Nobel Voices Video History Project, 2000-2001

Interviewee: David Lee
Interviewer: Neil Hollander
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HOLLANDER:

If you could just begin by stating your name and briefly identifying yourself.

LEE:

Okay. My name is David Lee. I am a professor of physics at Cornell University in Ithaca, New York, in the United States of America.

HOLLANDER:

Could you say something, first of all, about what may have interested you in science for the very first time in your life, if you can remember that?

LEE:

Well, as a child, I was always interested in railways, and I was a collector of timetables. I also made up my own timetables, imaginary timetables, and worked out all the schedules for the trains and so on and so forth, I guess when I was about seven, eight, nine, ten years old, roughly, and that was one of my hobbies. As I got a little older, I became interested in meteorology, the weather, and subscribed to the weather map every day.

Then one day, I was looking at my father's library, and it had one book on the shelf entitled the *Mysterious Universe* by Sir James Jeans. I asked my dad, I said, "Dad, what about that book?"

He said, "Oh, nobody can understand that book."

By that time I said, "Well, hmm, I'm ready to go out on my own and try to understand it." So I read the book, and I was tremendously fascinated. It was in the early 1940s at the time, somewhat after the time of general relativity and the ideas of expanding universe. This book just absolutely fascinated me, because it told us the story about how, according to the knowledge of that time, the universe developed. I said, "This is so exciting that I think maybe I'd like to be a physicist."

So I went to college and majored in physics, but I also had some idea that I'd like to go around curing—running around in a white coat, curing people. I took a little bit of pre-med, but somehow I decided that medical school was not my cup of tea. So after three and a half years of college, I graduated, and I ended up in the army for two years. After that, I came back to graduate school, and by that time I was really determined. I think the military service makes you grow up and realize what you really want.

So I grew up and I became a physicist. I went through all of the—I went to, first, the University of Connecticut for a year and then went to Yale for my graduate work, and studied at Yale and was awarded the Ph.D. degree in 1959. My Ph.D. was for a thesis in experimental low-temperature physics.

At that time, helium-3 first became available. It was a decayed product of tritium, which was an ingredient in thermonuclear bombs. As the tritium has a twelve-year half-life, so it took time for the tritium to decay, and as the tritium decayed, it converted into the helium-3. That helium-3 was collected and became available for university and government laboratory research. So my project involved liquid helium-3, and that's what I worked on for many, many years, culminating in our Nobel Prize experiment, which was conducted at Cornell with a fellow faculty member, Bob [Robert C.] Richardson, and a graduate student, Doug [Douglas D.] Osheroff. We continued in that field, as well as doing other work, in low-temperature physics until the present day.

HOLLANDER:

What was special about helium-3?

LEE:

Well, helium-3 is the rare isotope of helium. The common garden variety, if I may say, of the helium that's found in the gas wells that's coming out of the earth is helium-4. Helium-3 is a stable isotope, but a rare isotope, of helium. The difference between helium-4 and helium-3 is the fact that helium-4 is heavier. Helium-4 means that there are four; there are two neutrons and two protons. So there are four nucleons in helium nucleus, helium-4 nucleus. The helium-3 nucleus has two protons and one neutron. So it has an odd number of nucleons. This even/odd thing is very important. Helium-4, even number of nucleons, helium-3, odd number of nucleons, this is very crucial in the behavior of aggregates of helium. And this was essentially the focus of our studies for many years.

HOLLANDER:

If we can continue along this line, just if you can talk about the essence of your Nobel Prize-winning discovery, and especially how you would describe that, let's say, to a sixteen-year-old, if it's possible to do that, to be partly your audience.

LEE:

Okay. Well, I should first talk about helium-4, which was discovered to become a superfluid and by various experiments in the 1930s. Among the experimenters, famous experimenters, was Peter Kapitza, a Russian physicist who later won the Nobel Prize for some of his work in helium-4.

But the basic idea is, a superfluid is a fluid which can run through cracks and leak through very tightly packed powders, with no viscous resistance. It can just slide right through. You get a phase transition in liquid helium-4 called the lambda transition. That's for the shape of it, the shape of the specific heat current. What happens is as you cool the liquid, you can cool the liquid by pumping on the liquid. The vapor comes off. All the hot liquid molecules get pumped away, and what's left behind gets colder and colder and colder as the process continues.

