Physics Nobel Laureate Prof. Brian Schmidt's keynote speech "Science - Humanity's Universal Bridge" on Wednesday, January 21, 2015, at the National University Singapore (NUS)

I would like to share some of my thoughts about science and its role for humanity. Astronomy has been with humanity since the dawning of our species. When you go through and look at the sky, if you go to the Atacama Desert in Chile, one of the most amazing sights on planet earth, this is what it might look like. It doesn't necessarily look like this unfortunately in Singapore tonight, but let us look at one of the objects up in the corner. This is known as the Pleiades star cluster and it's made up of thousands of stars, and it is about 200 million years old, and this cluster has been around and visible to essentially every human who has ever lived on planet earth, because it is visible from both the northern and the southern hemisphere. It is 200 million years old and the human race only a hundred thousand years, so it has been seen throughout our humanity, and it has been recorded by humanity and by different cultures in a variety of ways. It turns out that, for example, the Greeks gave it the name that most of us in the Western world know, which are the Seven Sisters, but quite remarkably the Australian Aboriginals who have been isolated from the other people of the world for 10s of thousands of years also gave it the same name. If you go to ancient India it's known as the Seven Virgins, several parts of Africa gave it the name Seven Women, and in Thailand it is talked about as The Chicks, but there are seven of them. There is a reoccurring theme. Seven females are represented by these stars, and that is a story that

seems to be true throughout humanity, and what's remarkable is when you look at the Pleiades with your own eyes as depicted, for example, by a vehicle that I happen to own, a Subaru, there are six stars that you can see with your eyes, not seven; and that's because your eyes are not the Hubble space telescope, and so your eyes can only pick up the bright and faint things, so those seven stars to your eye, rather than looking like this, are going to blend together based on the poor sensitivity of your eye to look something like that.

The Seven Sisters is a story that seems to be shared and goes back to the prehistoric days, and it has been handed down through the generations that we all share. So I find it quite remarkable that one of the oldest things that you can trace of humanity are stars. We actually have proof of this, if we go and look at some of the oldest human artifacts that depict things, for example in a cave in France. This image is 17300 years old, and it shows a bull, but it also shows six stars and interestingly enough, what is the bull in the sky? It's Taurus … This is a picture of the sky from 17300 years ago, and we still call it Taurus, and we still see the Seven Sisters. So astronomy and our thinking of the skies go back to everyone, and it's something everyone and every human shares together.

Now let's move forwards to the Greeks and let's start thinking of the development of science, not just looking at the stars, but understanding them. So it was very important in the old days to be able to predict for various political and religious reasons where

the planets would move across the skies, and we knew of the planets, but wanted to know where they're going to be in the future, so you could predict things. The person who developed a great system to do this was an astronomer, a philosopher named Ptolemy, and to do this, he didn't have a free hand, and that's because he had some rules to follow, and these rules are axioms of the day and one of which was that the earth is the center of the universe. Now you could challenge that assertion back in his day, but it may cause you to have to drink poisonous substances or do something else, so it was not a wise move. The other axiom he had was that things move on circles.

Why did the Greeks adopt those? I have no idea. They were aesthetically pleasing I guess, and quite remarkably using those two axioms he was able to come up with a way of describing the motion of the planets that was very accurate. It was almost as accurate as the observations you could make of the day, and it used this funny way of having circles within circles within circles which we now call epicycles, a way of describing in many respects a poor theory, but this was a very powerful one. It was used by essentially the whole Western world to predict the motions of the planets for thousands of years. It really wasn't until you got to the time of Nicolaus Copernicus when people started thinking otherwise. Nicolaus Copernicus, in the 15th century, had an idea and that idea was, let's break one of the rules, let's not have the earth be the center. What happens, if I allow the sun to be in the center? Then of course you have this beautiful, complex spirograph become this elegant and simple concentric set of circles. But why did we eventually accept this? It had nothing to

do with Copernicus, because this was an idea and there was no reason to believe it to be true, because it turned out that his model was not nearly as good at predicting where the planets were going to be compared to Ptolemy's. He just had circles going around one thing and it turns out, he didn't actually know this, but they go in ellipses, as I will show you Newton figured out. But this model is different than Ptolemy's, because it makes some other predictions and those were figured out by Galileo, who had the fortune of improving the telescope so that you could go out and start looking at things, like the planets and when Galileo looked at Jupiter it didn't look like a star that moved around the sky, it looked something like this, it was orb surrounded by four other orbs that orbited it. Very clearly the earth was not the center of that system. But even more importantly he looked at Venus and when he saw Venus he realized that it absolutely showed that Copernicus was right. Because when Venus came to the nearside of the sun, then only a tiny bit of it would be illuminated and it would appear big, because it was close and if it was at the far side of the sun everything would be illuminated, and it would appear small, because it's a long way away. So it was the observations with the telescope that showed that Copernicus' idea was correct.

