices they use different frequencies. But your Bluetooth is not quite the same as your Wi-Fi is not quite the same as your digital TV is not quite the same as FM radio.

And that makes a cacophony across all of that radio spectrum. So we go somewhere remote and then all of the different signals across the different bands die down and then we can look at different frequencies in radio light. That's quite important because different astrophysical sources produce different signatures of these different frequencies.

So just trying to use a single frequency to explore the universe, it doesn't give you a complete picture.

So yeah we absolutely love it here.

And it's really with the support and help of the Wajarri Yamaji and the people of the Murchison region who do have to put up with some annoying constraints, like not using their mobile phones within a certain radius of the observatory.

Um, so it's been phenomenal working with them. And right now we are building the Square Kilometre Array at the same site. So this will be the world's most powerful radio telescope and we're building it here in Western Australia. So I'm hoping within the next 10 years I'll be using this to scan the skies.

Sarah Tout
Amazing. And what are you scanning them for? Are you looking for the origins of the universe, Natasha Hurley-Walker?

Natasha Hurley-Walker
Well, definitely there is a program to look for the Epoch of Realization, which is when the very first stars switched on in our universe.

Oddly, before the first stars switched on, the universe was dark. We call it the Dark Ages. Very hard to investigate the Dark Ages, because, no light. Um, once the stars switch on, then you start to get all sorts of interesting effects. And these low frequency telescopes can observe that epoch, which is exciting. But it's an unbelievably faint signal, so it's just kind of slightly out of reach of the telescopes that I work with at the moment.

So that's a very exciting program. And of course, I am going to pursue looking at these strange long-period objects that are doing inexplicable things.

But what I really love is that you always build a telescope to do certain things and then it ends up getting used for something completely different and makes a phenomenal new discovery that nobody could have predicted.

So that will be my favourite thing and I suspect that by the time I'm working with the SKA, it will be the new generation PhD students and postdoctoral researchers coming like through their undergraduate days now that will be making those discoveries and I am totally here to help and mentor and pass on the skills that I've learned.

Sarah Tout
Wonderful.

It sounds like a certain element of flexibility is required to have the humility to find the thing that we don't already understand, and a certain amount of leaving one's ego at the door?

Natasha Hurley-Walker
Yeah, and I think it also helps if you allow people to try lots of different things.

So I actually worked in– I did the pulsar study in my undergraduate. And then I did a completely different thing; I looked for the imprint of galaxy cluster gas on the cosmic microwave background with a high-frequency radio telescope in Cambridge. Then I moved here and I helped build the Murchison Widefield Array, which I then used to explore supermassive black holes and their life cycles.

And each of those projects gave me a different set of skills and a different way of looking at the data. It was almost my ignorance of what we would expect to see, plus the techniques that I developed, that allowed me to make this discovery. Because I was coming in with powerful new techniques, but I wasn't constrained by these theories that predicted that we wouldn't see anything.

And, like I say, I was in a creative mood. I wanted to see what would happen, and it turned out extremely well.

Sarah Tout
That's so wonderful.

And to come back to the idea that you mentioned earlier of women in this field: we have Dame Jocelyn Bell-Burnell, we have your colleague, Dr. Kat, and other women that you've mentioned… I'm curious as to if there's something specific about the way women look at the sky. Are we interpreting data differently?

Natasha Hurley-Walker
Maybe. I would be loathe to draw a general conclusion, right? In a way that would almost be a prejudice.

But I do think that women go through a different set of struggles in life. I have to say, particularly as a woman in physics, it's rare that a male colleague might –
Someone might comment, *oh, you're studying physics*, in that tone of voice. No one ever says that to men.

I also noticed a funny thing that I'm one of the shorter of my female colleagues and I'm quite tall. And I wonder if there's something about having that comment of, *oh, you're so tall* that gives you a little bit of a thick skin that allows you to get through the, *oh, you're studying physics?* phase.

