AT: Welcome to the infinite women podcast. I'm your host, Allison Tyra. And today I'm joined by Dr. Elizabeth Mahoney, a research scientist at CSIRO to talk about Australian astronomer Ruby Payne-Scott. So if you could start by telling us what she's best known for?

EM: Ruby is best known for really being one of the pioneers of the field of radio astronomy. So in particular, she was one of the developers of the field of radio astronomy in general. And that was largely based from her experience as working with radar during the Second World War. So once the war was finished, they then turned their eyes to the sky, and started to make discoveries about radio emission that was coming from space.

AT: All right, now, for those of us without science degrees, when you say words like radio physics and radio astronomy, what does that mean?

EM: Yeah, so radio astronomy, in particular, it's a relatively new field. I think people have been studying astronomy and studying the stars for as long as we can remember, since ancient civilizations. So radio astronomy is really about doing that, but using radio waves. So just using the radio part of the electromagnetic spectrum, and receiving that information. And that can tell us very different properties of stars, galaxies, our sun, and everything out there. So a lot of what she was doing was building telescopes, and really getting her hands dirty. She was doing it, required a really strong background in mathematics, in science, and engineering. So Ruby was part of a team, and her role in this team, she was an excellent mathematician and scientist. She was really strong in the physics, she was top of her class at university, she was one of the first women to complete a master's degree in Australia, which at the time was the highest qualification a woman could have. When she started the field of radio astronomy, there was a lot of hard work, she was climbing up ladders, putting antennas on roofs, and building a telescope to look over the sea cliffs in Sydney. And then a lot of the work was understanding the signals that those antennas received, and really having that foundation of mathematics and science, to know what she was looking for, and able to turn that into really interesting scientific results.

AT: So she got her Master of Science in 1936 in physics at the University of Sydney, and she was only the third woman to graduate from that program. And then she went and was a physicist at the Cancer Research Institute for a couple years, but then the project closed down, and she unfortunately discovered that there were just really no job opportunities for a woman in her field. And so, like a lot of women that I've heard about, she became a teacher, but then a job opened up at the Australian Wireless Amalgamated, which was like a huge company that ran all the wireless services in Australia. And it was one of the major employers of physicists, and so she became the first woman that they hired in a research capacity. So even before she ended up at CSIRO, she was doing some interesting work that would have been unusual for a woman at that time.

EM: Yeah, that's exactly right. I think at the time, as you said, it was quite typical for the women who did have an interest in science and math to be almost kind of forced into a teaching career because there was such limited options. But Ruby was able to get a job with AWA. And from that, I think that really launched her career to then work with radar during the Second World War, and then from that knowledge, then turn that into a field of radio astronomy.

AT: Well, and even at AWA, she was actually originally hired as a librarian in 1939. But she basically just expanded her role. So she's like editing their journal, she got involved in some of the research work, and I don't know how much she just sort of nudged her way into a full-time research position.

EM: Ruby has got a reputation of being quite a strong character. She was very intelligent. And she knew what she wanted, she knew what her interests were. I think she wasn't someone who was afraid to go for what she

wanted by by all accounts, which again, I think at that time, it probably sets her apart from maybe other women of that era. And potentially, even women today sometimes really struggle in that role.

AT: And so when she switched to working for what was then called CSIR, what was the impact? Like, how did this change science?

EM: So Ruby built these telescopes, and she used these to observe the sun. There were a few hints that there was this extra radio noise that was being observed. And actually, a couple of people noticed this during the war, using their radar technology, that they noticed there was this excess noise that appeared during the daytime and went away at nighttime. And so they started to piece together this knowledge that this extra radiation, the radio frequencies was coming from the sun. Ruby was able to build a new type of telescope. So she built what we call a radio interferometer. And that combines the radio light effectively, in a way that allowed her to pinpoint exactly where the radio emission was coming from, from the sun. And by being able to pinpoint exactly where the radio emission was coming from, it opened up a new area of physics, because it meant that the emission, what was causing this radio emission, must be a different emission mechanism, or basically a different way of producing the radiation than was first thought.

