The Norman Transcript, Feb 9, 2002

Talk About Town

How big is the universe?

Father Joe Ted Miller: Rector, St. John's Episcopal Church

Dr. Yun Wang: Theoretical cosmologist

MILLER: Yun, I have never spoken with a Chinese woman cosmologist before.

WANG: It is my pleasure to talk with you.

MILLER: Do you find that a lot of people don't even know what cosmology is?

WANG: It is true. It is really a shame.

MILLER: What motivates you to be a cosmologist?

WANG: It started when I was a teen-ager. I always wanted to understand the universe. As soon as I found out that cosmology is the science about the universe, I just went for it. Does that answer your question?

MILLER: Yes. I think most children wonder about how the universe in terms of, "It looks so big out there," with the stars and all. Some ask, "Where does it all come from?" Others ask, "What is it made of?" Others ask, "What does it have to do with me?" Some people say, "Can I ever go there, out there?" What did you ask?

WANG: Well, the science of cosmology answers all of those questions, except for the last two. Some astronomers are interested in the last two questions, because they are trying to search for life on extraterrestrial planets. The questions that I ask in doing cosmological research are, "What is the most important and exciting research that I can contribute right now that will further our understanding of the universe?"

MILLER: What really motivates you in cosmological research right now?

WANG: One project is to try to understand the pattern that is behind the distribution of the galaxies in the universe. All the galaxies that we see come from really tiny, primordial seeds of concentrations of matter, you know, when the universe was very, very young. So, by observing the galaxies and studying the pattern of how they are laid out today, we can try to infer how the primordial seeds were distributed. That, then, can also be related to particle physics theories about the very early universe, say, when the universe was 10-34 seconds old. What happened then? All these things are connected. The other project that I work on is to see what other means are ultimately the best ways of using cosmological standard candles to study the fundamental properties and the fate of the universe.

MILLER: What's a cosmological candle?

WANG: A standard candle is a candle that you know exactly how bright it is. Cosmological standard candle is something that is out there. Actually, the best candidate for a cosmological standard candle is a Type 1A supernova. You have probably heard of them because some people in our department are world-class experts on that — David Branch and Eddie Baron.

MILLER: I remember studying candle light. A lumen — wasn't a lumen a candlelight power of one candle?

WANG: I am not sure because here, actually, the unit of brightness that we use is actually the brightness of the sun.

MILLER: So, it is interesting to me that we go from candlelight, one sense of candle power, as in horsepower...

WANG: ... to many orders of magnitude brighter than the sun. They are basically the explosive death of a star that has just the right mass. So, when it dies, it explodes. After the explosion occurs, nothing is left behind. We have seen hundreds of these. They all have almost exactly the same brightness at peak. Now, you see what I am getting at, right? So, if we know what to expect in terms of brightness, then if we observe them and measure how bright they are, we can infer where they are placed, because their apparent brightness goes down as $1/distance^2$. Suppose, we observe hundreds of thousands of this Type 1A supernovae over the universe. They have different distances in different parts of the sky. Then, we can infer where they are placed in terms of distance, right? Then we can have sort of a three-dimensional picture of where they are. When we observe a supernova, we can also measure its redshift — how much its light has been shifted to the red, which is actually part of the consequence of the expansion of the universe. When the universe expands it is sort of like the raisin bread rises. It is the fabric of space time that has been stretched. So, the light is also stretched with it. If you stretch the wave length, it gets redder, because red light has longer wavelengths than blue light.

MILLER: And therefore you can tell?

WANG: Yes. So, now, we get to the spectrum of a supernova and we know what its spectrum is supposed to look like. So, by seeing how redshifted, how much shifted to the redward compared to a local supernova that is nearby, we can tell by how many times the wavelengths of the light from the supernova has been stretched. That tells us, basically, how big the universe was when the light left the supernova. Light travels at constant speed, right? You know that the speed of light is the absolute optimum of anything that can travel in nature. The universe started out small, right? When it expands, it gets bigger and bigger. So, if the supernova is very far away from us, then it will take light a very long time to reach us, right? If we see a supernova today, we are actually not seeing its image today. We are seeing what it looked like, say, 10 billion years ago. So, back then, the universe was a lot smaller. To go from a universe that was back then a lot smaller to the size of the universe today, then the universe would have to have expanded by huge factors. Well, that factor is reflected in the redshifted spectrum of the supernova. So, we really can tell. Today, in cosmology we have several different independent observational tests which tell us that the age of the universe is about 15 billion years.

MILLER: So, Dr. Wang, in a way, as a little girl, you looked at the universe and one of the questions you asked may have been, "Where does it come from?" and "How big is it?"

WANG: Yes.