So it's our backgrounds and our experiences and the expectations, perhaps, that society has on us. I don't think it's genetic. I think this is a cultural inculcation type thing. And also, I'm just horribly aware of how, um, we are not a particularly racially diverse grouping.

Our group is pretty good here in Perth, we're pretty good. But there are definitely biases across the world. And as you look into more and more senior levels, you do tend to see more *male, stale, pale*.

So there are certainly biases, and that is something that we have to fight against. I mean, one thing that I've always noticed is that if I'm in the room with a female colleague, she is probably amazing.

I can just make that assumption because she's probably had to fight that a little bit harder to be recognised, to be taken seriously. And that makes us maybe a little bit more passionate, a little bit more dedicated. I don't really want this to continue. I would really love it if science were more equal opportunities.

I would love it if the equal proportion of men and women in physics that I experienced when I started my PhD was the same thing now. But I look around and there are far fewer female colleagues that have made the full journey than there are male.

So there definitely are still biases. And I'd say that we would want to eliminate those biases and bring as many diverse voices as possible. Because it's that diversity that gives you the different perspectives, that gives you the different skills, that gives you the different ways of looking at the universe.

And that is how we make progress, not by all thinking and speaking and being and looking the same and coming in with exactly the same approach every time. You won't get anything interesting that way.

Sarah Tout
I want to come back to the idea of Western Australia and how we exist in, let's say, the constellation of different astronomical radio work that's happening internationally, because it's been a crucial part of your work to reach out to others, as you said before, observatories in New Mexico and in India to complete your picture of what you're looking for.

Can you illuminate for me a little bit, what's that international community like? What does it mean to reach out to New Mexico? Do they pick up the phone? Do they know what Western Australia is? How does that conversation come together? What's the culture like among radio astronomers internationally?

Natasha Hurley-Walker
That's a lovely question. So I think there are a few thousand of us across the whole world kind of grouped into concentrations of a few hundred here, a few hundred there.

So Perth now has one of the largest concentrations of radio astronomers. There's about 150 of us. There's, across the rest of the East Coast, there's about 150.

So that's it, you know, for radio astronomers in Australia. It's pretty small. But then you multiply that by the number of countries, in the US, the UK, the Netherlands: more population, more radio astronomers.

We get to know each other through conferences, through reading each other's work…

And reaching out is as simple as sending an email to a person and saying, *I really love that recent paper you wrote. Have you ever considered applying this technique to this data?* You know, or *we've just discovered this amazing source. I understand that you're the PI of this big survey program. Do you have any observations of this source in your data?* And it's a very friendly community. People are usually really happy to share their techniques, their data. Because honestly, there's so much science to do and there is not enough time. So any way in which we can work together, we can and we do.

Sarah Tout
Yes, that's wonderful. And it lends itself to suggesting that there is more of a collegiate than a competitive or, sort of, precious guarding of data.

Natasha Hurley-Walker
Yeah, I'd say within the international community, people are pretty, um, generous up to a point.

You know, we only have so much time. So if somebody asked you to do a big project for them, that wouldn't work. But if they asked to use your code, then you'd say *yeah, sure. Just put me on the paper. Great.*

The competitiveness I would say comes with the lack of funding generally for science in Australia.

In the OECD, we are one of the lowest performing countries in R&D and scientific research investment, and every dollar spent on research pays for itself. I know that I sound like I've been talking about very abstract things, but a recent analysis of the Murchison Widefield Array showed that it had brought basically four dollars of investment to Western Australia for dollar spent on the telescope.

So it paid for itself by a factor of four to one. That's an incredible ratio. And we could be doing that on a much grander scale if we, I'm not going to specifically name things I wouldn't invest in for sure, but we could pull back where funds are going from some areas and put a little bit more into research and it would really, really, really benefit Australia.

Sarah Tout
Something that is coming along is the Pawsey supercomputer. Can you tell us a bit about that and that's here in Western Australia and is that going to be used… by who?