AT: And so how did working with radar on Earth, transition into the work that she did with outer space? Because as we've discussed, she didn't have an astronomy background, she was very much a physicist. And so how did she end up looking up, I guess?

EM: Yeah, I think a lot of that was just really being in the right place at the right time, and knowing how to take that opportunity that was that was given to them. So Ruby and the team that was led by someone called Joe Pawsey, at the end of the war, they built up this enormous amount of expertise in understanding radar, and radio emission, and so on. And then, of course, when the war ended, it was not immediately obvious how they could use that expertise. And so I think it was really by having this knowledge and this deep understanding of what they were seeing in terms of the noise. So they kind of knew at the time that there was excess radio noise or excess radio signals coming from space. So they're aware that in the 1920s and 1930s was the first detection of radio emission coming from space, and that was led by Jansky out of Bell Labs in the US. So they knew about that, they knew that was something out there. And then during the war, they heard these kind of rumors that some of the radar technology they were working on had detected excess noise, they didn't really understand. So at that time, it took a lot of foresight, to say, “look, we've got this group who've built a huge set of expertise in radio technology. And, now we don't need to worry so much about radar anymore. What else can we look at?” And that's when they decided to further investigate these excess noise and these excess signals they were seeing, and kind of design experiments to build a telescope, point their radar technology at the sun, and see if they could measure exactly where that radio signal was coming from and try and understand better what was causing it.

AT: And so what did she find when they pointed their telescopes at the sun?

EM: They did detect excess noise, they knew that this radio emission was coming from the sun. But the real step forward, and I think the first real launch of radio astronomy as a field of astrophysics in its own right, was the detection of exactly where on the sun that the radio emission was coming from. Ruby and her team were able to do that by using their radar technology to build what we call a radio interferometer. So they built this new antenna on the edge of the cliff in Sydney. And so that was able to detect the radio waves coming directly from the sun, so light from the sun would hit the antenna, but it would also at the same time be reflected off the ocean. And that would mean that the light that they were detecting traveled to slightly different distances. And when you combine those wave fronts, you formed an interference pattern. And so that enabled them to be able

to pinpoint exactly where on the sun the radio emission was coming from. So Ruby and her team determined that this emission was coming from sunspots or different categories of what we now call solar bursts. And by comparing with what she detected, with what optical astronomers knew about what the surface of the sun looked like, that there were these dark spots that they called hotspots. She was able to also, from those measurements, determine that there was some really extreme physics going on in these regions of the sun that wasn't really known about before.

AT: So you mentioned an interferometer. And my understanding is that she also led the research to design, construct, and use something called a swept lobe interferometer that enabled them to image the sun 25 times a second and basically make like a movie where people could watch solar bursts happening.

EM: That's exactly right. It was the next step beyond what we call the cliff interferometer, which is the experiment I described earlier. And as you said, that allowed them to take lots of images and basically track that interference pattern as the sun moved across the sky.

AT: And so the difference between as we're talking about radio astronomy and optical astronomy, where you're just looking at the thing, this sounds like it's more to do with, I want to say like documentation, like recording what's happening. So were the optical astronomers not able to have that same sort of capturing what was going on to review and share the data?

EM: Yeah. The optical astronomers were absolutely able to use their telescopes to see similar things. But I think where the new science came from was the fact that in the radio, it was telling us new information and it was telling us different information than what we could observe in the optical. And that's still very relevant in astronomy today. If you have an optical telescope, even if you look at Milky Way in the night sky, if a radio telescope had a view piece that you could see, the Milky Way would look very different in the radio. And it's just because it's different physics and different processes that are causing the emission to occur at different frequencies. So in the optical light, what we're seeing is all the stars, basically the combined light of all the stars in the galaxy. In the radio, you're measuring different types of phenomenon. So the radio, for example, is very good at picking out regions of really intense magnetic field. Because that can cause a different radiation or emission mechanism that radiates at radio frequencies.

AT: Okay, so it's just like when we're talking about like medicine, an ultrasound can tell you stuff, an X-ray can tell you stuff, but you still want someone who can actually come in and look at what is going on.

