Speaker	Professor Michael Tobar
Talk title	Shining Light on Dark Matter
Venue	The Shoe
Time	Tuesday 29 October 2019, 5:30pm

Carina Marshall

Hello everybody!

I hope everybody is enjoying the Shoe Bar in the beautiful Yagan Square.

I hope everyone has a drink ready to go and learn something tonight.

Welcome to Raising the Bar. Tonight there are twenty-two academics and they are speaking in ten bars all across Perth.

To start, I would like to again acknowledge the Whadjuk Noongar people as the traditional owners of the lands and waters where we are meeting today and I would like to pay my respects to the elders, past, present, and emerging including any First Nations People who are here tonight. This land at Yagan Square, in particular, has been a place to gather food and live in community. Let us remember the past and continue to gather knowledge, food and community tonight.

At UWA, we are excited to make education a part of the cities popular culture, through transforming local city bars like this one into a place that you can enjoy a drink whilst learning about the impact that our research has in the community.

If you are sharing Raising the Bar on social media, please tag, like, share and all of that stuff on all your social media bits, at @UWAresearch or #rtbperth19. Tonight's talks are being recorded and will be published as podcasts on our social media channels. So, if you are like me and you would really like to hear more of those twenty-two talks but you can only be in one place at a time, you can go onto the UWA research website later on and you can listen to some more of them.

So, I think we are ready to get started. Our first speaker tonight is Professor Michael Tobar. He is currently a Professor of Physics with the Department of Physics at the University of Western Australia and he leads the Frequency and Quantum Metrology research group at UWA. His research interests encompass the broad discipline of Frequency Metrology, Precision and Quantum Measurements and Low-Temperature Condensed Matter and Quantum Physics.

Hopefully, he is going to tell us all about what that means.

In 2014, Michael was awarded a Laureate Fellowship by the ARC which is the top nationwide research fellowship and it’s incredibly hard to get and just very recently, he and colleagues across Australia have just been awarded $45 million for a Centre of Excellence in Dark Matter Particle

Physics. Michael is going to be the node leader in WA and five Dark Matter detectors will be built here in WA, so yay Mike, yay WA and I will turn it over to him.

Professor Michael Tobar

Thanks, Carina!

Alright, it's great to be here today to share with you guys, who are interested and maybe understanding a bit of physics. As Carina said, I am Professor Michael Tobar from UWA. Just a little bit about myself, I grew up in Melbourne, near the Mordialloc, Frankston area, a place called Aspendale, if anyone knows Melbourne and I ended up going to Monash University and doing a double degree in Electrical Engineering and Theoretical Physics and Applied Maths and after my degree, I wanted to do a PhD and what I did, is, I sat down and said, “I will go anywhere in Australia and I am going to go where the project I wanted to do is,” and that led me here to UWA, thanks to David Blair. Some of you guys might have heard of David Blair who searches for Gravity Waves and is fairly well known in the community. I did my PhD under him and what I really liked about physics here, is that we could do these great engineering and measurements and we could look for new physics, we could try and look for new things and discover new physics. Very exciting, very exciting!

And I must say, since I was a kid, I used to watch patterns in water, like you see a drop of water hit a pond, you will that you will get patterns and it was obvious to me as a ten year old that these patterns were always the same and they had to be pre-determined and that used to fascinate me. I used to think, “these must be predetermined, there must be some way of knowing?” and low and behold when I started learning maths and physics at school, I realised it could. And so what we have is the discipline of physics, which is experimental. It's like the drop of water dropping in the pond, that is totally experimental and the language is mathematics, and mathematics describes it and that’s what physics is.

Physics is reality, what's happening, how you can describe everything, how you can build buildings and mathematics is a language.

Now we live in this world here and there are objects which are “matter” and this “matter” is made up of different things. But before I get into and the topic of the talk I would also like to say that after being at UWA and doing a PhD and a Postdoc, I went overseas for a Postdoc in Japan and a Postdoc in France with the same principles, very interesting and then I came back here to UWA with a permanent position and I guess in that sense, now I have lived most of my life in WA. I calculated 28 years here and 25 years in Melbourne and actually when I came back, I started supporting the WA team, Perth Glory, so I have one WA team in my repertoire, so it makes me a little bit of a West Australian, but coming back here and getting the opportunity to work at UWA and doing this Physics has been a passion in my life.

My scientific life has been doing precision measurements and getting research funding to do precision measurements to look at fundamental physics, to test fundamental physics.