Galileo knew the power of convincing people and he was famous for giving his friends, and it turned out eventual enemies, telescopes, so that they could see with their own eyes what he saw. He was obsessed with convincing people that Copernicus was right, that the earth was not the center, and it turned out not to be necessarily his best political move at that time, it turned out

the earth was not quite ready for him to tell them and even demonstrate to them that the earth was not at the center. So he was sentenced to life in a Tuscan villa, which if you ever are in Arcetri, in Florence, you can see, it's about six bedrooms and pretty nice actually. Probably worth 5 to 10 US dollars in real estate right now. It was a prison for him nonetheless, but I would say a relatively nice prison.

However, in the process of all of this Galileo started developing the beginnings of what we call the scientific method, where you have an idea and then you test it. For whatever reason the Greeks never really developed that idea, you had axioms, and you stuck by them, so this was a major change for the way that we view the universe. It was expanded to the real modern form by Newton. Newton was able to take the ideas of Galileo and Kepler and to make a mathematical model which was able to make very precise predictions. The predictions made by Newton and the fact that his model would say that objects should move on ellipses, which Kepler had figured out, was so accurate that it effectively could predict better any of the observations of gravity that were able to be made, and it came up with this idea that we still use today where you are able to model things and to test them with very high accuracy. The reason you could test them with very high accuracy is because you can predict things with very high accuracy, and that is the fundamental basis of science: prediction with accuracy.

For a couple of hundred years all seemed well: Technology advanced, and we were able to go out and find the first planets by using large telescopes. This is something William Herschel did, and wandering through the sky he found the planet Uranus, a star or planet that evaded detection from the human eye for all of humanity to this point and as it moved across the sky something happened: It was not following the predictions of Newton's law of gravity.

So what did that mean? Did it mean that Newton's law of gravity was wrong or was something else afoot? Well it turned out that a French mathematician was able to realize that instead of Newton's law of gravity being wrong, there was a way of fixing it. It was simply necessary to put in an undiscovered planet at a specific place at the sky, and that allowed a German astronomer to promptly go out and discover it, in a rare form of French and German cooperation in the mid nineteenth century.

Gravity continued to essentially be perfect in predicting what we see until Albert Einstein was thinking, in this case he was thinking about someone falling of a ladder, but we're going to conceptualize it in a way Galileo thought of gravity. You've got a bowling ball, you've got a feather. What happens when you drop them? Well, of course they fall at exactly the same speed, if you happen to be in a large vacuum chamber, and that we all accepted. Turns out the Greek hadn't really thought about this but Galileo sort of reasoned through this, and when Einstein looked at that he thought, I think that no matter when you fall in a gravitational field, the gravity and your acceleration will be exactly

counteracted. That must always happen, there must not be any situation where that's not true. It is kind of a simple thought, let me express it in a different way: If I would put you in a box, and you don't have a window, there is no physical experiment that you can make that tells you if you are on planet earth, like we are in this room, being accelerated by 9.8 meters per second squared, or if you're in a rocket-ship being accelerated by 9.8 meters per second squared, they are exactly equivalent. So from that thought he was able to go through and work for 8.5 years, it was a hard problem to solve, to figure out the consequences. The consequences were quite remarkable: Space would be curved, gravity would cause space to be curved. So if you would go out and look, for example, at stars during a solar eclipse, as Eddington did in 1919, you would expect from his (Einstein's) theory that the stars would be in a different place than they would be when the sun was not there. So, from pure thought alone Einstein was able to do something quite remarkable, which turned out, when it was confirmed, made him a public figure. Einstein was famous within physics circles in 1920, but this is the event that made Einstein world famous. Most people in this room will know e=mc, but to us physicists it is the theory of general relativity for which we most respect Einstein, because it is one of the only times where an idea came out of really thin air and made predictions, that there was no reason to go out and look for, except for this idea of aesthetics. Copernicus had that same idea, no real reason to go out and suddenly rearrange the solar system, but he did. Einstein had this idea that acceleration must always, sort of be the same whether it is gravity or not and from that he was able to predict things we did not know, and so it is a very rare moment that science is able to dream up something from pure

thought alone. So this is a special moment in science. This comes down to the question, and I've given this illustration of the development of gravity because it really is the catalyst behind the scientific method that we all use throughout science, and it comes down to: What is reality?