Natasha Hurley-Walker
So, Pawsey has been absolutely essential to my work. The data that we take from these radio telescopes is phenomenally large and complicated and we have to perform a lot of very expensive computational operations in order to make pretty images or find cool repeating radio sources.

That is a very useful investment though for many other groups. So Pawsey is used by geologists, by meteorologists, by oil and gas, by agriculture, fisheries. Anybody who's looking to analyse large amounts of data has started a big project at the supercomputers there. So that's been of broad benefit and absolutely we will continue to use the Pawsey systems for the next decade or so.

The grand kind of eventual goal for radio astronomy at least is that there will be these things called regional centres for the Square Kilometre Array. So the amount of data we produce is quite absurd. It's like an entire internet's worth every minute or something absurd. So the idea with the regional centres is that you can dial in essentially, you know, connect with your computer from anywhere in the world and access the data close to where it was taken. You know, you bring your code to the data.

And so there will be eventually an Australian SKA regional centre, and whether that incorporates Pawsey or Pawsey runs that… that's all sort of – how you structure these things is a little bit, uh, TBD. But that's the eventual goal that people want to get to.

Sarah Tout
Amazing. Natasha, thank you so much for your time. I want to ask you, if people are listening to this at night time, if they went outside now and looked up what you ask them to consider? What would you ask them to look for?

Natasha Hurley-Walker
Oh, well, if you're listening in winter please do look for the Dark Emu. Because it is absolutely phenomenal. So June/July, it's directly overhead around sunset to midnight, and it basically looks like a huge emu with its legs swept back and its head pointing proudly towards the sky. And it's just phenomenal. I just love… I get an eerie sensation when I think about how many people would have looked at that emu and we're all still observing it today. It's been walking across the sky for tens of thousands of years. It's just beautiful.

Depending on the time of year, the planets are really beautiful down here. We have very clear horizons in Western Australia. This is not something to take for granted. Other countries have mountains or clouds; we have beautiful flat landscape and it's often clear.

So – you can check online – but you can often spot Mercury, the smallest planet that's closest to the sun, around sunrise or sunset. And that's amazing. You know, very few people in the world get to see Mercury and it's just casually here, you know, a few months a year you can, *oh, Mercury*. So yeah, I think those would be my top two picks.

Um, the Magellanic clouds are also really beautiful, and you can see those at most times of year. Summer's slightly better than winter for seeing the Magellanics, and they are dwarf galaxies that orbit around essentially the South Pole from our point of view. They're hundreds of thousands of light years, they look a little bit like clouds, um, but they actually each contain hundreds of thousands of stars.

And I love that we can see galaxies with our, with our naked eye. Like, that is a Southern Hemisphere special. You cannot see that in the Northern Hemisphere, so.

[music link: Planets Pianos Reprise by Bridget Turner]

Sarah Tout
It sounds like we're quite blessed to be in Western Australia.

Natasha Hurley-Walker
We really are, and that's why I'm here.

Sarah Tout
The insightful, the wonderful Dr. Natasha Hurley Walker. You can find out more about her work by looking up the International Centre for Radio Astronomy Research at Curtin University.

We move now to Chapter Two of this three-part podcast as we meet Paul Jones.

Paul knows a lot of stuff. He's the Secretary and the Heritage Coordinator at Perth Observatory. And they have had their telescopes pointed at the stars almost since the foundation stone was laid in 1896 under the oversight of the state's first government astronomer, William Ernest Cooke.

Perth Observatory, and the archives within it, hold almost as many tales as there are stars in the sky. When the observatory began operating almost 127 years ago, it had three main jobs: to contribute to weather monitoring and collate data about our tides, to survey land and to help accurately work out where in space we were…

Paul Jones
And, uh, the other very important thing was timekeeping. They established Western Standard Time and distributed it from even early in 1896. Cooke, the first government astronomer, had a number of ship's chronometers that he used to keep mean solar time and sidereal time.