However, this technology has also gone up into the domain of radar. We also help to start-up companies, so everything we do new physics also spins off into the community, so this is really worthwhile stuff, not only worthwhile for our understanding but worthwhile for technology and bringing the intellectual environment in developing technology in this state.

The topic of the day is “Dark Matter” and as Carina pointed out we have just been funded all this money and this money is going to be my next ten years of my career and this is what I am going to do and I am very excited.

Before we talk about Dark Matter let’s just talk about “Matter” because we have to know what Matter is before we can really have an idea of Dark Matter.

Now, I can look around here and I can see a table and I can see different things, glass, and they are all made of chemicals, but what are the chemicals made of? You might know they are made of atoms, but what are the atoms made of? Electrons, Neutrons and Protons. Maybe you remember that from school.

So, an electron is an elementary particle abut a proton and a neutron isn’t. A proton and neutron is made up what is known as plaques. Plaques are a more elementary particle and these plaques make up lots of many particles and they are held together by something called a “glue-on” and that’s Matter.

To humanity arriving at this point in time, we have come up to this model called the Standard Model of Particle Physics and we understand Matter very well and where all this technology, the world you see around us comes from that.

So, what is it about “Matter”? Well, we all know Matter is in the Universe and Matter, the Earth is made of Matter but Matter has one property, all Matter has one property which is called gravity and that gravity is a property of matter, it is just totally dictated by the Mass and I want to do an experiment, because I am an Experimental Physicist, so I have brought my experiment here and we are going to do an experiment. You might remember Newton dropped and apple or an apple hit his head and he worked out Newtonian Gravity but today, we have funding to do better experiments so I have upgraded the apple to a pear. [laughing]

A pear is more juicy and tastes better, so I upgraded. Now, this hard and fairly massive, now let's do an experiment where we drop a massive object with a soft object.

I have got a soft object here, this is the best two. It’s the best quality football you can get. Everyone knows this is the best, good!

Now we are going to do this experiment where we drop a heavy object and a soft object. Now you know I am from Melbourne. Which hits the ground first. The answer is, the light object and the hard object hit the ground at the same time. So we can see from that that it's not really a property of the gravitational attraction, it is a property of the Earth itself, the mass of the Earth. So, we can use motion to understand Mass. If we see things in motion, we can understand its Mass.

So, that's what we do.

For instance, if we want to work out the mass of the Sun, for instance, we can look at the Earth orbiting the Sun and the other planets orbiting the Sun and we can work out the mass of the Sun, so this normal matter and it has this gravitational effect and that gravitational effect and the Mass can be determined from the motion just like dropping these high-quality objects.

Likewise, the Sun's motion around the galaxy is dictated by the Mass in the galaxy.

So, astronomers over the years have observed all the luminous matter in the galaxy moving and they determined there was a lot of missing Mass.

Back in 1993, Zwicky determined that he thought there was 400 times to Mass and what he could see, but then to date, we know that when we look at the Universe, out of the Matter we know and the Matter we see in this room is only 20% of the Universe, the other 80% is unknown. We do not know what it is and that's amazing and we get that from the rotation of the galaxies. Also, we can see from galaxy collisions that there is this Matter that we don't know which we call Dark Matter and when the galaxies collide, the Luminous Matter that we can see as stars collides differently to the Dark Matter. Everyone has seen that and that's really interesting because the Dark Matter acts in a different way to the normal Matter and the Normal Matter acts like we would think and the Dark Matter happens in a strange way. There are clusters out there where we can see galaxies colliding and also we can see from out in the Universe, that's where Dark Matter and when Luminous Matter, that we call Luminous Matter like stars exist, they are in different places of the Universe, they can be in different places of the Universe.

Then there are other experiments that confirm that there must be these so-called Dark Matter particles, these particles that exist that are totally different from any other particle that we know and this is 80% of the Universe, 80%! So, what do we do about that? What do we know about the Dark Matter, well you understand where we have got to today, people like Einstein, really smart people in this world. There are a lot of smart people out there thinking about it and we have come to a point where people think they know what the candidates … what these particles should be.

I am an experimentalist, I like to do a bit of theory but there are some really smart people out there who have looked at the evidence and think they know what it is.

So, as Carina also suggested, we have this funding to look for Dark Matter. We have got this big Centre of Excellence and it is going to be very exciting. This Centre will develop new technologies to look for Dark Matter but it will also be technologies that are very important for other applications.