EM: Yeah, exactly. So you really want someone to be able to piece those pieces together. That's what Ruby was able to do with the radio data she was receiving. She actually contacted people who were working at Mount Stromlo Observatory in Canberra. And it was through that collaboration that she was able to determine that the location where the radio emission was coming from, corresponded to where in optical images they saw these dark spots on the surface of the sun.

AT: Now, while she was clearly doing really impressive work that I barely understand, which always makes it seem more impressive, one of the things that she is really remembered for today is the fact that she was forced out of her career, essentially. First, when it was revealed that she was married, because she'd actually been married like most of the time that she'd been working at CSIR, but she'd hidden it because there was this nasty little thing called the marriage bar that restricted women's positions and advancement opportunities. And I think she also lost her pension. Like there were all of these penalties, essentially, if women who were working for the government, specifically, I'm sure this was in the private sector as well, but the fact that this was government policy is still just insane to me. But anyway, so she was married for I think it was something like

seven years. And she and her husband just hid the fact that they were married and pretended that they were living in sin. And God love him for going along with that ruse. That's a really supportive husband. The guy who will pretend not to be your husband because he doesn't want to mess up your career. So first it came out that she was married. The bosses found out. And I think this was 1950. They basically asked her, like, “are you married?” And she had to admit it. Like I said, she lost her pension. She was reduced to temporary employee status instead of permanent. She also got a sarcastic handwritten note placed in her personnel file that no disciplinary action of any kind was to be applied because they wanted her employment to continue. And so they knew she was valuable. They knew they wanted to keep her. And you do have to wonder, like, how much of this is like her bosses did what they could, it kind of seems like, because they didn't make this rule. This was coming from, I assume, Parliament, since it was federal government and they had no control over this. You know, they did want to keep her. They just were bound by these rules. So when we're talking about like, oh, you know, God love her husband. But you also have to assume that, you know, her bosses didn't want to penalize her necessarily. Like, I can't speak for any of those men, but their hands very much were tied once she was exposed as a married woman.

EM: Yeah, I think that's exactly right. It seems that her immediate bosses and the team that she was working with, it was probably a bit of an open secret that she was married. But she was so well respected within the team that everyone was happy to go along and basically not dob her into the higher-ups who had to probably enforce this government policy. It's a real shame that eventually she did get found out ,as it was, because I think it really cut her scientific career short. And I always wonder what other discoveries and what other things she would have achieved if she was in a position more like today, where she would have been able to continue her research and raise a family at the same time. It still astounds me when you think of it, it's really not that long ago, like this was in the 1950s, well within living memory.

AT: One of the things that she herself pointed out, because we have the documentation and the letters and everything that she wrote, but she was pointing out, like “all the married women research officers I have met feel that their classification as temporary puts them at a considerable psychological disadvantage in their work. I told you my story not in order to implicate you in any way, but to demonstrate that the present procedure is ridiculous and can lead to ridiculous results.” And so she did stay, like she did want to keep doing the work, even with all of these disincentives. But unfortunately, because maternity leave was not a thing in the 1950s, and it's worth mentioning that the marriage bar that we're talking about did continue on until 1966. So this is happening to her in 1950, and she was by no means the first or last woman who was having to deal with this. But the reason that she did end up finally completely leaving CSIR was when she had her son, who interestingly, both of her kids are what I would say are really high achievers. So her son, Peter G. Hall, became a really well known mathematician and professor, and her daughter Fiona Hall is like this internationally renowned artist. So, I will say that I'm bummed that she had to give up her career, but the kids turned out really well as far as I know.

EM: Yeah, she's really left a great legacy, not only in terms of her scientific legacy, which for such a relatively short scientific career is amazing. But I get the impression that she really embraced motherhood as well, and obviously raised two amazing human beings who've achieved so much in their lives as well.

