Interview with Prof. Rana Adahkari (Caltech)

Conducted by Ying Li (Tsinghua Center for Astrophysics)

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(This is only my personal feeling, it's not an opinion of any official announcement. ——Rana)

Q(uestion by Ying Li): So thank you for taking the interview, is this your first time to come to China?

A(nswer by Rana Adahkari): I came to shanghai maybe eight years ago. We had a gravity conference there.

Q: So what about Beijing?

A: Never, this is my first time.

Q: What's your impression of Beijing so far?

A: Pretty good. Recently I went to India so I expect something like that， some chaotic place. Beijing actually seems very reasonable to me.

Q: Compared to shanghai which city do you like better?

A: I have yet to experience Beijing. So far I've just seen some labs, some offices and my apartment. So I didn't see anything really yet.

In Shanghai everything is big and looks very nice. I have some time to walk around and see. The market, the clothing market. So when I see the same thing in Beijing, I can compare.

Q: I presume that you have come across many Chinese students. What do you think of their strengths and weaknesses?

A: It's a very tricky question. I can't say anything bad about the students here. I have worked with students from here for a long time. Because of course at Caltech we have many students from Tsinghua and also Peking University. They're very strong I think. They have very intense education in mathematics or something like that. But in general their background on experimental work is not deep in the beginning. But then they are good enough, so that after one year or something, then they become very capable. Usually I would say it would be very similar to India. When they come to us I find that they have very strong background in theoretical physics and mathematics, but not on the experimental side. Because I think it's just a cultural thing. Because in some cultures if you work with your hands very often and do the

hand work like fixing something, your hands get dirty. It's not seen as a high class work. It's a second class or third class thing. Experimental physics is a mix between mathematics, classroom work, also the work with your hands and people who are good in the experimental physics enjoy working with their hands. Sorry it's not just China or India. In many countries, the people who get their hands dirty or that sort of thing, are not seen as the top-level people. But you need to have this experience so that when astronomical instruments get broken, you are ready to fix it. And it seems natural. Just like at home when your coffee machine breaks, someone has to fix it. I don't want to wait for someone to come. I need it right now so I fix it.

Q: So when and why did you choose the gravitational wave detection as your research area?

A: I was thinking about this recently. Because we always think back like: what if I would have chosen this? What would my life be like now? Because when I went to university I could have studied music and then I could be a musician. Because that was my main interest at that age. So I played the guitar; played in a rock and roll band. There are many more people around the world who want to become a famous musician than a famous physicist. So the competition for physics is not as strong as music.

Actually my whole life has been training for the experimental physics work since I was probably three years old, although I didn't realize this until recently. When I was three, my mother started to teach me mathematics. In the U.S. you have to be 4 or 5 years old before you enter school. At three years old she decided that I should learn. And she started to teach me the simple mathematics, so by the time when I became five years old I was more advanced in mathematics than the other children in the schools. My father taught me how to fix everything in the house starting when I was five years old. So by learning mathematics early and learn to fix things at home like the automobiles and coffee machines, television, and video games. That's the perfect training for experimental physics. By the time when I went into university I almost had no choice. My music skill is only a little bit, but my whole life has been training for experimental physics.

Q: But why do you choose physics instead of mathematics?

A: Oh for me physics is much easier. The people who are mathematics experts, whose work is directly applicable to physics, they think differently. You know the whole universe is in their mind. And their thinking is so fast. But my brain is not so fast. It works very slowly just like the turtle. So physics for me is the easiest. In biology and chemistry, you have to remember things. And in mathematics you have to be super-fast. In physics I did the calculations but mostly it is about thinking. So you don't need much prior information. You just need the logic to

think. In the experimental physics it is not important to be so fast. You have a problem and it takes some long time to solve the problem.

Q: Young generation who begins to take interest in science are easily frustrated, do you have any suggestions for them?