Radar, looking for weak nucleus signals. There is going to be a lot of technology and our Centre will also translate technology that we develop with Dark Matter. It will also try and inspire our young scientists, diversity programs to lift science much higher in the public eye because, tertiary institutes, research in this is really high valued stuff and worthwhile.

Getting back to this Centre, there are a few problems in physics which are outstanding. One of these problems which we think is related to Dark Matter is that when I was telling you before about these particles, what Matter is made of, there is a particle, the neutron, the neutron I told you was made of plaques. Now, these plaques have certain charges just like an electron a positive charge a negative charge and they mix together to make a neutron and because they have charge, the charge shall be distributed and if you have a distribution of charge, you get what is known as an electric dipole, an electric dipole. If I have an electric charge I can get an electric field and if I have a distribution of charge which might be zero I will get an electric dipole.

Now, according to what we know, these neutrons should have a certain electric dipole and we have measured them in the lab and we are talking about ten orders of magnitude that is if I write a number with ten zeros less of a dipole than it should have and this is a real quandary in physics. It is one the next biggest quandaries that we have like the Higgs Particle, some of you might have heard of, was discovered.

So, what is this particle? This particle was called the Axion. This Axion, this theory, this new particle was one of the events of this particle, this well-known physicist named Frank Wilczek. When he was a kid, his parents used to use this detergent called Axion and he thought to himself when he was a kid that that would be a cool name for a particle. So he got the chance to name the particle, so he called it the “Axion” so it's named after a dishwashing detergent because it is going to clean the Dark Matter.

This is interesting because this particle, if it exists also interacts very, very weakly with normal matter. In other words, it’s got the right properties, the big Dark Matter. So, there is a big part of the physics community that thinks this Axion, that solves this major problem in physics is also Dark Matter. Because, when you do calculations of the early Universe, the Axion, if it exists should be produced in the early Universe and if it’s produced in the early Universe, it can be the Dark Matter.

This is where the problem comes in, we think it’s the Dark Matter and this Dark Matter only interacts with normal Matter through gravity. But Dark Matter particles, which we think exists, we think they might interact very, very, very weakly with normal Matter, so if can make the conditions right, we can convert this Dark Matter into some sort of signal like a light signal and we can turn it … so this is why I have named the talk, “Shining Light on Dark Matter” because the physicist, if this Axion is the Dark Matter, we can make it shine if we make the right experiments and so, over the last few years there have been some standard experiments. The biggest experiment that we know, is called the Axion Dark Matter experiment and it's in Seattle, Washington University and we have become official members of this collaboration. We are part of this collaboration and they are now running an experiment to search for the Axion, but the Axion has a Mass and has to be a particle-like, neutron has a Mass and an electron has a Mass and we have no idea what the Mass is. We have some idea, not totally true, but it has got to be in a range. There are theories that tell us where the Mass should be. So when we do this experiment, we convert this particle into light, you know the Einstein formula equals MC squared, if we make light of a certain energy, it should have a certain frequency and we try and measure that. So we have to scan for a very, very weak signal. So we have to make it an experiment because you look around you now, every centimetre cube here has about ten to the power of fourteen Dark Matter particles in it. That's fourteen zeros, give or take in order of magnitude, depending on the Mass, but there is Dark Matter everywhere in this pub right now and we can't interact with it, but if I build an experiment and I do the right things to my experiment, I can make it shine, I can make it shine!

So that's what we are going to try and do in our lab. We are going to try and do this. We have already done a few experiments showing we can do new ones, and we are now known as one of the well-known groups in the world doing this and we are going to build five experiments in our lab that will be scanning for Dark Matter.

So, With this Centre of Excellence there will be an experiment in Melbourne, they have got a big mine, they are looking for a different type of Dark Matter, there are two main candidates, the other ones called a weekly and interacting massive particle, some more bigger particles and they need to go down in a mine to shield from all the cosmic rays. So there will be a big experiment there in Melbourne but we will have five here in UWA.

So that's very exciting for us and we have got lots of students and lots of people who are interested and we are eager to get lots of people interested and we are also eager to do Outreach because as part of the Centre, we have to do Outreach. I guess that's why I am here talking at the moment, because we want to share what we are doing with everyone and let the State know what we are doing, so this is very exciting and in ten years, who knows, once we understand Dark Matter then we have a new way of doing things.

People have even proposed communicating with Dark Matter.