I argue, and some people might disagree, that reality is a set of ideas which predicts the observations we make, no more, no less. And it's ambiguous, because our ideas change over time, but this is important, because when I ask you what is reality, is Newton's law reality? Well, that's what most of us understand gravity is, and if I threw a ball across this room, I am not going to use general relativity to figure out what's going on. I am going to use Newton's law of gravity, and that's how I think about it. So reality is a relative thing, it's a thing that can change over time, and it actually can change within the circumstances you're thinking of things. If I am thinking about gravity around a black hole, then I don't really use Newton's laws anymore 'coz they don't work, but in this room they do work pretty well. Not perfectly. You have our GPS and you don't use general relativity, well, turns out you're in Malaysia rather than in Singapore as far as it's concerned, so you need to use it to do the corrections. Even something like general relativity is useful.

Why do we do science?

This is a question that people ask me all the time, especially ministers in the government. Why do we do science, and I always tell them, because it's interesting. That is really why we do it. But

the minister, after thinking about this for a second will always say, ok, let me rephrase my question, why do we pay for science? That I have a good answer for, the reason we pay for science is ‘coz all of this philosophy about predicting things is valuable. It turns out it is very valuable and useful to be able to predict what happens in advance, and that’s what science is all about, and it turns out it allows you to make fabrics for the floor very efficiently, to construct chairs, to make watches, it allows you to manipulate the world and make our lives the way they are today. If you think everything around us, the vast majority of it, is humans using science to manipulate the world to make it more convenient for us. That’s fundamentally why we do science. We all take it for granted, but it’s there and it goes right back to those days of Galileo and beyond, thinking about gravity.

Science really has transformed our lives. I show you here the life span as best estimated in different times of humanity and if you go back some 30 thousand years, then the best guess they have is that humans lived on average 32 years. This turns out a little longer than the Greeks who were too busy killing each other in their wars, so they had short lives, 28 years, which is well documented, Romans 30 years, medieval British 30 years, the average age of a human in 1910 was 31 years. Since the hundred years when we really had the scientific revolution the average human has gone up from 31 years to 67 years. That is the average across the entire 7 billion people, and that’s a remarkable change in just a hundred years, and it is something that is almost entirely due to our understanding and advancements in science. It is something that most of the world is actually sharing, not

everyone, there are a few countries where science has not permeated where they do have very short life spans and, of course, countries in conflict have issues in the short term.
But it has a cost and that is that for most of the ancient times the world's population was steady at a very meager rate, which didn't, quite frankly, affect the earth much, but since we developed technology and then science, not just technology, but technology based around science, the number of people on planet earth has started to exponentially grow, and those of us who know mathematics know that anything that exponentially grows, something happens in the future if the universe is not infinite. Exponentials grow so quickly that they always break whatever is going on, sometimes in a relatively near-term future. So that is something we need to worry about.

Of course, all those people were using energy, because energy is one of the principal components that science and technology uses to manipulate the earth and the universe and that has consequences, because that energy has to come from somewhere. In our case it is coming from a variety of sources, and it is leading us as we manipulate the environment around us to things like deforestation, which is causing the amount of CO2 in the atmosphere to rise rapidly over the last 50 years. So there are consequences to technology, and technology itself can be a double edged sword. Everything that we do can be used for good purposes, it can be used for bad purposes, and it can be used in a way that seems good, but may have some long term negative consequences, and we need to be aware of those things.

Technology can make life better, but it can also create its own problems. For humanity's future it is imperative in my opinion that we focus on using science and technology on not just solving our short term problems, but to worry about our long term problems. Quite frankly science and governments have not focused, and we have not focused on the problems 50 or 100 years from now. We have focused on the problems of now, and I am going to argue that we need to have a long term focus, if we're going to cope with what lies before us.