A: The important characteristic is that you become obsessed about the problem, and you dream about the problem. And you wake up in the morning still thinking about the same thing. And you spent many many days just thinking, thinking. Then you try some ideas and the ideas don't work. So every day you fail in some way. Then it's okay. Every day you learn something new because you try something and you do not succeed. And then you just continue for a long time sometimes, it's years of time, and you don't succeed. I think some people can become depressed if they do not succeed every day. But I don't mind. I think I'm always learning something. It's interesting to try and solve the puzzle. So we work in the field for gravitational waves for twenty years. For me it's twenty years for other people it is even longer. And it is not so bad. We did not succeed for twenty years and then we did. It's just personality. Some people like to have the reward every day but I do not require the reward every day.

Q: Gravitational wave seems to be a very abstract idea. If you are asked to describe it in a few sentences of words, what would you say?

A: You can imagine that you're a fish. You have two fish, one is a scientist fish, and the other one is a musician fish， The two fish are talking. One fish says that I have discovered water. And the other fish says, what is water? what do you mean by water? Because they don't understand water because the whole universe is, water, all the time. Just like I'm looking at the empty space, and talking about the empty space. And you could say what is there? There is nothing, it's empty. But we know there is water. It's just the fish doesn't understand.

We can study the way the water works. If something shakes in another part of the ocean like a very big fish. Then we can detect the waves. And other people say what do you mean, it's nothing; it's very tiny. But then the fish scientist can say no it's very important. Because we can understand the behavior of the whole ocean: Where is the food? which part is warm? Where is Cold? And where are human beings coming? So we can use the waves in the water to understand the whole universe. For the fish the whole universe is something very small. For us, the whole universe is something very large. Because we're more advanced than fish.

So we use the gravitational wave to make a picture of the sky, which tells us where the gravitational energy comes from and the things which make the gravitational energy. Those things are extremely powerful things. Like someone who is very, very old, whose hearing is very bad. They can hardly hear anything. But if you make a very loud sound, they can hear something. And we are like

that to the gravitational waves. Our sensitivity for the gravitational waves is not very good yet. We're just beginning. Like if you put your hands in front of your eyes you can still see some lights. The very bright lights you can see because it comes through your hand. So you can tell something about the universe but it's not clear.

It's very difficult to think about, because now we have the things like hearing, seeing and smelling and tasting. But gravitational feeling is something that human beings do not have because it is very difficult to describe in words. It's just a new feeling.

Q: Since we cannot see it we cannot feel it, maybe through certain technology we can detect it. What is the critical technology for the first direct detection of gravitational waves?

A: You know the whales in the sea, they're talking to each other all the time but we cannot hear them because they're speaking in different frequencies. But if we make a special technology at least we can listen to the whales even if we don't understand them. We have the technology now so that we can record the whale music. So this is like the new gravitational wave detector which lets us record the gravitational signals from the space. So we take the signal and we turned them into a kind of recording that we can listen to on our phone. Whenever there is something happening in the space, we can record that signal onto our phone and listen to it like music.

The technology we use is Laser Interferometer. It is a very old technology. But we have been making it better for more than one hundred years. So people used to use the interference of light to measure things even one hundred years ago. But they were using something like candles or the sunlight or something like that. Sometimes on top of the water if you get some oil, you see the funny colors, funny patterns. That is the interference of light. The light is making some wave pattern inside the oil. And in the modern times we use the laser. Laser is just like the light from the Sun. But it is precisely just one color. While the sunlight from the Sun makes all the colors. So lasers are very pure. A very large system for making measurement of the laser, we can measure the interference. The interference tells us how much the space is being stretched.

You see sometimes the children blow the bubbles from soap. And the bubbles floating around. If you look at the edge of the bubble, it has many colors. That's because the sunshine is coming into the bubble. And then light is dancing around inside the bubble, like the surface of the oil. The light is bouncing around. That is called interference. And if the bubble is shaking, then the color also changes. So the interference pattern you see that is changing the color is telling you something about how much the soap is changing. So that's the technique we're using.

Q: What is the most difficult setback you've encountered in the discovery of the gravitational waves?