AT: I'm aware that I can come off sounding like, “she gave up doing this amazing work to become a mom.” And that's never the sentiment that I mean to express because looking at this situation, like, yeah, she was doing really interesting work that she clearly found fascinating, but at the same time, they treated her badly. I don't think even CSIRO would argue that they treated her badly. And even, I assume, her bosses recognized that, this is not the way to treat people that you want to continue employing. Again, as far as I know, everything I've read about her husband, Bill Hall, they had a really lovely relationship. And it does seem like when you have

the choice between doing work that you love, but in an organization where you are not going to be treated fairly. And you're very aware of this because while she was in the organization, she did a lot to protest gender inequality, including, I love this, she protest smoked because men were allowed to smoke and the women weren't. But even before it came out that she was married, she was protesting, unequal pay and other conditions. She was very aware. It wasn't just the marriage bar. I could honestly just see her saying, “you know what, I'm sick of this.” And apart from all the practical concerns about, “I'd need childcare and I'd be away from my kids” and all of that. I can honestly see her just saying, “you know what, I don't want to go to work every day in a place where I'm being treated like this.”

EM: Yeah, and that would be a very fair thing to say, because I think you're right. She definitely was a really strong advocate for women in science and for women having careers that they wanted and that they love.

There's an anecdote that, per the dress code, women weren't allowed to wear pants. They were forced to wear skirts. And Ruby just straight up said, “I'm not going up on a ladder with a skirt on. We're climbing up on ladders, up on aerials every day. This is absurd.

EW: Which really is quite a reasonable and sensible decision. I think that just highlights how unusual Ruby was at the time that she was in a role where she was climbing up ladders and putting antennas on roofs and things like that. I suspect that the people who made these rules probably didn't really ever consider that a woman would be in that kind of role.

AT: I just love that she's pointing out how these things are, ridiculous and absurd and pointing out like, “this is just dumb. This doesn't make any sense. We're supposed to be scientists.”

EM: “This is ridiculous and will lead to ridiculous results.” I love that. I love that letter.

AT: Even shortly after she was hired, this is about three months after she was appointed in 1941, the head of the division wrote about her. “Well, she's a bit loud and we don't think she's quite what we want, and she may be a bit unstable, but we'll let her continue and see how she works out.” And I'm very curious how much of that perception was just because she was a woman acting the same way that would be perfectly, not worth commenting on in a man.

EM: Exactly. That was what I was going to ask. I wonder how many comments like that were made on men's files at the time.

AT: So she's often held up as this example of “see what sexism does,” like “see what we lose when you don't treat people fairly.” And I will say from everything I've heard, CSIRO has gotten significantly better. And in 2008, they even established the Ruby Payne-Scott Award, which supports researchers who have taken extended leave for parenting or other family obligations, which I believe you're a recipient of. So could you speak to why programs like that are important, not just for individuals, but also for the organization? Because we've talked about how CSIR lost this amazing scientist because they refused to be accommodating. And who knows what more she might have accomplished if they had been a little more flexible, been a little fairer? Well, been a lot fairer.

EM: Yeah, I'm definitely pleased that CSIRO has come a long way since Ruby's time. So I've been a recipient of the Payne-Scott Award twice after the birth of each of my two children. So for both of them, I took a period of parental leave and in coming back to work, having that extra little bit of funding was really helpful in just really getting back into the swing of things. So it's designed to help you re-establish your career and to help try and

compensate a little bit from taking a long period of time off work. So, for example, one of the things that I was able to use this funding for was to organize a small workshop for my team and my collaboration. And I was able to do it, hosting it basically, in Sydney, in my home city, which meant that I had a bit of extra funding to get people to come to me. So I could come to work during the day and have this conference, have this meeting, but then go home and look after my children at night, which at the time was something that was important to me to be able to do, rather than having to travel across the other side of the world or to a different location for a week or an extended period.

AT: It is always encouraging to see initiatives like this. So, for example, I know in sports, there's an elite athlete named Allyson Felix, who, shall we say, was not treated fairly by her sponsor Nike, when it came out that she was pregnant. And I believe there was even a situation where she was told to know her place. And so she launched her own line of athletic footwear and declared, “I know my place,” and I love her. But one of the things that she's done is basically gotten funding to support women athletes to take their kids with them when they have to travel for these competitions, where they're going to be away for a long time and having to travel internationally. And that fact that if you want parents to continue to be engaged in the work where they are objectively valuable, then you need to support the parent as well as the employee, both sides of the person.