Science can help. It turns out that, as I showed you, we use a lot of energy, and there is a reason for that. Energy is very useful, we can grow plants very efficiently with it, we can make things, manipulate our environment, and so as the earth soon to have 8 billion people, it's going to need a lot of energy and a lot of manipulation of our environment to grow food and to live in a way which is sustainable. But it's not all bad, because the energy sources we use today are convenient as they are stored reserves from what the earth has done for a million of years, and there are a lot of energy sources out there. The sun essentially has a thousand times more energy than we use in a year, so if you can harness solar energy with a reasonable sufficiency, it is not impossible to imagine powering not just the current needs of the world, but even more, with solar energy. We also have the reserves of natural gas, oil, uranium and coal up our sleeves to help, and we have other sorts of renewable energy, for example wind, hydro and geothermal, which are also useful. So it is not hopeless, but it is going to be science and technology that allow us to harness these sources, to allow us to run in a way that

allows humanity to go into the distant future in a way where everyone has good lives.

Science can only be a bridge, a tool, it is not sufficient in itself to help us reach where we want to go. Science can only be the bridge, because it provides the means for prosperity only if humanity is willing to share the technology and the affluence that each person on earth wants for their own.

One thing that I have seen is that there is a very universal human trait, and that is that we are not very happy living next to someone who has a lot more stuff than we have, some people are content, but most are not. So if we continue to move forward in a way where there are people who are much, much richer than others, the people who are not rich are going to want to be richer and that will, in one way or another, lead to conflict, as it normally does. I was describing to a reporter today who was saying ‘I am skeptical’, let’s just take Singapore. The city and most people here are very well off, I bet I can walk down with a thousand Singapore dollars taped to my forehead, and I bet with you that no one would hurt me, no one would try to steal the money from me, they’d stare at me and wonder who I am, but that’s the nature of being in a place where everyone is reasonably well off. It feels safe, and it works well, and the world’s going to have to be that way until we manage to get the vast majority of people up to a standard of living where they don’t want to risk all to have what other people have.

While science is our best means to find solutions in my opinion, it's a very logically consistent system, it is not guaranteed to find solutions to problems that we may create, there may not be a solution, or it may be that we cannot figure out the solution fast enough. So science is a great tool, but we need to give it as much help as we can.

I was reflecting that science indeed is a bridge across humanity when reading the Australian news of a possible leak at the International Space Station. The ISS has a couple sides, the US side, the Russian side, and this problem seemed to be on the US side, so what happened? Everyone on the US side jumped to the Russian side, and they closed the hatch and together they were figuring out how to make everything work. At the same time we are discussing various things with Russia on earth where we are not so civilized. Up there they don't have a choice, they work together or they die, on the ground we probably don't have a choice either, we work together or we die, but we die in a hundred years into the future and not in 15 minutes. That change of time changes the way we interact, so we need somehow to get – and I don't have a solution for this, but I know we need to do it – we need to realize that problems a hundred years into the future need to be solved just like problems that we face 15 minutes from now, where it is very obvious that we have to work together. Science is a way where we do this all the time, we work together at the ISS, but across science, even in the middle of the Cold War people from all countries were able to get together in science to discuss things. We discussed how the stars were formed with the Russian nuclear scientist and the American nuclear scientist. So it

is a place where we have a culture of being open, and why do we do that?

Because the goal of science is to learn as quick as possible. It is not to hold your information and tell anyone about it, it's about sharing my knowledge, you get credit by sharing your knowledge in science and not by telling people that, yeah, I've already done that, but I don't tell anyone. Also no one would believe you, and if they'd believe you, then they would think that you're kind of an idiot for not telling anybody, because this is not the culture based around science. It is great to help break down the barriers between our cultures, a great place to share. I am not naïve enough to say that everything is going to work out through science, but it is a great place and way to start. We do it all the time. For example 22% of students in Australia are foreign students, and we have people from around the world. It is actually not for free, it's a money making business, but it is a way to go through and transfer knowledge to people from around the world. What is maybe more interesting is that 45% of all the papers, scientific publications written in Australia are collaborations with people outside of Australia. Try to think of something else we do in a country where half the activity is foreign. This is very unusual. It is a very international activity, and you will find here in Singapore that your activity is even more international than the one in Australia. What I really like is who we are work with. Obviously the US, the EU and China are huge, but let's divide through by the number of scientists in each country, and look at who we're working with relative to the number of people to work with. Then this is who Australia works with: New Zealand, makes

a lot of sense as it is nearby, and it is culturally the place that is most similar to us; Singapore, I would say is also nearby and also culturally very similar; but then things start getting interesting as we have South Africa, the United Kingdom which is not a particular surprise, and then we have Iran. We preferentially work in Australia with Iran based on the number of scientists compared to European nations and the United States. Now that to me is a complete surprise, but it tells you something about the nature of science, and it also tells you that Iran doesn't have a lot of scientists, but the ones who are there we work with. That is the beauty of science, and if you did this for Singapore you would find the same thing, you work with people who you don't realize you do, through science. So science can only be the bridge and can only provide the means to prosperity if humanity is willing to share the technology with one another.