MILLER: How in this world on Earth, can you measure how big that world is out there? Do you have a big ruler?

WANG: Yes.

MILLER: What is the ruler?

WANG: There are several rulers. One ruler is the distance that sound could have traveled since the Big Bang to when the universe first became transparent.

MILLER: What makes us think that there was a Big Bang?

WANG: Well, because today everywhere in the sky we see this very, very cold background radiation. That is what has been referred to as the afterglow of the Big Bang. But, if you trace that back how it was distributed, how the temperature varies very, very slightly, like 1 part in 100,000, then everything points back to a Big Bang having occurred.

MILLER: So, in a sense, the cosmologist says everything is coming from somewhere, some original point?

WANG: Actually, no, because the Big Bang actually happened everywhere at once. So, in cosmology, there was no universe until the Big Bang.

MILLER: Was there a first step? Some people move off to the religious answer and say God took the first step and the cosmos began. I know the cosmologist does not immediately pause at an external source for the beginning, but rather, as I understand it, looks at what they observe about the universe now.

WANG: Right and how far back in time we can infer.

MILLER: So, that is the critical inference?

WANG: Right, exactly. I think that is what science is all about — inferring from observational evidence.

MILLER: Aside from what sometimes is an easy religious answer as in, "God caused it," the cosmologist-scientist says, "Let's see what we can tell from observation."

WANG: Yes. What cosmologists do is really to go observe with as big of telescopes as we can lay our hands on and see what are the clues for the fundamental principles of why things are the way they are and keep on gathering more data and keep on inferring further and further back in time to how the universe started. But, we cannot answer the question of what caused the Big Bang. From the evidence we have, we can go back to say a time that is 10-34 seconds, as I mentioned that already. But, then, also if we add a little bit of speculative thinking...

MILLER: Like Hawkings does?

WANG: Yes, then we can try to go back to a time that is even closer to time (T) = zero. We can go back to 10-43 seconds. We can not go beyond that because at 10-43 seconds, even space time, was not well defined because quantum physics would become very important. So, space time itself would be fluctuating. So, that is why I say that empirically in cosmology we can never answer, "Why was there a T = 0, zero time?" "Who started the clock going?" Some cosmologists attempt to address that as well. It is sort of interesting. They suggest that maybe the universe is infinite. So, here, in different local regions, you can have different things going on. So, suppose that in a region where you have a lot of mass, things are going to, you know, get even denser and denser, because gravity makes mass pull into itself, because gravity is attractive, so if it gets dense enough, you know, extremely, extremely dense then you are going to have a Big Bang there.

MILLER: Another bang?

WANG: Exactly. You can have multiple bangs. That is a fascinating idea that a Russian cosmologist, Andrei Linde of Stanford, proposed. There he was attempting to go beyond what scientific evidence supports.

MILLER: Do you ever wonder, Yun, simple questions like why it is so big?

WANG: First of all, it is so big because it is so old. The universe expands, so if it is 15 billion years old, it is really, really big. I don't think I can ever answer the question, "Is there a purpose behind the universe?" That may be more in the domain of something other than science.

MILLER: Is truth's trueness relative to the discoverer's experience of it?

WANG: I hope not, so the truth that we are believing would have to transcend beyond the particular discoverer's bias. That is why I was drawn into science, because in science someone can claim to have made a discovery and they can claim all sorts of things. But, it is never accepted as fact or truth until it has been verified by many other independent scientists.

MILLER: As a person who grew up for 21 years in mainland China, and now has been an American citizen for a year or two, but has lived in this country since 1985, you bridge many cultures. You are a woman scientist. You transcend the earth to the heavens.

WANG: I hope to. I try. The way I see it is that politics is sort of intimately related to the complexity of human nature. That is why it is so messy at times. It is unpredictable. Science is sort of transcendent of human nature. Humans are mere mortals trying to pursue some truth that is beyond our everyday existence, beyond everyday life.

MILLER: And then there is the difference between women scientists and men, especially if they come from China and then continue to grow on this side of the ocean.

WANG: I think the difference has been used and exploited in different ways in different cultures. The physical differences between men and women have sometimes been extrapolated to mental differences, which have been used to discourage women from becoming professional scientists, which is really a shame, because I don't think there is any difference to mental capabilities between men and women.

MILLER: Some of that is religious in origin and some of that is political.

WANG: Yes.

MILLER: And some of that is experiential or social.

WANG: Right. But, if you keep on discouraging women from entering professions where their mental capabilities will be challenged and displayed, then you keep on pushing women into professions which you do not consider to be very brainy. You sort of perpetuate this stereotype of women not being brainy.

MILLER: So, it comes back to experience?

WANG: Exactly. Exactly.