When you get to a certain temperature, which is actually 2.17 degrees above absolute zero, the liquid undergoes a very strange transition. When you first see the helium, it's bubbling like champagne at 4 degrees, 4.2 degrees, the liquefaction of the temperature of helium. As you pump on it, it bubbles more and more vigorously. As you approach the lambda point, it bubbles very, very vigorously. At a certain point at the lambda point, suddenly the boiling stops and the liquid becomes completely quiescent. It's still cooling down, but it's completely quiescent.

What has happened is the helium becomes a perfect thermal conductor, so you no longer have the possibility of localization, little local hotspots, which can produce nucleation of bubbles. So the bubbling ceases because of the large thermal conductivity of the helium-4.

This, another thing that happened, for example, when I was in high school, a kid came up to me and he said, "Well, I read somewhere that if you take a test tube full of liquid helium, it will run over the sides and down and drip and empty the test tube."

I said, "No, no, that just can't be so." But little did I know that I'd be talking about it here fifty years later or perhaps more like fifty-five years later. So here we are.

So, helium-4 is a fascinating fluid, and I can spend an hour talking about it, but I won't, because I really want to talk about helium-3. So liquid helium-3 is different from helium-4 in the following sense.

[Taping interruption]

LEE:

Let's see how we go from here. Okay. Where was I? I was talking. I was about to talk about helium-3.

First of all, helium-3 becomes superfluid because helium is a quantum fluid. We have to think of each helium particle as composed of a packet of waves. As you get colder and colder, according to quantum mechanics, those wavelengths, the wavelengths become longer and longer, so eventually you get overlap between adjacent atoms. After that, eventually, the onset of superfluidity, these overlapping waves somehow organize themselves into a single wave, and it's the flow of this single wave in accordance with the rules of quantum mechanics, which gives you your superfluid behavior.

The process which occurs is closely related to a phenomenon called Bose-Einstein condensation. Bose-Einstein condensation can only take place if you have an even number of nucleons, an even number of total elementary particles. Let me go back and say helium has four nucleons; two protons, two neutrons. Helium-4 also has two electrons. So the total number of elementary particles is an even number, and therefore we obey Bose-Einstein statistics. The even number of particles give us Bose-Einstein statistics, so we get Bose-Einstein condensation. That gives rise to superfluidity, and that happens right at the place, at the temperature about where you start getting overlap between adjacent atoms, quantum overlap, these waves overlap. That happens to be about around 2 degrees kelvin, 2.17 kelvin, where the lambda point is.

Now, for helium-3, that obeys Fermi dERAT statistics. In Fermi dERAT statistics, you will not have Bose-Einstein condensation. I won't go through all the details of the mathematics of this except to tell you that what you would like to do is to get to a situation where two helium-3 atoms could form a pair. Such a thing happens in superconductivity, superconducting electrons. They form pairs. The pairs of electrons can undergo a process which is almost identical to Bose-Einstein condensation, and this gives rise to superconductivity.

A similar phenomenon happens for superfluid helium-3, or was at least hypothesized to happen in the sixties and the seventies, really throughout the decade of the sixties, that you would get pairing between the helium-3 atoms and this should eventually give rise to superfluidity. Now, for electrons, the temperature at which they become quantum fluids, electrons and a metal, is tens of thousands of degrees kelvin. Helium-3, the place where helium-3 becomes a quantum fluid, is about 2 degrees kelvin. Superconductivity occurs at 5 degrees, which is thousands of degrees lower than the quantum fluid temperature. Similarly, you would expect superfluid helium-3 to occur at maybe a factor a thousand below the quantum fluid temperature.

This is indeed what happens, but people looked for it and didn't find it. It turned out with our method, which is a very powerful method, Doug Osheroff and Bob Richardson and myself were able to observe nuclear magnetic resonance phenomena which showed that we had a new phase of matter. The magnetic properties, I should say, rather than saying nuclear magnetic resonance. The magnetic properties showed that we had a new phase of matter. Your MRI machines nowadays use nuclear magnetic resonance, and the experiments, our experiments, used techniques similar to what you would use in an MRI machine. This was the Ph.D. thesis of Doug Osheroff.