What are humanities biggest challenges? Is it health or life expectancy? I would argue life maybe, life expectancy – most of us are already up to 67, here in Singapore or in Australia we live to about 80, while the average in the world is 67. We are getting pretty close to getting all of us live to a similar length of time, but the quality of our lives around the world is vastly different, and so clearly health is an issue. But what allows us to live long lives and quality lives? Having access to good food and nutrition, water, energy, accommodation, it's being educated, so we can get employed, we have stable and safe environments in the form of usually strong governments. So those are the types of things we need, and science can help on many of those things, but not on all of them. One of the things we can't deal with is having a world that instead of having 8 billion people has 20 billion people in it.

Because that's so many people that I am at the point of saying it's going to be very difficult for science to solve the problems of a world that has 20 billion people living in it or 30 billion. If we continue to exponentially grow, you know exponentials are such that the 8 billion will turn into 20 billion within 100 years, that won't be sustainable in any shape or form. But there is an interesting feature that is almost universal around the world, which is as you get rich your fertility rate drops. This diagram shows most of the countries in the world's fertility rates, the number of children each woman has, based on the GDP per capita, and the dotted line is sort of the replacement rate where you reach a steady growth, where you have the same number of people, and already the world is almost at that level where we do not exponentially grow anymore. We are close, but we are not there. If you look at the projections of the world's population, then you can see that if we continue as we are doing now, as indicated by the dotted lines, we will have well over 10 billion people by 2050 and that is going to cause problems. But if we get people rich and the faster we get them rich, then we would level off quite conveniently.

So from my perspective, if we can achieve a level of prosperity around the world where everyone is moderately content and are at the point where the fertility rate drops below 2.33, then that will help stabilize the population of the earth, it will lower the drivers of conflict, because it is people having very little versus people having a lot that drives conflicts. Most of the conflicts, when you look in history, are based on times when people felt they didn't have enough; and it will allow the entire world to focus on living sustainably through the advances in science. But you really do

need that stability to allow science to do its magic, otherwise conflict just destroys everything that you might want to achieve.

Humanity's biggest challenges? We should not underestimate the effects of things that are already in the pipeline. Climate change is being one of it. For reasons I do not understand people who come up and tell me they do not understand anything about science are more than happy to tell me why they're experts on climate, and that there is not a problem. The vast amount of evidence shows we do have a problem, and it is one that we're going to have to manage in the future. It is going to affect weather patterns, impact agriculture, especially in the developing world, and we are going to have to manage that. For example, when weather patterns make crops fail in poor regions, we can just let them starve, but that will lead to conflict. Yet, the total production of the world is through this time capable of supporting everyone in the world. So being able to figure out politically how to share the food and the resources of the world is going to be an important part of this. There are going to be water issues, especially in this part of the word where the glaciers running off the Himalayas are going to radically change over the next hundred years, and this is going to lead again to agricultural issues, for example, in the peninsulas around here, the Mekong delta, all this will look different in the future, so we need to figure out how to do this. Rising sea levels are going to impact. A hundred years from now sea levels can be up to a meter higher, which means places like Singapore are going to somehow either elevate or move up, and you can do that, but what about Burma? This is not going to be so easy, but if this problem is not solved, you have 50 million Burmese on your

doorstep wanting to come to Singapore and that will cause conflict again. So we need to solve these problems together. These factors can be managed with technology, but this also has the potential to create conflict.