And they had a theodolite, which, a transit theodolite, which he used to check the time against the rotation of the Earth.

Sarah Tout
Perth Observatory has played a pivotal role in our international understanding of space and even the laws of physics. For example, in 1922, scientists observing the Wallal Eclipse took measurements that helped prove Einstein's theory of general relativity, and NASA once commissioned reports from Perth Observatory for an international planet monitoring project.

Paul Jones
The main research telescope at the observatory was funded by NASA in a project that was run by Lowell Observatory around the world. And the project was to actually monitor the planets for NASA. It was called the Planetary Patrol Project and it was just continuous observations of the planets, which NASA – and it was all done by film, and then the film was sent back to the US – and they used it for their planetary exploration projects.

Sarah Tout
But long before we were considering launching expeditions into space, there was a stunning project underway internationally to collate a map of the stars of the Southern Hemisphere. I am most intrigued by this story, and it takes us to before World War I, and it illustrates how, not only did WA play a crucial role in mapping the stars of our hemisphere, but how these images were captured by staff. And, unsurprisingly, their names and their identity were almost completely lost.

Paul Jones
Well, they were very hidden. They never appeared on the official observatory records. In fact, when I first got there, one of the astronomers had produced a chart of all the people who'd worked at the observatory on a timeline and what period they worked for and what they did. And the ladies never appeared on that, because they weren't permanent employees.

But how it all came about was that Cooke, who did the meteorology and the timekeeping, he was also very keen to do astronomy. And the opportunity came up for Perth to replace Rio de Janeiro in the big international project, there were two parts to it –

Sarah Tout
Okay, so the first part was the Astrographic Project: to use hundreds if not thousands of photographs to capture what we could see.

Paul Jones
And so that was one part. Another part was called the Carte du Ciel, and that was going to record every star down to magnitude 14 and produce it in a photographic image. Not all the coordinates.

So, the Astrographic Project was going to measure the coordinates of every star, and the Carte du Ciel was just going to produce maps of the sky.

So, they did that by taking glass plates which were six inches square and they had the gelatine film on it. And so having taken each plate, they ended up – because each plate you could end up with, you know, seven or eight hundred stars on a plate, and they then had to be all measured, and their position computed. That's where the ladies came in.

Sarah Tout
The first was 16-year-old Prudence Valentine Williams, whose sister had married the assistant astronomer. These young women, these girls, were essential.

Paul Jones
They liked their ability to concentrate, their nimbleness with their fingers. (I'll explain what they did in a minute and why you need to be nimble.) And they had a lot more patience than the men.

So what the job was: they had a machine, which was called a micrometer. And it was like a little telescope mounted so you could move it on an X and Y axis. And the gelatine plates – before they were exposed on the telescope to get a picture of the stars – they're exposed to a grid and so you ended up with a grid on the photograph.

And so the ladies, before they actually started the project too, they had to accurately measure the position of what they called standard stars.

And I think, The Perth Observatory, they measured about 250 of them and they were spread such that there would be three or four of these standard stars in every plate that was taken so they knew a position that was very accurate and then the position of all the other stars could be worked out in relation to that.

So what the ladies had to do then is – through this little micrometer – look through it, and then they'd focus on one little square at a time. And the eyepiece had a cross hair in it, and they would move the cross hair across and get it on on each star and then call the measurement on the X and Y axis of the machine, and there would be another lady there who would be writing it all down. So each star would get an X and Y measurement.

And they also had to measure the intensity, or the brightness, of the star. And so they'd record the position of the star and its magnitude for, whatever, however many stars on the plate. And they might, so, there could be regularly be three or four hundred of these measurements.

So they'd have that all on a sheet and then they would have to do the computations to convert the X and Y axis to the actual position, the coordinates in the sky.

Sarah Tout
It strikes me that these women, and their enormous contribution, were as overlooked as the obscure stars they were mapping. The women had to advocate for decent pay, which they were able to achieve to some degree, but they were never made permanent, and they had to leave the institution when they married. And then came the Great War.