HOLLANDER:

It sounds like your discovery is almost an invention of something. You mentioned a new stage of matter.

LEE:

A state of matter.

HOLLANDER:

A new state of matter.

LEE:

Well, it's a quantum transition. Let's put it that way. In that sense, it's a new state of matter. That's a somewhat grandiose way of saying what actually happened, but it is definitely. There are several superfluids available. I just mentioned superconducting electrons in various metals, superfluid helium-4, and now superfluid helium-3. So here we now have one type of superfluid of superconducting electrons, which exists in many metals, a very large number of metals, in fact. Superfluid helium-4, and now our latest discovery in 1972, was superfluid helium-3.

Of course, a large amount of work followed our discovery. We certainly did not do it all, to verify all the very fascinating properties of this liquid. But the initial discovery already was very exciting, especially to us.

HOLLANDER:

Would you, first of all, consider yourself a kind of inventor? And secondly, inventors usually have some kind of impact on life and how we live. Could you trace some kind of line [inaudible]?

LEE:

Well, there was some small influence, actually; the development of MRI. A physicist named Paul Latimer visited our laboratory at the time these experiments were going on, and the technique which we used was very, very similar, although we didn't know about MRI at the time. The technique which we were using was very similar to what is used, was used, in some of the early MRI experiments. Paul Latimer saw our results when he visited our lab, and he became very enthusiastic. I mean, he was already enthusiastic, but he became more enthusiastic about developing MRI. He was one of the principal developers of MRI, so I think in a way we probably made him happy about what he was doing.

So I don't think we invented anything, but at least we were somehow in the loop on this thing in a rather weak way. But we were in the loop, I'd say, in a rather—I mean, we certainly did not push that. We were too interested in what we were doing, but clearly we had possibly a small influence in encouraging Paul Latimer to continue with his work, only a very small influence, I'd say. I think he would have done it anyway, but he was happy.

HOLLANDER:

You went a long way from a fascination with trains and timetables to [inaudible] and this kind of thing. That kind of wonder that you experienced when you first [unclear], did you find yourself fulfilling that wonder when you did your work?

LEE:

Well, I don't know. What I really should say now is that in my next life maybe I'll be a string theorist.

HOLLANDER:

Do you still like trains?

LEE:

Yes. But there aren't very many left in the United States, but they're getting better. Of course, when we're here in Europe, we take full advantage of it.

HOLLANDER:

Do you have model train sets, anything like that?

LEE:

Well, we had ones when our kids were growing up. Now, of course, I don't know, I seem to be so busy, there isn't very much time for it. So I guess I'll ride on the real thing.

HOLLANDER:

What does the Nobel Prize mean to you?

LEE:

Well, I think it's very deeply satisfying, and I think that that—I don't know as it's really changed our lifestyle particularly, but I think that it gives you an even deeper reverence for science. Coming to a conference like this in Lindau, you get to meet many other Nobel laureates, and I think that each person has a sense of accomplishment, which I don't think I would have had otherwise. I mean, of course you're always proud of your accomplishments, but this adds something to that and gives you really a deep feeling of reverence for science, as I said before.

HOLLANDER:

Along the same line, can you generalize about the significance of the Nobel Prize in general for society?

LEE:

I think it occurs—well, first of all, not everybody who does great science gets a Nobel Prize. There are many people out there who do not get Nobel prizes for various reasons. I mean, usually the Nobel Prize is for some very specific discovery, a very sharp advance that takes place in a short period of time. This is not always the case, but a large fraction of the Nobel prizes are this type of thing. So if a person has a long and distinguished career, but you can't point to any singular feature of that career which constitutes a major discovery, a major change in direction of science, then more often than not, that person would not be awarded a Nobel Prize.

So I think the Nobel Prize really is a prize for discovery, for original discovery. I mean, I have great respect for those people who do science who do not win Nobel prizes, but who, nevertheless, do great science.

HOLLANDER:

Looking to the future, what would you say to a young person today to pursue if one were looking for Nobel Prize-winning areas?