What are the prospects for humanity? We have some challenges and I don't want to gloss over and say it is going to be a cake walk, because I think we have huge challenges ahead of us. But what I note long term is that humans have been on the planet for about 100.000 years while the earth is around for 4.54 billion, so our time on the planet is very short. If you think of the entire life span of the earth being one day then humans have been on it for the last 2 seconds of that day. So we haven't been here for long, and I think sometimes we take it for granted that we will always be here; we should not, because there are challenges and they are probably a hundred years from now and they may not affect any single person in this room substantially, but they will affect your children and your children's children unless we deal with them now. We need to deal with them gradually and get better and more sophisticated, but they just cannot be ignored.

What can we expect for the future? I told you about climate change, but there are other things that can happen, for example, the earth likes to through a super-volcanic eruption every 5000 years, that doesn't actually warm the earth up, but cools it down and causes crops to fail. Think of the world where we got one of these things and where the crops fail for a few years, not just in one place, but across the entire world. Is our current infrastructure able to handle that? We could, but we have to work collectively

together. I grew up in Montana, and it turns out that Yellowstone National Park likes to do this every 100.000 years, more close to home, Indonesia likes to do this every 20.000 years as well, so it's not something you can say that will never ever happen. I can't say it's going to happen tomorrow, but it is something we need to worry about. In a longer term the world does go naturally through warm and cold periods, things that would dramatically change life here on earth for humans.

The sun's nuclear reactor is getting more and more powerful over time, the sun is gradually heating up, and in about 500 to 800 million years from now the earth is probably going to be approaching 100 degree centigrade, and that's not going to be good for us. There is not much we can do about that except to move to another planet. Mars will probably be comfortable, it doesn't have much of an atmosphere so we have to figure out how to deal with that, but think of how much time we have, how much we have done in the last 100 years, think about how much time 500 million years is compared to the 100.000 that humanity has already had. Science has the ability to solve problems like this, if you work collectively, and that's what is so amazing about humanity, because we do have amazing abilities when we work collectively. Finally, Mars is not going to be good enough long enough, because in 5 billion years from now the sun is really going to change gear, swell up to become a red giant and will consume the earth, or if not, the sun will just simply die.

Now, let's think big. This is the galaxy. Our galaxy has got 100 billion stars in it and is about 100 thousand light years across, and when we look out to a tiny little piece of the sky, shown here, which I am going to zoom in using the Hubble space telescope, I see 20 thousand galaxies in this tiny part of the sky, each with about a 100 billion stars in it. What is remarkable is that we humans have been able to figure our part in the universe, despite being an insignificant little speck in it. People always say, are we alone? Well, I don't know, we haven't yet figured that out, but in the next 15 to 20 years we are going to be able to answer this question. We are going to be able to start answering this question, because we are going to be able to look at the atmospheres of nearby planets. 20% of all the stars in the universe have planets and the ones in this distant part of the universe, we can't see their individual planets, but the ones in the nearby part, around our galaxy, we will. So maybe 5 billion years from now humanity will somehow, in whatever evolved state we are in, be able to move to the nearest stars. Let's think about that a little bit more. The nearest star in the sky which you can see in Singapore, because being on the equator you can see every star in the sky, on those clear nights that you often have, the nearest star in the sky is Alpha Centauri, 4.3 light years away. The problem is that that is a long way. 300 thousand kilometers per second, something that a Maserati that passed me on the way here doesn't quite achieve, it takes a long time to get there. However, if you use some of the technology we have right now, then it will take you 26 thousand years to get there. So clearly if we want to go there we have to come up with a way to deepfreeze ourselves or whatever way to make this possible.

That is actually quite interesting, because imagine we are able to travel interstellar. We would not go to Alpha Centauri, because we are pretty sure it doesn't have something that looks like a habitable planet around it, but there are some nearby stars that do. But once we got there, it doesn't have to take us long to mess up earth, and we were able to use up all the resources here pretty quickly, so pretty clear we would be there a hundred years and mess that planet up, and then we have to move again and we would have the technology, so, of course, we would.

How long would it take to move across the whole galaxy? It is roughly 100 thousand light years across, and so it would take less time than you might think, less than a billion years even with our feeble technology of today to go through and visit the entire galaxy, especially if you're exponentially going from star to star and remarkably, as I said, 20 billion of those stars have habitable planets in it. Now this leads Enrico Fermi to think about our chances. He was a very famous guy who helped develop lots of the fundamental nuclear physics that we use in various ways today, he reasoned the following: If the universe is 13.8 billion years old, and imagine any civilization has mastered interstellar travel in this time, then it turns out it only takes half a billion years to populate the entire galaxy at the feeble rates we do, and probably we would be going faster in the future, and so it would have a chance to spread across the entire galaxy, yet, at least myself, I have never met an alien and my own view would be, despite the views of a couple of faculty members in my department, probably no aliens have ever visited the earth. The fact that we see no such civilization indicates that no such civilization in our galaxy and the 20 billion stars that have

habitable planets has managed yet to master interstellar travel. This is known as Fermi's paradox. So we are positive and maybe humanity will be the first, and that is one of the big challenges for humanity long term.

