

AT: Welcome to the Infinite Women podcast. I'm your host, Allison Tyra, and today I'm joined by Dr. Toner Stevenson, the co-author of *Eclipse Chasers*, which includes women's contributions to solar eclipse science. Dr. Toner's PhD research delved into the stories of the women that worked as computers, star measurers, and clerical assistants at Australian observatories on the Astrographic Catalogue Project. So let's start with what was the Astrographic Catalogue?

TS: In 1887, there was a very important meeting in Paris of astronomers from all around the world, and Australia was represented by Sydney Observatory New South Wales Government astronomer Henry Chamberlain Russell. And at that convention, the idea of creating a standard way of mapping the sky was the heart of the discussion. And you can imagine Paris in 1887. The Moulin Rouge was about to open. It was a time of international expeditions and exhibitions. You can imagine what was happening around the world. It was a time of global discovery and cooperation. And Australia was allocated quite a large section of the sky. At first, it was only Sydney and Melbourne observatories who were allocated their section. If you thought of the sky as a sphere that went around our planet, Melbourne Observatory was allocated the South Pole section, then Sydney Observatory the next section on top. Now at that stage, a third observatory, Perth Observatory, wasn't involved. However, over the next decade, Perth Observatory was built, and the astronomer was very, very keen to be involved in this Astrographic Catalogue, this mapping project. And they too were allocated a section of the sky when Rio de Janeiro dropped out. So in the end, Australia was looking after 18% of this global star catalogue.

And it's called an Astrographic Catalogue because it's about stars, but stars photographed. And this was at the beginning of stellar photography. It was early days. Photographs of people had existed for some decades. But photography was still in its early days, using a sort of wet plate process. Well, in the late 1880s, this dry plate process was developed. And that made it very ideal for astronomy. So what was happening was these new telescopes were developed that were more like large cameras, looking at the sky, photographing sections of the sky onto glass plates. And each section of the sky had so many glass plates allocated to it.

Adelaide Observatory is often missed out in the whole history of this project. Yet it played a really important part in that Adelaide Observatory measured, observed and measured what were called reference stars. So just imagine in front of you, you have a glass plate that's probably about 200 millimetres by 200 millimetres in square. On that glass plate, there might be hundreds, there might be 500, 600 stars. 12 of those stars will be well known stars that have been measured and computed many times. They will be the reference stars that you'll be able to compare every other star to. So that was Adelaide's job, because here in the southern hemisphere, not many of the stars that we can see from our part of the planet were already reference stars. So it was a big job for Adelaide Observatory.

AT: So they were doing some of the necessary but overlooked work.

TS: Absolutely. And it was quite important, because that's where one of the first women to work in astronomy, that's where she started. So Adelaide Observatory was run by Charles Todd. And he was a very interesting man. He is quite well known. People know the Todd River in Alice

Springs. They'll know Alice Springs was called after his wife Alice. Well, he had daughters, very bright daughters, and daughters had friends. And daughters were very interested in what was happening in the Observatory. And so were the friends. So when I looked at the visitors book for Adelaide Observatory in the archives, I saw these women coming to visit Adelaide Observatory. And then I looked at the time sheets, and I saw that one of them, Mary Emma Greayer, she wasn't just visiting, she ended up working there. And her job was to catalog the reference stars. Now, her job involved, first of all, just doing fairly rudimentary work. But as time went on, and we're talking about the 1890s, 1892 to 1898, as time went on, she started to go up to the telescope. And I could see that in the time sheets, she started to work later at night. And then the logbook of the observations made each night, it started to feature her initials, M E G, Mary Emma Greayer. And she started to do the observations. So Adelaide Observatory in my view was very, very important for two reasons. One, those reference stars, but also Mary Emma Greayer, who worked very closely with the astronomers, the male astronomers, of course. She ended up marrying one of them. And that's why she had to leave the Observatory. But yes, yes, it's a terrible story. So, and we'll see that story happen again and again. But, she did incredible and productive work while she was there that was pivotal to the whole Astrographic Catalogue.