Paul Jones
Yes, yeah, the war comes. The war sort of finished it off. Yeah I think, interestingly, Prudence Williams left because her brother had been injured in the war. He'd come back injured and she left to look after him and was lost.

They're obviously… they were very talented women. And they were inaugural members of the WA Astronomical Society, and gave talks and all that.

So they weren't just clerical people doing a job. They had obviously learnt a lot of astronomy.

So, the WA Perth Observatory employed about 11 women over the period. And they measured about 940 plates on the Astrographic Project, and about, I think, something over 200, 000 star positions. *[laughs]* An astonishing body of work.

And they almost disappeared without trace, yeah.

Sarah Tout
I am so glad that traces of these women do remain, and they are forever imprinted in our maps of our sky, and in the formation of Western Australia as a significant contributor to our understanding of our galaxy, our stars.

By following their trace through the archives of Perth Observatory, we know their story. And it's just one of myriad stories held within the observatory, one that informs not just where we are in our universe, but who we are.

I want to end this podcast with a final story. Indeed, a picture book.

Julia Lawrinson is a writer. Normally, she's an author of novels and literature for young adults.

But earlier this year, Julia Lawrinson published her first picture book. One that explores Perth, the capital city of Western Australia, and our identity as the City of Light.

[music: Demake/Demaster by Alice Humphries]

In 1962, astronaut John Glenn was the first American to orbit the Earth on a voyage fittingly named Friendship 7. He was going to fly directly over Perth and Perth was ready to say hello.

In the 60s, Perth, Western Australia was not just far away from everywhere else, it felt far away. Impossibly far away. So when the city organised to leave all their lights on, to signal a greeting to the lonely astronaut, when he saw these lights, saw the message, and said hello back, something about this event, this era, this moment, changed our small city forever.

I wanted to ask Julia to take us back to Perth at this time, and we begin with why this story made sense to transform into a picture book.

Julia Lawrinson
It just works really well, I think, the poetry of the event is portrayed beautifully by the artist. So, Heather Potter and Mark Jackson who did the illustrations went back and found all these beautiful reference photos. I sent them a couple as well.

And I think they've just done a wonderful job of capturing just the slowness of the era, and the details actually in the illustrations make you slow down.

I think it's hard for us in this day where there's a lot of flights that you can get anywhere that are relatively cheap and frequent and safe.

And compared with what it was like in the 60s where you could not fly anywhere unless you were already fairly wealthy. It was a very, very expensive thing to do.

The only way to get here from anywhere else was by boat. If you're coming from Europe or Asia or those kinds of places. If you're coming from the Eastern States, you might want to drive. Which meant that coming to Perth was a huge undertaking: if you weren't already here or you didn't have a reason to be here, it was incredibly isolated and incredibly distant from the rest of the world in general.

And it was a very quiet place then. My father actually arrived off a boat from the UK a couple of years before 1962, and he and his sister just looked around and went, *where are all the people? [laughs]*

It was a very, very quiet place and very provincial, I think, and conservative and, I think it felt isolated to the people who are living here.

Sarah Tout
Mm. And those words *provincial* and *conservative*, they also kind of – if we're thinking about the 60s as this time of massive interest in space and technology and advancement – it didn't really feel like a lot of that was happening in Perth.

Julia Lawrinson
No, it didn't feel like that, but it actually was happening. And I think this is one of the things that John Glenn enabled people from WA to understand is actually we can do some stuff here.

So, in partnership with the States, building the space stations at Muchea, and Carnarvon later on, was absolutely groundbreaking. So we were using amazingly advanced technology here in sleepy little Western Australia.

Sarah Tout
Yeah, in part because we are so isolated, right?

Julia Lawrinson
Exactly. And because of the – I think it was just the orbit of the earth – it just happened to be that this spaceship was going to be going above Western Australia, happened to be a summer night, happened to be that it was very likely going to be a clear summer night, so that people would be able to see this amazing thing happening above them.