But what I love about ourselves is our ability to keep on inventing ourselves, and it may well be that we are relatively unique in our galaxy. I'm confident there is life throughout our universe, but how many civilizations like earth are out there is an interesting question, and it may well be very, very few.

So science is integral to our future and we know this deep in our cultural selves. Why? Well I want you to think about how culture thinks about the future. In the best way we do this is through movies and these are movies about our future. The genre is known as science fiction. Think of a movie about the future that is not science fiction. I went through Wikipedia today which has, very conveniently, a list with movies about the future and every single one of them is science fiction. Science is integral to the future, and we all know that deep in our hearts that's the way we think of our future. Science can help us, but we need to help it.

What will be humanity's faith? We have the power through science to survive and thrive through most at what the universe can throw at us. But we also have the power to destroy ourselves, to not plan in the future and to become prey to the random acts of mother nature. That is what humanity has before us, our fate is largely in our own hands. But not entirely, because the universe is

a funny place and my discovery that the universe is accelerating tells us that the very distant fate of humanity is sealed, because the universe is expanding, and it is expanding more and more quickly over time. Eventually all of the universe that we see today will be so far away that the light will be not able to reach us from these distant galaxies, because space is being created in between us and those galaxies move faster than light can travel. Our own galaxy, with its hundreds of billions of stars, well those stars will start to die, as well as our sun in 5 or 6 billion years from now, and eventually the smallest stars in the milky way, several trillion years from now, will run out of energy, and we will have a galaxy full of dead and lifeless stars. But it gets even worse than that, because eventually, we believe, even the atoms that make up those stars will begin to decay and you will end up with the entire universe separated subatomic particles with nothing around them except for empty space, and I am afraid there's nothing humanity can do about that.

I will stop there, on that cheerful note, and realize that this is dialogue, so I am hoping I brought you to think about some various issues in ways you wouldn't normally think about them, and now it is time to talk about it and for you to be able to tell me what you think.

Thank you very much.

Question:

If we go back in time before Isaac Newton, was it true that there were also scientists that were hidden from view for many years, yet they made discoveries that subsequently were discovered to have preceded Newton's important discoveries? I am referring to scientists from the Islamic world. How come these people have not been collaborating then, and what has changed since then?

Prof. Schmidt:

If you look back to various civilizations, for example the Mayans in Central and South America had quite elaborate astronomy knowledge through science, the Chinese were very good at predicting where things where, much better than their western counterparts. The whole notion of math, as we know, was developed in the Arab world. We didn't have very good communication back then, that's what it really comes down to, and so there was some technology, the press was being able to produce books, but from some important works there were hardly 100 copies like from Copernicus' manuscript for example, but Galileo could get a copy of it despite being separated in time and space from Copernicus. The tables from Greece had been copied by hand through the ages so they couldn't be widely dispersed, they were handed down from monastery to monastery. So there was a lot of stuff that was lost and when we try to recover, in my field, records from China, because they made the best astronomical observations 2000 years ago, and we have things

that blew up, supernovae, and when we want to understand what happened then we consult these Chinese records. But I would say they were done in a way that is varied on the time they were made and they are not quite how we would do it now, handwritten and only with a single copy. I think it really comes down to communication as being one of the great technological breakthroughs that has helped us work better. One of the reasons the Europeans didn't work very well with the Islamic world around the 11hundreds was that all the crusades were trying to kill each other and that comes down again to conflict being a big barrier to working and moving forward collectively.

Question:

Can science be inherently neutral, or is it something that leans to a positive or a negative side?

Prof. Schmidt:

Science, to my mind, is all about knowledge and truth, so there are good and bad sides to knowledge and truth, and we see that in every walk of life. In my mind science is meant to be neutral, the problem of course is, because things can be used for good or bad, there is always an ethical or moral component to how we use science. Is it knowledge or is it a technology that will almost certainly be used for bad purposes? Now you have to make a decision.