A: People. Nature is very simple, very easy. But people are the most difficult thing in science. Because people cannot be predicted. You have a large number of people, hundreds of people. And everyone has to work together somehow to make this discovery. And how to coordinate the effort. If everybody does the right job, then everything would have happened a long time ago. But you have to somehow coordinate the minds and efforts of all those people. And everyone has some feelings all the time. Like I'm happy. I am sad. What will I do on the weekend? And what food do I have for lunch? You want to tell them just be quiet, do the work you're supposed to do. And all of us work together in the same direction. It would be so much more powerful if we work like this in the same direction. But instead everybody's moving around in different directions. Maybe ten percent is in the right direction. Ninety percent is in chaos. So people are very difficult but machine is very easy. During the times when everybody kind of feels the same passion for the same thing, we are very powerful. Sometimes we have three or four people working together. And they have the same good feeling about what to do next, and then everyone has the same idea. Everyone agrees. And the work goes really fast, and the progress is really great because everyone gets excited by the same thing. It's an incredible time, but most of the time is not like that.

Q: How large is your team? Who contributes a lot to the team?

A: It's difficult to say because it’s like asking how big is your family. It's a very broad thing. There are people working directly on the instruments. However, besides these people, there are many, many more people in the last forty years who have been doing some discoveries. Maybe they're even in different countries. But it helps in this direction. For example, some people are developing laser systems. Some people are developing the computer software. Some people are teaching. Because of the teaching of the young people, after ten years the young people become really great. It's difficult to define what the group is. Because it is the combined work of so many people.

Q: How do you think about the American research funding system, or management? What do you think about the tenure track system?

A: The tenure system is fine. I don't know, when I'm very old I can give you wisdom. A lot of young people are worried about the tenure problem because what if they start working and do not get a permanent position. Does this mean after you've achieved this status, now that you have a permanent position, you no longer have to work? For me there was no change. I cannot tell the pre-tenure year and after-tenure year. I have the same interests so I keep working.

But I can't say if it's a good system or a bad system. Because I don't know other systems. Some disadvantage is that young people feel a lot of stress during the tenure decision time. Usually in the US one begins as an assistant professor. And after five or six years, they make some decision. If the decision is positive, they stay. If the decision is negative, they have to find another position. That can be very disappointing for a person. After working so hard for six years, it isn't nice. But the purpose of this system is that if you get someone in the position, they should stay there for a long time. You want to make sure they're really a high quality person. Because they are responsible for managing the whole research group and teaching so many students. This person should really be very qualified. So there should be some system but somehow this system should be nicer.

For Astronomy, the basic research in physics and mathematics, it is not very directly applied. I apply for the funding, let's say if the government gives me one million dollars, they would expect more than one million dollars of profit. Sometimes maybe they give one million dollars and in five years, we should give back some important results. This is true in some place. A company like Apple or Samsung does some research into electronics, they have to turn that research money into profits very quickly. And that's reasonable. So it's kind of amazing we are living in a world that some countries are willing to put money in for the long term. Because they see the benefit and they want to put money into this research. And the scientists are doing the work, only because of their internal curiosity. They want to understand how things work. And we should support this kind of thing because it is part of the main essence of human beings to try to find out new things or do things. In the past they find sometimes it takes fifty years or a hundred years. That you put money into the research and the profit comes one hundred years later. If you think many many years ago when human people are struggling to survive and eat and everyone is dying because of disease, we didn't have the time to do the research that needs hundreds of years. But now the human beings are at such a good stage that we can put efforts into things that have one hundred or two hundred years before they return. So it is a great achievement of humanity. I can imagine in the future, the government funding agencies would give money and say do this research into mathematics and maybe in one thousand years, the mathematics will become useful. I think it's very noble. I'm very pleased by what the world is doing.

Q: What would you expect for the next major achievement of gravitational waves?

A: In the next few years, I think we maybe just detect many more waves from the same kind of thing that we have found. So we found the signals from the black holes. And I think we should make the machines better. We will find more signals from more black holes. I often think about these questions from the point of view of, what if I'm not a scientist. I do not like people wasting my money. In some countries the government wastes money. So I'm thinking if we already

have the gravitational waves why do we need more of them, we have one or two, give me ten or twenty?