Sarah Tout
And tell us more about the idea to turn the lights on.

Julia Lawrinson
So the idea to turn the lights on came actually from a journalist at The West Australian, who was just taken with this romantic idea about this person being in space… alone up there and wanting to send some kind of signal. And this romanticism really appealed to the people of Perth.

So people were really, really enthusiastic about it. In those days, they used to turn off the street lights, I think at about 10:30 at night. So they knew that it was going to be happening at night. And so the journalist went to the mayor who was very conscious of ratepayers money, said, *no, we're not leaving the lights on. Don't be foolish.*

He later claimed he was taken out of context and that he wasn't quite as sneering uh, as he was made out to be. So the journalist went to The Premier at the time (Premier Brand) and said, *Hey, how about it?* And Premier Brand went, *Yep, let's get on it,* and gave permission for the lights to be left on at night.

And from then there was this huge community movement. And, again, this is the time where we did actually have a couple of newspapers, but The West Australian was the thing that everybody read and it was delivered to a lot of people's homes in the morning.

And so this whipped up this excitement amongst the kids at the time. So if you speak to adults who were children then, they remember chiefly being allowed to stay up at night. So that was, that was a big draw card for them.

Um, and so they were encouraged to be creative about how they got the attention of this person floating above them in space. So they hung white sheets from clotheslines. They lit torches, they lit fires, they left the porch lights on, they did everything they possibly could to make Perth seem bright and visible.

There was a lot of scepticism from other people going, *uh, we don't think that they'll be able to be seen anyway, doesn't matter what they do, and it's a waste of money and it's a waste of energy…* all of those kinds of things.

But in the end, the, the light-leaver-on-ers prevailed. So, yeah, so they did leave the lights on and John Glenn says, and I've got the quote at the end of the book, um, *thank everyone for leaving the lights on. They show up very well.*

And it was an amazing thing for Perth to be reported in the news in other parts of the world because it kept its lights on.

Sarah Tout
Yeah. And we were seen.

Julia Lawrinson
We were seen. Absolutely. Yeah. And that was such a rare thing.

And I suspect it probably set the groundwork, I think, for WA to become a bit more connected to the rest of the world.

But it also reflected that move away from Britain and towards the States in terms of our partnerships and where we were looking and this kind of idea of looking at the night sky as this beacon of optimism was really strong, I think, at this time.

Sarah Tout
Tell me more about that, because if you've dedicated time to creating this story into a picture book, I imagine there's a number of ways the themes resonate with you. Tell me more about this optimism and this hope and what grabs you about this story.

Julia Lawrinson
I remember being at kindergarten. I was actually a very shy child, so I really, really hated kindergarten. One of the things I loved about it was the book corner.

So I remember that. And I also remember a puzzle, which was a rocket ship, right?

So this is the early 70s. So this is also – I was growing up sort of post, um, or coming to consciousness I guess, post people landing on the moon.

So it was still, even then in the 70s, this idea that you could go into space and you didn't know what was there. And I think it fed into also the idea of UFOs, which were huge in the 70s.

For people who weren't alive then, it's very hard to imagine how captivated children were by the idea of being able to go into space. But also other beings, perhaps being in space, wanting to communicate with us.

And I do think that was triggered off by the events described in City of Light. Like, I think there was a continuum of a sense of possibility and a sense of communicating with people who are different to us.

So the other consequence of people from Perth not traveling was that I didn't know anybody when I was a child who'd been to the US. Like, it just wasn't a thing that anybody I knew ever did.

Some people, and even not very many, went to the UK because a lot of people in the suburb where I grew up came from the UK, and so some of them who were better off went *home* for holidays sometimes. But there just wasn't this experience of other people from other places in Perth, unless they were migrating here.