EM: Yeah, that's absolutely 100% right. And that's another good example of what this funding can be used for. In fact, after the birth of my first child, I used the Ruby Payne-Scott funding that I was awarded to go and continue or re-establish a collaboration with a colleague based at Oxford University in the UK. So this was a great opportunity for me to go and visit, reconnect with colleagues overseas. We had planned what papers we were going to write, what we were going to work on, and actually got funding for my daughter and my family to travel with me. And I would go to work during the day and they could cover childcare costs and things like that.

AT: As someone who comes from a country where paid maternity leave is still, *still* not required for employers to offer, one of the benefits that you had as well being here in Australia is that you actually had paid maternity leave, which Ruby Payne-Scott did not have access to. And that is, I guess, the straw that broke the camel's back, so to speak.

EM: Yeah, that's exactly right. I think even after being demoted to a temporary status, so Ruby did continue working at CSIR or CSIRO, even once she was demoted to a temporary employee by CSIRO. And it was really, as you said earlier, when she became pregnant, that she was forced to make that decision of, “do I want to take time off to raise my child?” I mean, there was no option of maternity leave, so I don't know if it was really much of a choice. She is definitely one of the uncredited women of astronomy. But that's actually, I'm really pleased that that's starting to change. Unfortunately, it was well after she died, so she didn't actually get to experience this kind of recognition. But I think particularly over the last decade or so, the work that she did is starting to be recognised. And I think a lot of that started with an astronomer in the US called Miller Goss. He did a lot of research into Ruby's life and Ruby's legacy and wrote a book about that. And then he really brought her to the forefront and really pointed out that she was one of the founding figures of this whole field of research, radio astronomy, which is now an active field of research around the globe.

AT: So we've talked about how the award has helped you do your work, but what is the work that you do? We haven't actually talked about that yet.

EM: I actually use the techniques and the technology that Ruby developed and pioneered, but my sights are a little bit further out into space. So what I study is more distant galaxies and really using the radio emission we detect from these galaxies to understand basically how they got there. So how they formed and how they evolved over billions of years. So we know that at the centre of every galaxy, there is a supermassive or every

large galaxy, we think there's a supermassive black hole. And that can have a really big impact on how the galaxies lie, basically, and how the galaxy grows over time. And because it's a black hole, we can't image it directly because it's black, we can't see it. But we can see the effect it has on the surrounding material because it's such a huge, strong gravitational well that we basically track the effect of light and stuff surrounding the black hole. But in the radio, it just gives you a different insight into the properties and what these black holes are doing to the galaxy that we can't see it at other wavelengths. And to do that, I'm also using a radio interferometer. So using the technology that Ruby developed, in my case, we've kind of moved beyond putting a few antennas on top of the cliff, which is a very cool technique. But now we tend to mostly use dishes. So the telescope that I'm working on is called ASCAP. And it's located in Western Australia, the site is called Inyarrimanha Ilgari Bundara, which is the name that was gifted to the site by the traditional owners of the land, the Wajarri Yamatji people. And this telescope is actually 36 dishes, which all point at the same direction, and we combine the data from those 36 dishes, and that's how we build our interferometer.

AT: So it's a bit bigger than what Ruby was working with.

EM: Yeah. And it's really just a step to what we're currently building, which is called the SKA. And this is an international project that is two telescopes. One will be built in Australia, in Western Australia, in that same very remote location, and the other will be built in Africa and have dishes spread across the African continent.

AT: So you sort of embody her legacy, not just in the professional work, but also in the changes that have been made in the last several decades.

EM: I wish I could embody Ruby's legacy. Ruby is such a huge role model and powerful figure that I'm not sure I will ever be able to achieve as much as Ruby did in such a short period of time. But yeah, it's a really nice thought that I can continue the type of work that Ruby started, but also that I was given more of an opportunity to, and I was given more of an opportunity that Ruby wasn't.

AT: Join us next time on the Infinite Women podcast and remember, well-behaved women rarely make history.