AT: Well, and you mentioned Alice Todd, and also that she had daughters, one of which was Lorna Todd Masters. And Mary, Alice and Lorna were, as I understand it, the first three women to join the Astronomical Society of South Australia in 1893. And this was one of the world's first astronomical societies to enroll women as members without prejudice. So can you tell us a bit about the significance of that?

TS: Astronomical societies had existed for a long, long time. And people will know like the Royal Astronomical Society and others' names like that perhaps. Usually they were for professional, and nowadays there are societies for professional astronomers. But back in the 1890s, there were professional astronomers, but amateur astronomers were operating often at the same level as professional astronomers. They were making important discoveries. Now, South Australia is very progressive or was very progressive at that time with franchise for women, women's votes. I know that Mary Emma Greayer was in the first cohort of women to vote. And that the Todd sisters, as I said, were very active within society, very influential. And when the society was established, the government's astronomers were involved. And the women were invited to partake on equal status. That was a real change to even other societies overseas. This society was two years ahead of another society established in Sydney, which was the New South Wales branch of the British Astronomical Association. And that association also invited women to join on an equal status. So things were changing. But it's very interesting that you see, it's often the connections that women had within their own society that sort of gave them entree and status to feel comfortable to join the societies, which were, of course, still very male dominated.

AT: So can you tell us about the process and what these women actually would have been doing on a day to day basis?

TS: That's a great question, because, and one that I feel very fortunate to have interviewed two of the women who worked as star measurers and computers at Sydney Observatory on the Astrographic Catalogue. I interviewed Verlie Lee, who has unfortunately now passed, and Winsome Bellamy, who I have to say is a sprightly 98 years old. And it was very, very fortunate because I was able to get a really, a firsthand account of what they were doing. They worked in pairs. One woman would be looking through what was called a micrometer. And just imagine a microscope. And instead of looking at an insect on a small piece of glass, you've actually got this large glass plate, like I said, around 200 millimeters by 200 millimeters square. And that's positioned. And you're looking through this little microscope at that glass plate. You're able to measure that, to move that glass plate up and down, because stars are measured in, just like latitude and longitude positions on our planet. So they're measured in right ascension and declination. But we don't need to worry too much about that. Just imagine the glass plate with a grid on it and lots of tiny little black dots. Because remember, these were negatives. So instead of seeing a black sky with white dots, they were seeing a clear sky with black dots on it. And they were the stars. Now, their job was to actually work out the position of the star. And we've talked about reference stars. So they had some stars they could refer to, and just check. They also had to work out the magnitude or the brightness of the star. Now, this was really part of why the astrographic catalog came about. Because in 1887, there was no standard measure for brightness of stars. There were star catalogs that went back to the ancient Arabic culture. There were many, many star catalogs, but no set global standard. And that's what was established for the Astrographic Catalogue. So these women were matching the size of the star to a standard measure. In a way, they were taking over what the astronomer used to do, looking through a telescope with the eye. And working in pairs, one would be looking at this glass plate measurement and calling out the numbers. You didn't want to take your eye away, once your eye had adjusted, and it was it was hard work on the eyes. Once your eye had adjusted to the microscope, you didn't want to take it away. And so the other person would be writing down very neatly, very precisely, both the position of the star and the magnitude or brightness of the star. And that went on. And then they swapped every 30 minutes because the eyes would get tired. People would get a little bit, you'd sort of get a little bit frustrated perhaps at times. But that was a very rigorous system. And it was a system actually developed in Paris in the early 1890s by Dr. Dorothea Klumpke, who was in charge of the measuring bureau in Paris Observatory. She was an amazing person. She was one of the first people in the world to, women in the world to get a doctorate in physics. And she had one from the Sorbonne. And she set up the astrographic measuring bureau at Paris Observatory. Yes, she had male supervisors. But because of her expertise, and she'd been working with astronomers for some time as a student, she was more or less given free rein to work out how it would all happen. And they had decided that women would do this work. Primarily because women were much cheaper to employ than men. Hmm, surprise. But there were also attributes that were considered feminine. And when you think about women doing that very fine needlepoint work that women did at that time, lace work, it all actually required precision and calculation. It didn't just happen in an airy fairy way. It required great concentration. And a very strict adherence to a methodology. And these were important attributes. So Dorothea Klumpke set up the bureau and she had women working with her in pairs. And then she actually published a nice booklet about how it was all

done. And she gave talks. And I'll just quote from her. Because in 1899, she wrote, "Ours is a work of the night and day. Astronomical science now becomes universal. She knows no boundaries, no rank, no sex, no age." And they are precious words that we can reflect on today when we know that in, pretty much globally, women only make up about 30% of the professional astronomical workforce. So, she was outstanding.