The reason that we want to use this is not just say that we have detected one thing but we would like to use this signal to learn how the universe works. Because it is a new kind of information. So when the first time somebody invented the phone they just say hi and hello. They now use the telephone to talk a lot. That is very useful. The gravitational waves tell us something happening in the universe. If we get ten of them that's fine. That tells us ten times more about the universe. But as we make the instrument more and more sensitive by listening to the music of gravitational waves, we will find details about what is happening in the space. So the very small details can tell us a very big picture.

Q: Why do you think the discovery of gravitational waves are significant for the mankind?

A: There is no easy answer for that question. Well it may turn out to be not significant in the end. We don't know. But of all the things happening in the universe, we understand something about the beginning of the universe. And we use all kinds of telescopes to learn things about the temperature of the universe, how bright this universe is and how many stars there are. All of those things you can ask: what is the use? why do we even look at the sky at night time? What is the significance of mankind seeing stars? We look and people feel inspired. And gravity is another way to look. Gravity is so different from everything else that people used for the telescope. What we can imagine is that the picture of the universe made using gravity will completely change what we think is out there in the universe.

Q: What will be the critical technologies for the next generation of the gravitational wave detectors?

A: We have a lot of arguments internally. And that is a good thing. Everyone who is thinking about the next generation detector has some great ideas. And they are different from somebody else's great ideas. So we come together we all discuss, and then we have some arguments.

Q: So what do you think is the critical feature of the next generation detector?

A: One is that the detector should be larger than the previous one. When the gravitational wave comes it stretches the Earth. And if your detector is one meter, then you cannot find the signal. And if it is one kilometer you can barely measure it. If it is ten kilometers or one hundred kilometers, then you can measure much bigger. So for the countries which have enough space, their large detector can be the leader of the world. That's one thing requiring some money, but it is basically easy. Because it just repeats the same thing. But we can do much better than that one.

The two major problems of the gravitational wave detection are: one is that the mirror is moving too much in the system that the instrument is vibrating too much. The second one is that how can you measure the vibration using the laser. Recently myself working with Yanbei Chen who is also at Caltech, we've been thinking a lot about the second problem, which is how good can you measure something using laser and what is the limit. And people often think about quantum mechanics and say there is a limit. Because the world is not smooth, the light we have comes in some individual pieces. When you shine your laser beam there are many pieces called photons. We'll look at the light with some very fast instrument you can see that the light power comes in pieces. But we understood recently that this limit is not a real limit. The details are very complicated. But the point is if we have a good understanding of quantum physics and we have a good understanding of our instrument, we can surpass the limit that we used to think is there due to quantum physics and by a large number, which means we used to think that we will make a big detector or a small detector. And the limit is… we are very close to the limit of what can be done with human technology. But now our understanding is that by understanding the laser physics and quantum physics better, we can make the detector so much more sensitive than it is now, that we can find all the gravitational waves in the universe. And that means we can measure the beginning of the universe. When the universe began there should be a sound and that kind of sound is mainly in gravity right in the beginning. And the vibrations from that sound should still be drifting around in the universe. And we would like to listen to them to find out what was the sound at the beginning of the universe.

Q: Recently the Indian government has funded the LIGO India. How much is the fund? And why is that important?

A: It's around one hundred and eighty million dollars. The idea was that the US LIGO Project will have three detectors. We will put two in the same place and one more in the other place. But then ten years ago the idea came out to take one of the three to put in a separate country. The idea is that the more separated the detectors are the more time it takes for the gravitational waves to get from one detector to the other and the bigger the distance the more delay. And with more delay, we can tell a little bit better where the signals come from. So you can think about it. If you only have one ear you cannot tell where anything is coming from. You need two ears to tell the direction and that is because we think everything is on the ground. But if we also have things coming from, up or below, then we need three ears. You have to look at the whole globe. We have two in the US and we'll have one in Italy, which is from a different group. And then the Japanese group will build one in Japan in maybe two or three more years. So then we will have four. But four are all in the north. So we'd like to have one in the south.

Q: Given all the facilities, do you think it is necessary for other countries like china to build another one?