You take the Dark Matter beam, create Dark Matter beam, send it over to the other side of the Universe, it just goes through the Matter, it doesn't interact with the Matter and then you recreate it but that like a bit of science fiction at the moment, probably do it on Star Trek but you know?

I hope that you guys were interested in my talking and my experiment, especially with the best team, the best equipment we could buy and thank you for listening and I, have no idea if I have gone over time or under time.

Thank you very much for listening and now we can open up for questions.

[clapping]

Carina Marshall

Michael is happy to take questions. Does anyone have any questions on physics? Of course, Michaels team would have questions, are you allowed to do that? Okay. Well we will let Michaels team have a question.

Audience

Just a quick one.

Axion, if it exists, would it be different and kind of, gravitational in direction with the other Matter. Would it be behaving like anti-gravitational?

Professor Michael Tobar

No, no. So Dark Matter behaves gravitationally like any other matter and this is the key aspect to Dark Matter which is very puzzling.

If we look anywhere in the Universe, and we can see it and we can see its gravitational effects. So, gravitationally it behaves exactly the same as any other piece of Matter, where it's different, its all with the other forces.

If I take, for example, you know when you go through the … you go in on a plane and you try and dodge the guy who wants to test if you have got some bomb material on you, I am always there trying to dodge this guy, you know, time it so he doesn't get me but occasionally you get caught and what they are doing is they are picking up some atoms, and when they put those atoms in that machine, they are looking at the spectrum and from the spectrum, they can see what chemicals they are and this is because Matter, our normal Matter interacts very strongly with light, very strongly.

A lot of technology is built on this Matter/Light interaction. Dark Matter has a very, very small interaction.

If the interaction is what we think it is, it is like orders of magnitude.

For us to detect the Axion, we have to build a big magnetic field, twenty Tesla, we have to build the most best receiver system you have got and we have got to try and convert that Dark Matter into a couple of boutons if we are lucky.

Dark Matter interacts … does not interact with the forces that we know other than gravity. So, it acts like any other matter but you could not see, maybe if you could have a Dark Matter bomb, no one could detect it. That might be one for the future, I don't know.

Carina Marshall

Easy as listening, Mike!

Professor Michael Tobar

Are you converting the Axion to energy?

Audience

Yes. Just E = MC squared

Professor Michael Tobar

That's exactly right.

Audience

Thanks for the talk, it was really interesting.

I am a total physics novice. You mentioned before the different … you are an experimental physicist and the idea of a theoretical physicist, can you explain the difference to me and does the experimental physicist do experiments with the ideas that theoretical physicist is working on?

Professor Michael Tobar

Okay, that's a good question. I used to want to be a Theorist when I went to Uni, but I did and Engineering degree and that warped me I guess. Physics is an experimental discipline. As I said, when I was a kid and watched this drop and you see it pre-determine, that's an experiment and that's reality.

The theory, the Mass describes it. The theory is a description. There are lots of wrong theories. There is a whole industry of theories, making up theories before they are relevant. Sometimes they are relevant, maybe they are a hundred years before their time, but theorists are like mathematicians, but there are some theorists that work strongly with experimentalists but I am an experimentalist that likes to work with theorists because I do a bit of theory myself.

My group and I have come up with new ideas because we have done the theory behind them so the theory of the experiments … to be a good experimentalist, you must know theory and to be a good theorist, you must know experiments.

It is not as clean-cut as that but there are people on the spectrum … there is a spectrum of people, but we must know both, we must be able to do both.

Carina Marshall

Mike, very nice. I have watched theorists and experimental physicists go at each other, he is kind! Are there any questions? There you go.

Audience

So, back before Einstein, there were some variations in the orbit of Mercury, I believe and they were looking for another planet to try this Dark Matter and then Einstein came along and he got a new theory and he explains your bit of Mercury amongst lots of other things. I guess, what I am asking is, one possibility is that Einstein's general activity isn't complete?

Professor Michael Tobar

Yes, well that certainly has been a possibility people have considered and it's called Modified Newtonian Dynamics "MOND" and it exists.

What has been hard for those people to explain is like collisions of galaxies, because when you see collisions of galaxies of the Dark Matter the centre of Mass is totally different to the illuminous matter, you know it's a particle of different properties. So MOND cannot explain that.