And once that system was set up, it was copied, copied in Greenwich. Australia was part of the British group. All the British group had women measurers. Down in Italy, in the Vatican, the nuns did the work. It was universal. A lot of people will have heard of the Harvard computers from Dava Sobel's book, *The Glass Universe*. And there the women were doing the work. In some cases, the women got to do a little bit more though.

AT: I do just want to clarify how long this project took. Because we've mentioned the 1880s multiple times. But then you're saying that you were fortunate to interview some of these women. So I feel like we need to explain that this project did go for decades.

TS: The project went on for a long time. And that was, the break on the project was the measuring and computing. So the idea was to set an epoch or an era for the stars. And that was set at 1900, the turn of the century. So pretty much all the photography had been done around 1900, certainly in Sydney and Melbourne. And when Perth came on board, by about 1912, all the photographs of the sky had been taken. And the men took the photographs. The women didn't take the photographs, the men did in Australia. Now that meant you had a lot of this data that needed to be processed. However, you didn't necessarily have the resources to employ too many people to do this. And the men didn't really want to do it. A few men did bits and pieces. Men certainly supervised, did checks. But it was the women who did the groundwork on this project. So, the first measuring bureau in Australia was set up in Melbourne. And the agreement was made that Melbourne Observatory would measure the Sydney and Melbourne zones. And that's where we see Charlotte Emily Ffordde Peel come into the picture. Because she became like the Dorothea Klumpke of Melbourne Observatory. But what happened was, there were different social occasions that had a great impact. Melbourne, when they started off, Melbourne was still in the great gold rush era. There was money. However, by 1912 or so, that money was running out. And they were in dire straits. They had financial problems. The same with Sydney. And then we come across the First World War. And of course, a big war effort was needed. So no one was really that interested in the Astrographic Catalogue. In the meantime, Perth Observatory had picked up its own. And then actually the women there had made huge inroads because they had pretty much stayed as a solid group. Remembering there was a great turnover because women, if they wanted to marry, had to leave. So you might spend six months being trained for this project, a year working on it. And then, "Oh, I want to get married. I have to leave." So there was a lot of factors that meant that it was not a continuous workforce, that money came and went to employ women. And in fact, it wasn't until 1948 when Sydney actually took control of the project, the Melbourne and Sydney project got all the glass plates up to Sydney and actually said "we're going to finish this now," that the project actually did get finished in the 1960s. What happened in Perth, Perth had pretty much measured most of their zone. They had an agreement with the Royal Observatory Greenwich that Edinburgh Observatory

would finish up the measurement of some of their zones. So glass plates went across the ocean in the middle of the First World War, over to Scotland. They were unloaded. There was a group of four women there. What was happening back in Sydney at the time was that the astronomer from Perth had come and taken over Sydney Observatory as the government astronomer. And he kicked off the Astrographic Catalogue again happening in Sydney and a bureau of women there. But the 1920s after the war, we were heading towards a great depression. So there was a lot of pressure on resources. And he eventually was pensioned off. And so it was not an easy ride. And each time a new group came in, they had to learn the ropes. There were a lot of glass plate negatives that were not useful. You can imagine every part of the sky was taken many times. There was a lot of calculation to do to make sure that the work was accurate. Every star was measured at least two, usually four times. So the plates were flipped to check the measurements. This was not an easy project and it went on for 70 years in Australia. And Australia, the Sydney and Melbourne zones were the last zones to be published. Harley Wood and Winsome Bellamy particularly put the last effort in to get the publication out. And then Harley Wood wrote a sort of finishing chapter in 1972 about how it all happened. And he did acknowledge the women. And he particularly acknowledged Winsome Bellamy and Margaret Colville, who, without who I know the Sydney Melbourne chapters would never have been completed.