Question:

One thing that is often said in the climate change debate in Australia is that it is a debate and that there are 2 sides of this, but many people who are in science and who are doing research are saying that it's not really a debate, but quite conclusive. From your perspective how do you think public policy in the way this debate is held should go and in what ways could it be improved?

Prof. Schmidt:

Everything in science is a debate at some level, but it needs to be made sure that the debate is between experts in the field. Some people may come up and say that the Big Bang didn't happen and that's fine, you're entitled to your opinion, but if you are an astrophysicist and know all the laws of physics and the evidence and can have a sensible argument with me, then I am happy to have that debate with you, even if I think you're wrong. But if someone just says I don't believe in the laws of physics, then it's not a very constructive conversation, and I am not going to have it with you. I still respect your right to have an ill-informed opinion, but I am not going to waste my time. Just to be clear, I am not an expert on climate change, but I think I have become an expert who is looking at the scientific debates made by the various people who have views on climate change on different levels, and we have to understand that there is a lot of uncertainty among the science of climate change, and we need to have debates, and we

need to be able to say that that is wrong and that is right, that's an important part of it. But we don't want politicians suddenly becoming experts in some area of science when they will literally say in the next sentence 'Well you know I don't understand anything about science, but that climate change stuff is crap!' I am always just stunned when I hear that. Do you realize how inconsistent that is?

As scientists we need to realize that we are here to tell the unadulterated truth. It is not our job wearing our scientist hat and then say 'As scientist we think you should do A, B, C and D as the policy response, because that's a political decision.' We can all have our opinions, but we should know when to move out of the science hat, so I am very keen on discussions of science and facts and probability here and political discussions there and to make it very clear that we do not mix those. Many of my colleagues believe in mixing those, and my own view is that that is a bad way to move forward, because it essentially undermines your scientific reasoning.

So you have to expect people to be able to take the information that you give them and not cherry pick and do all the things that they like to do, but you also have to be careful not to then suddenly way in and say science tells you that you need a emission trading scheme. Science doesn't say you need an emission trading scheme, it says, if you don't do something about the carbon production the following consequences are going to occur. If you abate carbon, using a mechanism like a carbon

trading scheme or something else, these are the effects … That is what science does, and that is different, and we have to be careful not to mix them. I have colleagues who I deeply respect say things on science to public audiences which are not true, which they know not to be true. I ask why did you do that and they answer that they have to combat the bad people who are lying to them, and I say, but you just lied to them, too. We don't want to do that, we have to be straight. That is the role of science.

Question:

Since politics has shown an unfortunate ability to stunt science when it's convenient for it, especially since it concerns itself with the short term, what kind of collaborations do you see for the future between policy makers and scientists in general?

Prof. Schmidt:

You try to get to politicians when they're first in, when they are elected, what you have to do is visit them early before they become jaded. The other thing is, we need to have education. So here in Singapore you are very lucky as you have a very highly and uniformly educated society who sort of does get to science on a deep level. My home country, where I was born, the United States, is in a very interesting situation where the science was, when I was a child, very highly respected by the entire congress with just a few outliners and now that's been undermined, and the

only way I know how to fix it is to convince the population to vote for the people who are sensible and do have the ability to interact with evidence well. My concern is that we have to have a lot of catastrophic decisions made along the way before this becomes clear, but little things can tip the vote. In Australia in 2000 about 80% of the population was convinced that climate change was occurring. Why? The entire country had been in a draught for 6 years, and then it started raining, which was very convenient for my vineyard it turns out, but people then said that the climate change wasn't real after all as it started to rain again, except the people in Perth where the draught continued, and when you look now across Australia then you see that people in Perth believe in climate change as they still run out of water while the rest of Australia where it started to rain again does not. So when people are ill-informed little things will sway opinions. In the United States there was hurricane Sandy that filled the subway with water as it had never happened before and that is something you'd expect from climate change, and that really hit home, because now people in New York really believe in climate change.

It would be nice to have something that affects everyone that doesn't kill to happen to the entire United States, because people need to see things to believe it to be true. What I worry is that things will get more and more astray, and eventually in 50 years or so people will say "Gosh! This really is real!" and "How do we change it?", and then the answer would be that we should have started to change things about 50 years ago. I don't want us to wait for 50 years to see. Ultimately people who are educated and

who understand science get it, so if I really want to fix the problem, then it has to be done through education.