There are a few other examples which I haven't gone to. There is a microwave background and a few other. There are about five different experiments that are well known that says that universities land a QCD model and this model consists of so much dark energy and so much Dark Matter, so it is very hard for the people who have those theories to explain all the experiments and some people who are … some theorists, I am not a theorist, I am an experimentalist, so I believe anything but some of these theorists say the knife has been put into those theories already and others will argue and theoretic physicists argue and shout at each other and stuff like that. I am an experimentalist, it doesn't really matter, I will do what I can.

Carina Marshall

I am super short, so you might have to jump up and down if you have a question.

Another one over here?

Audience

I have two short ones, firstly, if in the next few years you happen to find Dark Matter, how will you know that that is the only type.

One possibility is that Einstein's general activity isn't complete?

Professor Michael Tobar

That's a good question because there is conjecture that there might be more than one type of Dark Matter like we have more than one Matter particle. But you should know by the sensitivity that you measure. So, we know the density of Dark Matter here, right here in this pub. We know how much Dark Matter there is, the density. Now, that depends on the Mass of the particle, how many particles. If we convert some Dark Matter and that is consistent with the density that we know then we will say, "It's all Dark Matter!" but if we do an experiment and it's only half then we will think, "Oh, we don't know what the other half is?"

There could be a whole zoo … there is this theory that whats is called again? I can't really remember but it is where they believe that in the Dark Matter sector, there is a Dark Matter Proton, a Dark Matter Electron, there is asymmetry, no that's for the theorists, but you know, there's …. But that's a good question, we don't know what Dark Matter is. We have best brains in the world have an idea, people are building discovery machines now and we will have five in our lab that, there will be some in Melbourne, we are involved in some in Washington, we are involved in them and they are popping up everywhere now.

Precision, quantum measurement, we are using these techniques to try and find it and one day, there will be a discovery and that will be exciting.

Audience

Thank you for that and the second part was, as an experimental physicist, you describe physics as primarily an experimental science, have you met any theorists that agree?

Professor Michael Tobar

Yes! Yes! There is a bunch of theorists out there that come up with theories for experimentalists to test. One is Alan [inaudible 31:26] in Indiana, a brilliant theorist, does [inaudible 31:30] and variance violation and we did a lot experiments he suggested. There are other ones who come up with theories but you can't really test because it is more mathematics. Quantum field theories and things you can't test but I am interested in the ones you can test and if I have got the equipment, I will generally try and do it.

Carina Marshall

I have just got one here.

Audience

Thank you.

You said that when you see … when you observe, rather, galaxies colliding you can observe the collision of the luminous matter and I guess it's characteristic of regular Baryonic Matter, kind of colliding, electromagnetic waves, heat, whatever. What do you observe … you said that you observe the Dark Matter colliding, so what's the outcome? What do you observe?

Professor Michael Tobar

That's a great question, brilliant question! Someone sharp enough to … how the hell do we know where the Dark Matter goes?

It's because of this phenomena called gravitational lensing. Just like someone brought up, it's depending on the light around the Sun and we thought … it's depending on the light of the Dark Matter that we can detect. That's how we know where it is. There is a famous cluster called the "Bullet Cluster" where people have seen the Dark Matter, they have been able to map the Dark Matter through the gravitational lensing of the luminous matter behind it, so that's how we know and the other way we know is through the motion.

Like, dropping this, I can work out the gravity and the motion and like the rotation of the galaxy you can work out the missing matter.

Carina Marshall

Are there others?

Oh, I see one way back there, hang on, I am coming. No, never mind, he was just scratching his head, not really a question.

Are there any others? No, okay, well … Oh wait, there is one.

Audience

You said that we know how much Dark Matter is in this room, can you explain how?

Professor Michael Tobar

I can definitely explain how? I can drop the footy again but, have you looked up into the stars at night, maybe?

When I am at home in my Spa I can look up and I can look at all the galaxy. You see a bunch of stars, you see the Milky Way, astronomers observe the Milky Way. Now, through all their techniques, they know the motion of the stars, it’s called a Redshift. They can measure through the light coming from it and how it changes, actually the velocity. So we know the velocity of all the luminous matter and the only way we can explain the velocity curves, the rotation curves is there is this big halo of Dark Matter around it and this halo is much bigger than the galaxy itself, to explain it, so that’s how we know.

Carina Marshall

Did that spark any more questions or? Oh wait, there's another one, I knew it would!

Audience

Is the Dark Matter distributed evenly or?

Professor Michael Tobar

They call it the Dark Matter halo, it's like this halo around the galaxy which is quite uniform and because it drops off, in our vicinity it has a certain density and we know exactly what it is, that’s how we know how much is here.