A: So this is for curiosity, not necessity. I would say if China gets involved then this is an interesting time, because China can become a world leader in this field. There are a few reasons I think: Now we have a much better understanding of the technology; the current detectors being installed in the world are using the knowledge from ten or fifteen years ago. Our new knowledge is so much more advanced that if we build a new detector today, it will be very different from what we designed ten years ago. And we also understand the idea of a larger detector. So in China just making the detector larger and using one or two new technologies, the detector could be ten times more sensitive than the current generation. Ten times means it can see ten times farther away. And ten times is just the range but when you think about the volume of the space, and how many sources there could be. So if the detectors are made so much more sensitive then the Chinese detector will be detecting one thousand times more signals per day than the other ones. That is a huge number. That means maybe the other detector may find ten signals per day but the Chinese detectors will be recording ten thousand gravitational waves per day. And there is a big difference if you have a few signals or if you have many signals. Like we are talking in a small room we can tell by the sound of my voice that the room is small. Because you can hear the voice coming back from the walls. And in the same way gravitational waves are like some kind of noises happening in the space. And when that signal travels to us, it tells us something about the shape of the room, and in this case the room is the whole universe. And we have questions like how big the universe is. And how big the universe was a long time ago. When it was small, when it was big and we think that we have three dimensions like this. Up, down, left and right. Maybe in the past the universe is in different shape, and the universe is more flat, and then it became big. Or maybe somehow in the beginning, there were more dimensions than three. Instead of three it could be four. And we almost cannot imagine what that means to have four. It is an opportunity for China to find other universes and other dimensions. It will be the biggest scientific discovery to find out some really new things about the geometry and the history of the universe.

And even deeper I think. To us it is still a very much mystery why Einstein's theory of gravity is true. It is a nice theory and it seems to be true. But we do not know why it is true. Could the universe be different? Maybe if our gravitational waves are really precise, we find out that Einstein's theory needs a correction. Then after one hundred years, we make a new gravity theory, and there will be a new Einstein.

Q: Before the announcement of the Nobel prize winners, a lot of people think that the LIGO team would win the Nobel prize so how do you think about it? Have you thought about winning the Nobel prize?

A: No. I prefer not to. Because I like the work I'm doing. If you have the Nobel prize you cannot play the game anymore. The person who is rewarded the Nobel prize will be moved from the football field and become the owner of the team or the coach. But I still like to play on the field.

We have the scientific discovery. It is great. What is a bigger reward? The Nobel prize is some money and a gold medal. But none of those things can compare to the joy of the discovery. Now we have the discovery, we have the new knowledge of what to do next. And the number of new discoveries will get even more. I think it's a great prize for people. Some People win the Nobel prize and the rest of us continue on the exciting adventure. I think it is a great honor to get the Nobel prize. And people should get it. But I have plenty of honor already. I feel just the chance to work with these great scientists is already a whole reward by itself. It's so much fun.

Q: As far as I know India does not have many experts in this field. So how do you build up your expertise?

A: It is very tough when the project was approved in India. How to build up the expertise is a problem. Well, it is very challenging. I think the main thing is that the initial fuel is there. You have the young university students and high school students. They don't know the details of experimental or theoretical physics. I think reading stories can be inspiring to people. Like a lot of scientists now watch these things like star-wars and learn about the space and ideas. And in China and in Germany many people are excited by these ideas, Like space aliens, black holes. and that is all that is required. And we always need young people. And these people can come and ask the crazy and interesting questions. And in five or ten years they become experts. Anybody can do it. And then they can win the Nobel prize.

Q: How do you balance your work and life?

A: Work is just one piece of my life. It should be a good piece I think. Because it takes so many hours. Even if I am on a train and it takes two hours, my mind is just thinking about my work. There is some detailed work when you work on instruments and things are happening. But sometimes the important work is just having some coffee with some friends, and having a fine discussion about something like what would we do on weekend, and shall we go to the beach. You know you watch the ocean or something like that and you get some great idea about science. I am having fun and then I have a great idea about science. So for me the life and work is just a mix. I think people should work as much as they feel like so they are very excited about their research. They just work as much as they want and then they feel tired. They should go do something else and relax and enjoy some other things. And then their brain starts asking them more and more about their work problem. So they can go back to work and keep

going. It's not good to keep working if you're not interested. Being driven by the curiosity is the best way.