AT: And we've talked a bit about specific women from Adelaide, from Melbourne, from Sydney. But there was also a woman named Prudence Valentine Williams, who was just 15 years old when she was recruited to work at the Perth Observatory in 1907. And she stayed on for over 10 years.

TS: Yes, Prudence Valentine Williams is certainly one of my heroes. She was obviously a woman with great spirit, very young, very capable, because she had to sit an exam. And she would have been sitting an exam like a public service exam. And she would have shown extraordinary mathematical, geometrical results. She went to a good school, yes, in Perth. And she was very, very skilled. But not only was she skilled at mathematics and geometry, she was a manager. And it was not long before she was the supervisor of the Bureau, of the Perth Astrographic Bureau. And she was training other women how to do the work supervising their work, calibrating the micrometers that they were using to measure the glass plates and checking the log books. But she was also interested in the wellness, and what we would these days call the wellbeing and equity of her staff. And this is the early 1900s, 1913. She wrote a letter to the head astronomer on behalf of Minnie Harvey, Ethel Allen and Ida Tothill, the three other women who she was working with, and said, "we're not being paid for the level of work that we're doing at the right, we're not being compensated accurately." She said, "we're not doing rote work. We actually have to use skills, we're highly proficient." And the then-government astronomer Harold Burnham Curlewis, he listened to them. Now, the work was hard on the eyes as well. And they mentioned that. But he took this very seriously. And he wrote to the undersecretary of Western Australia about this, that he supported this cause. However, there was also something else going on at the time. They wanted to restrict the length of time that the women could work. Now, these women were the equivalent of our fixed-term or casual

staff. And he wanted to restrict their term to three years. And this was really ridiculous, because as Harold Burnham, Curlewis complained, it took at least six months to learn what you were doing. Plus, they generally employed young women with the idea that they would stay for quite a few years. Women had to leave when they got married. So if you could find someone who could stay for quite a few years, that in fact was a very efficient and ideal way of working because they could then train others and gain new skills. But you can see that there was no prospect of a career in this. And that was not because of the astronomers, that was because of the government, the law, the social environment at the time. So anyhow, what happened was they did not get a great rise. They did get a little bit more eventually, 48 pounds instead of 40 pounds as the starting wage. And that rose to 96 pounds. However, I find this incredible that they did actually acknowledge the work the Prudence Valentine Williams was doing. And she got a more senior wage eventually, and a new title. Assigning a title to do with the library, which essentially the books and the log books coming out of the Astrographic Catalogue and the glass plate negatives. And then the bulletins, the international bulletins that kept everyone on track for this project were a library. Assigning library to her title and astrographic assistant really did help raise her status and her salary. So by taking on board all of these issues, she did in fact help her co-workers. She wrote everything down, which now we can read, and this was gold, finding these letters in the West Australian archive was like finding gold. And there was more, there was more. She was very, very active. She did not like the way the women were being spoken to.

AT: Speaking of her letters, there is one from 1914 that I love where a male astronomer was complaining. He actually reported the women for spending too much time talking. And Williams's response to this is just hilarious.

TS: Yes, she responds, "Mr Nossiter must have a vivid imagination when he states that some days we talk almost incessantly. He is evidently judging us by himself. As for about two months, he and Mr. Whitby talked almost incessantly." So she uses the words that Clive Nossiter used to describe her. And it's very, very interesting because also Clive Nossiter was her brother-in-law. She also accused him and Mr. Whitby of spying on women. And there's a few letters, there's one where he writes and it's his words, where he says things about the women to Harold Curlewis, the government astronomer, but it's clear to me that the government astronomer really did listen to the women because he must have shown the women these letters because in every case, Prudence Valentine Williams responds. And she responds with gusto and evidence, "how many stars we've measured. How Ida Tohill, who was one of the younger ones by this stage, she seemed to have been particularly picked out by Curlewis for criticism. And Prudence Valentine Williams goes into bat, how she's only been here for a few months, she's still learning and the work's being checked. And, these women, I've looked at their log books, they are amazing, but they were also identifying things like double stars. When you look through a telescope, sometimes at what appears to be a single star, you see it's two stars very close together, one going around each other, a binary star in some cases. And the women were identifying these on the glass plate negatives. They were never acknowledged for that. Years later, a paper was produced using their data. They were not mentioned. It's a sad story. But I always feel positive about the Perth Bureau, because of Prudence Valentine Williams, because

she really stood up for her rights and for the rights of the women around her. And in a way, in a written, concise, and methodical way that the government astronomer could take what she wrote and do something with it. Well done Prudence.