That’s not my expertise because astronomers know this better than me, I just know it’s there, I just want to detect it.

Carina Marshall

There's another one.

Audience

Can you describe the machine you were talking about for measurements?

Professor Michael Tobar

The machine, yes. If you come to my lab you will see something called a Dilution Refrigerator and this Dilution Refrigerator can cool an experiment to about ten-thousandths of a degree, some like that, a thousandth of degree above absolute zero and [inaudible 35:46] so, it's the coldest place in WA in our lab. We can cool this quite big objects to very low temperatures.

If I want to do a precision measurement, besides Dark Matter in the room, we have thermal energy in the room because we are all hot, it's getting to summer and that's vibrations. That vibration gives you noise in your experiment, so if I cool it down, I get rid of all that thermal noise. Instead of thermal noise, I get what's known as quantum fluctuations. Those Quantum fluctuations are now the limit of my experiment.

Quantum mechanics is a funny subject, we can do things to surpass that limit, so we build a detector which is from … we Quantum engineer a detector that can measure a bouton with very high precision, so when we change the Dark Matter into a bouton or light, we can detect it. At the moment, we are collaborating with people in Sweden and Russia and they have just given us a device which we are trying to make into a … which will count single boutons at microwave frequencies. The same frequency you heat your food up in but this is more a radar type thing and so as single boutons get emitted as we change the Dark Matter into boutons we will be able to count them.

Of course, what's stopping us from counting them is the thermal noise of our receiver. We have got ways to see the signal over the noise.

Another way … what helps us too, is a very high magnetic field and a high magnetic field will help us convert that bouton, that Dark Matter into a bouton.

This thing has worked out from the Axion to solve this strong CP problem. We know what its properties should be and we know how to turn it into boutons, though its very, very small signals so we have to cool to the lowest temperatures and then we have got high precision stuff and this equipment that we develop has technological spin-offs.

Our work started a company in Fremantle that built the lowest noise systems in the world. A factor of a thousand better than anything when we invented it and that company was going for a long time and the US defence were buying these things for their radar and probably missiles, but they … [laughing] yes, they kept having to buy new ones for some reason but …. [laughing]

This is an example of, when we do these physics, we develop new technologies and this new technology, it is always important for some application and now there's Quantum computing and we are using the same techniques as Quantum computing used to try and measure these signals below Quantum limits and its really exciting stuff, I really love doing it.

Carina Marshall

Just remind me Mike, zero Kelvin absolute zero is negative two ….

Professor Michael Tobar

Two hundred and seventy-four, probably or something ….

Carina Marshall

274 Celcius, that's going back to high school physics now, hang on!

Audience

I have finished most of a large glass of wine now, so, when they make a movie about your science that's a horrible dystopia, what's the most likely outcome of how your … just like this stuff is being used for the missile construction … where is your science most likely … unattended consequences most likely and most egregious.

Professor Michael Tobar

I like the idea of ….

Carina Marshall

I love that question [laughing]

Professor Michael Tobar

I like the idea of a Dark Matter bomb!

Audience

I was just joking you know.

Carina Marshall

Wouldn't that just cancel out all Matter on Earth?

Professor Michael Tobar

No idea?

Carina Marshall

I think we should write a short story about that Mike, that's our plan.

Any last questions for Mike before? No? Okay.

Thank you very much, Mike, a round of applause for an academic being brave.

[clapping]

Professor Michael Tobar

Thank you, Carina.

[clapping]

Carina Marshall

I want to know who is going to play you in the movie of your life? I don't know, we'll think about it.

Thank you so much for coming, we hope you enjoyed Mikes talk and hope you learned something new.

The next talk is going to start at 7 pm so I am going to have to ask you to move out into the main bar. If you have tickets for the next talk, you can just see the staff in the blue shirts at the entry who will just scan you back in.

The next talk is not sold out, so if you would like to stay and continue the academic conversation, it's Dr Brendan Kennedy and he is talking about bionic gloves improving the surgeon's touch. We can't let anyone else into the room due to licensing restrictions … sorry, it's not sold out … but if you would like to attend you are welcome to register for a ticket via the website which is our rtbevent.com/rtbperth and the staff will scan you back through or you can see them or see me and I will help you do that.

If you are going somewhere else in Perth to see another talk, enjoy!

The talks are all recorded and published as podcasts on our social media channels and they will be emailed to everyone who registered for a ticket.

Thank you.

Good Night.