You know, we just didn't have a huge tourism industry. I think it was later in the 70s where American sailors started coming to dock in Fremantle and were a bit more of a presence, but this fascination with the other and what's different and wanting to be able to communicate across a divide, I think was really a hugely important thing for kids imaginations in the 70s.

Sarah Tout
Yeah. It's about the idea of what is possible.

Julia Lawrinson
Yes. And everybody is equally insignificant. You know, if you're looking into space all of the things that dominate primary school life like, you know, social status and all of those kinds of things, that all drops away when you're looking together to the stars.

Sarah Tout
Something I will ask you about is your research process for this story, because you had a lot to learn and a lot to find.

Julia Lawrinson
Yes. The first place I went, which is the first place I always go, is the library. Now I know that there are online repositories for things and they are helpful to an extent. But honestly, nothing beats going into the State Library and browsing the shelves.

So the State Records Office had a blog, which has since disappeared sadly, but it had a blog which had some great information about the event. So I used that and I sent that to the publisher as well because that was the first thing she was asking me: she wanted more detail about what had happened. Because the first draft that I'd written was very much… it was much more whimsical.

And she said, *no, I want to ground this in what happened and how it happened. Even though it's a book for kids, we want the adults to appreciate it as well.* And so to drop in some of that detail about the newspapermen and things like that.

So I went to the microfiche because, as you know, the West Australian newspapers aren't digitised. (Well, most of them aren't digitised.) So I spent a long time looking at the microfiche and writing notes about when things happened. And I went to the shelves of the history of Perth and that's where I came across Jenny Gregory's City of Light.

I'd probably found it in the catalog search as well, but that was probably the most useful research. And of course, she had spent a lot of time in the State Records Office getting the information that went to that. And in fact, The West Australian in conjunction with the Perth Museum – so they did the 50th year anniversary spread and event, and the information that they used there came from Jenny Gregory's City of Light book.

So I guess that's a nice way of how that initial research ends up really having a huge impact beyond the initial commemorative book called City of Light. It goes on to inform a whole pile of other publications.

Sarah Tout
Julia Lawrinson and the ripples of significance and stories of archives, and a pivotal moment of Perth's history, and formation of identity, as captured in her book City of Light.

[music: Distance by Erasers]

It never ceases to amaze me what we can find if we only choose to look. Be that in archives, in our stars, or in ourselves. Orbiting each of our stories today, there has been a theme that information, meaningful insight and connection – that truth – may all come when we look, listen, and include that which has otherwise been overlooked.

We have heard also how to be left out is to have a particular vantage point, and perhaps a surprising advantage. Whether it's a source emitting radio waves in our vast skies overhead, the potential and skills of teenage women in the early 20th century, or the paradox of why being far away, one of the most isolated and removed places in the world, It's precisely what connects us, allows us access, and makes us important.

When we slow down, suspend our assumptions, when we look, we can learn. We can grow. We can become. We can see. We can be seen.

Thank you for listening to Overlooked: Western Australia's Place in the Universe.

This has been the Geoffrey Bolton Lecture for 2023. Produced and recorded by myself, Sarah Tout, together with the State Records Office of WA.

Additional production and recordings by Marnie Richardson. This podcast was edited and mixed by myself and Adrian Sardi, and mastered by Sardi at Sugarland Studios. Thanks to Natasha Hurley-Walker, Paul Jones and Julia Lawrinson. Her book City of Light was published in 2023 by Wild Dog Books.

This podcast features music by Alice Humphries and Erasers, with additional original compositions by Bridget Turner.

For more information and podcasts of the Geoffrey Bolton Lecture, please head online to the website of the State Records Office of WA.

Julia Lawrinson (reads an excerpt from City of Light)
Here we are, in the place where we live, a city called Perth, Western Australia, the world, the universe.

Perth is small, Western Australia is big. The world is bigger, the universe is biggest.

He's going to fly over the place where we live at night on February the 20th, 1962.

We'll be able to see a tiny light, and we'll know that it's him.

But will he know we're here?