AT: I do like in that letter where she's badmouthing her brother-in-law, she's pointing out that, "we four women have twice measured, calculated, and prepared for publication 21,221 stars in this six month period." And she says, "I am afraid he cannot show a corresponding amount of work for the same period." And I feel like it's this larger trend of perhaps particularly women in the sciences, when they're pointing out discrimination and sexism, they bring the documentation. They have the facts. They have the data. You don't mess with the women in the sciences is what I'm saying.

TS: Well, certainly not with Prudence Valentine Williams.

AT: But interestingly, when we're talking about how she was fighting internally for better treatment, better pay, etc., for the women, there was also another woman who is actually really well known as a pioneer of women's rights and equal pay. She's a feminist. She's a trade unionist. And she worked at the Melbourne Observatory from 1906 until 1910. So can you tell us about her?

TS: Yes, Muriel Agnes Heagney, very interesting woman. A young woman brought up in the family that was a trade unionist, as you said. She was a real champion for women's rights, particularly for equal pay for women. She worked at the observatory. Her work, I've looked at her log books, they're very much like all the other women's log books. She's not picked out as outstanding in any way from the other women there. It looks to me like she was earning a regular wage, mixing with other women, getting skills in mathematics and in thinking about things that she would later use in her life when she was putting forward very well-calculated reasons why women deserved equal pay and what was at fault with the thinking, with the law at the time. And she did this repetitively. She published papers. She traveled. She was very well-known in her field. And she really devoted the rest of her life when she left the observatory to fighting for women's rights. So this is, yes, as you said, Prudence Valentine Williams was not alone in this. Muriel Heagney, she took another step in becoming far more public about the inequity that women faced. Why should women, when they married leave the workforce? Why should a man's wage be calculated on a family and not a women's wage? Some women were bringing up families alone. Women did have responsibility for others that was financial as well as men. And she did all the maths that was required to put forward those arguments. An incredible person who, unfortunately, she didn't live to see the law changed. But I'm pleased that politicians today have picked up her, that she was very influential and important in gaining those rights. And you'll see her documented in many online forms. Muriel Agnes Heagney is her name. But you won't see her work in astronomy usually mentioned. And I was delighted when I found her amongst the women who worked at Melbourne Observatory.

AT: When Winsome Bellamy started working at the Sydney Observatory in 1948, and she did

stay there for 20 years. But in 1948, they were still using the same equipment and techniques as their predecessors had been using for 40 years. And surely, surely we had some technological advances that they could have used in that time.

TS: Oh, yes, you are right. And Winsome said some of equipment was very, very clumsy. But I will say they did change the equipment not long after Winsome started. The then-government astronomer Harley Wood, he ordered new equipment for the women to use for measuring the glass plate negatives. Computer technology was not so advanced that they could use that then. So it was still a very manual process. However, the machines they were using were had, for instance, inbuilt lights behind the glass plates. Hooray. They didn't have to sit at a window that faced south so that they got glow but not sharp light coming through the window. The machine was far easier to use and didn't require as much calibration as the old, the old machines they had to put wires in. It was quite hard work to calibrate them. They had to be done very regularly. But what was interesting at that time, they had to retake a number of the glass plates, had to retake new photographs because some of them were just not usable, had broken or deteriorated. Observatories can be leaky places. So, they did have to do some work. And then more calculation is required then to kind of process that star position back to 1900 to make it work within the whole catalog. So, you know, the mathematics was quite interesting. They did have improved tools for doing the computational work though. And over that time, of course, they did have calculators and things like that to help do that work, which would have been very welcomed. But lots changed in our world since, 1968 in that, I know in my own workplace, I did not use a computer when I first started work. Now, how can you imagine work without a computer?

AT: The thing that we're talking on right now.