LEE:

I don't know. I mean, it looks like right at the moment biology is very exciting, and with the deciphering of the human genome, it may very well be that there will be a large number of discoveries coming out of that. But I think that you're going to find that physics and chemistry and medicine are all advancing very rapidly, and I would certainly not go for the Nobel Prize, but I would advise a young person to pursue his own interests, and if he's really interested in physics, to do physics and pour his heart into it, and he might make a big discovery. Then again, I mean, if he does or whether he does or doesn't, he would probably derive greater satisfaction from pursuing the science he loves, rather than changing one's direction for a particular prize.

HOLLANDER:

If you were looking back again to a point in your life when you decided to go into science as a young person, were there people that particularly interested you? You mentioned the book. But any mentors, any particular people, family, or outside your family that got you going in that direction?

LEE:

I guess I'll have to say no. My family encouraged me to do whatever I wanted, but nobody ever dangled the bait of science in front of this fish. I think it was purely because I loved science.

HOLLANDER:

Can I hit you with a question from left field?

LEE:

Absolutely.

HOLLANDER:

Suppose a little eight-year-old girl were to wander up to you, jump in your lap, and want to go to sleep. What story would you tell her?

LEE:

I don't know. I could probably put her to sleep with some scientific discussion, because she probably wouldn't understand that discussion. But I'm not sure I could really do that with an eight-year-old. I would rather show the eight-year-old various phenomena. For example, we can pump out a bath of liquid helium and what the boiling suddenly stop. That's a very dramatic thing. We could take a little test tube of liquid helium-4 and watch the helium crawl up over the edges and drip off. There are other effects where you can make, if you do certain—if you have a tube with a fine powder in the bottom of it and heat that powder, then you cause superfluid helium to surge up the tube and form a fountain, so you get the fountain effect. So I'd rather say, "I won't put you to sleep, but I'll try to excite you with some of these phenomena."

I could take a superconducting magnet. I mean, I could take an ordinary permanent magnet and suspend it over a bowl by magnetic levitation, a magical levitation. You can almost do this with liquid nitrogen now, because you can do it with liquid nitrogen-cooled high-temperature superconducting bowl and just use a very small ferrite permanent magnet. So you could show levitation, superconducting levitation. All these things, I think, would be very exciting for a child to see. I don't think I'd put her to sleep at all.

HOLLANDER:

You're waking her up.

LEE:

Right. Quite the opposite.

HOLLANDER:

What other things turn you on in life like science does? Music or games or—

LEE:

Well, I love to listen to music. I try to go jogging every day. We do sometimes when we have time—we haven't done so the last couple of years—go hiking in the mountains. We like fishing.

HOLLANDER:

What kind of music do you like?

LEE:

Well, generally, classical music. But I don't mind other things. I don't mind folk music either. I'm not—I guess I'm in the wrong generation to really like rock and roll music. Sometimes I listen to country music.

HOLLANDER:

What do you dislike?

LEE:

I don't know. I don't know what I dislike. That's a—

HOLLANDER:

What gets you angry?

LEE:

Sometimes, I guess, reading the newspaper and finding out some of the foolish things going on in the world, but I don't think I could point to any specific thing that does.

HOLLANDER:

I'm in left field. I'm hitting you from left field. If you're going out to buy your wife a present, what are you going to buy her?

LEE:

Jewelry.

HOLLANDER:

Jewelry. What kind of jewelry?

LEE:

Preferably gold, but next comes emeralds or rubies, and finally at the bottom I put diamonds, because diamonds are carbon, and you can show off—well—

HOLLANDER:

I guess one last question here for you. You were talking about newspapers getting you mad and so forth. What role do you think the science you do, or the role of science has in the larger scene in society?

LEE:

The larger scene in society. First of all, we educate young people and show them that you can do very hard things. I guess we also show people that there is a physical world out there which can be investigated, and science is the best means of investigating, the only means of really investigating that world. I think that this is something that people really have to realize. You can go into a virtual world of computers, but to do the real world, what I really like is the idea that you can do experiments on real things and see what happens. I mean, you can imagine things and do things with the Internet and so on and so forth, but until you see a real system behaving in a real way, no number of simulations is ever going to be satisfying. On the other hand, if a simulation comes along that agrees with our experiment, then I'm extremely happy.

HOLLANDER:

I guess that will be a wrap for us. Thank you very, very much.

LEE:

You're welcome. I hope I've been helpful to you.

HOLLANDER:

Extremely so.

[End of interview]