TS: Exactly. Exactly. So, the last sort of calculation work for the Catalogues was really done around 1960. It was then a matter of compiling everything. And when you see the piles and piles of logbooks and then the transcribing onto other pages and then the preparation for printing, and then the cost of printing had to be absorbed. And the International Astronomical Union stepped in. The last Catalogue was printed in around '61 by the International Astronomical Union. So, the whole catalog has now been digitized. So that happened a couple of decades ago over in America. And that Catalogue, that digital Catalogue took into account the errors of the women who measured the stars. Every woman had an error measurement assigned to her after testing because, as you can imagine, they do sample measurements of stars, a number of people would do the same group of stars, and then they'd re-measure them, and then they'd work out the error. Just as you do for a machine, they did the same thing for women, and they put in the standard errors and that Catalogue, that digital Catalogue, has then been used, combined with many other catalogs, to send space telescopes into the sky. So it's still useful, which is great. When I spoke with Winston Bellamy, she wasn't aware that her work was still being used. And it did make her feel that her 20 years at Sydney Observatory had been worthwhile.



AT: My understanding is that, at least from an Australian standpoint, most of the information that is now readily available online about the Australian women who were working in these observatories comes back to your own research. And that sort of speaks to the fact that in the past, women's work in astronomy was not fully acknowledged. You mentioned work, like specific instances of work where the women's contributions just went completely ignored while their data was being used. And then also the extent of their work and its significance just sort of disappears if no one is telling people about it. So why do you think that it was so easy for these women's work to just be erased in that way?

TS: Yes, it is interesting. There was one woman, Charlotte Emily Fforde Peel from Melbourne Observatory, whose work on comet Delavan was acknowledged in a formal paper. And she's an interesting case because she's the only one of these earliest women who became permanent because she was a teacher beforehand. She had a permanent job in the public service as a teacher. And that was pretty much the only one of the few permanent jobs that a woman could have. I think post office work was another one. But so she was able to be a permanent member. And she led the astrographic bureau at Melbourne Observatory. And James Baldwin, the government astronomer, acknowledged her work in the paper that he wrote about the comet observations. The other women are mentioned in the catalogue, but often it's just their initials. So, as a group, it was known that women measured the stars and did computations for this catalogue. But the individuals, the actual, the person behind the initials, those people were not known. And that there were some women that did more. That wasn't really known or acknowledged. And as you said, that sort of story had not made it into the annual reports, into the papers that were sent to the British Astronomical Association, weren't published in astronomy journals. And it was also not seen. The Astrographic Catalogue was seen as a bit of a waste of time by some astronomers, particularly to do with Australia's contribution. Because it did take up, there's a reason for that, in that it did take up the resources of Sydney, Melbourne and Perth Observatories at a time that the new astronomy, astrophysics was blooming, spectroscopy. And all of that was really taking off. And it's often seen, and there has been written about by intelligent astronomers that in fact, the Astrographic Catalogue stymied more advanced work in astronomy. And it probably did, to some reason. Except really, all the photographs were pretty much taken in the early 1900s. And it was the women behind the scenes who were doing the work. And would those women have been working on this more advanced astronomy? I'm not sure about that.

AT: Well, it's also a question of, we've mentioned that you could pay women less. And so as it takes about four hours to measure 150 stars, you consider we're talking about 218,000 stars out of Melbourne, 200,000 from Perth, 430,000 from Sydney, plus the reference work that was happening in Adelaide. That is many, many, many hours, but it's spread out over all of those decades as well.

TS: Yes. Yeah, that's a really good observation in that, probably that is one of the reasons that their names are not known, because one, there were 72 of them, approximately. There might be some others I haven't found, but they came and went. And there were a few that stayed for like

20 years, but they had to leave when they got married. So, there was no real opportunity for a career. And it tends to be people who make their name in their career, whose names we know. It tends to be the people who were permanent, who became the government astronomer. We don't actually know the name of male computers, there were male computers before the Women's Bureau was set up. And I'd have to say, I don't really know much about them because they, this work was seen as very much behind the scenes. It wasn't seen as important, although it was important to actually getting to the end result. And I guess it's just the nature of how history is, how we represent what happened historically, we always go for the star figures, the ones that made it to the top. And often in every field, leave out the ones who actually helped them get there.

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