Nobel Voices Video History Project, 2000-2001

Interviewee: Robert Richardson
Interviewer: Neil Hollander
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HOLLANDER:

Please introduce yourself.

RICHARDSON:

My name is Bob Richardson. I'm a physics professor at Cornell University in Ithaca, New York.

HOLLANDER:

What is it you do?

RICHARDSON:

I do research and teaching in physics in the university. I teach courses to undergraduate students and graduate students, and guide graduate students in research. Then more recently I've been involved in some university administration work.

HOLLANDER:

What particular branch of physics are you in?

RICHARDSON:

Very low-temperature physics. The central idea of the field is to understand how the properties of matter change as the matters cool to temperatures near absolute zero, where all of the energy's been removed.

HOLLANDER:

What is this absolute zero?

RICHARDSON:

That's the temperature at which all thermal energy is gone. It's zero, so it's the lowest state that matter can lie in. That's why there's no way to get colder because there's no energy less than no energy. You can't have negative energy. Except there's special circumstances that people talk about in temperature where you define temperature, for example, by the number of magnetic moments that are pointed in this direction, and that talks about a temperature. If you suddenly turn the piece of material over so that they're pointing that way, that's called a negative temperature. But that's sort of an artificial construct.

HOLLANDER:

Doctor, if I could ask you just one thing. Why are you teaching undergraduates? Is that normal for a man of your—

RICHARDSON:

Sure. It's very common in American universities, of the strong research universities, that people to do teaching as undergraduates as well as graduate students.

HOLLANDER:

Doctor, how did you become interested in physics? In other words, why are you a physicist?

RICHARDSON:

It depends on how far back you want to go.

HOLLANDER:

All the way.

RICHARDSON:

All right, so when did I think there was some amazing thing in science or the universe?

HOLLANDER:

When did you learn to spell the words?

RICHARDSON:

Which, science?

HOLLANDER:

Or physics, either one.

RICHARDSON:

Or physics. Physics, probably in high school. But my first thing that attracted me but was, I remember very vividly, in the second grade, the boy that sat in front of me had this terrific book about the planets and the solar system, and he was absolutely consumed with a passion about it. Then I thought, "Hey, this is really neat." He had these pictures of Jupiter and Saturn, and he'd memorized the names of the planets coming out from the sun and which one was the biggest and how long their years were. So that it affected me, and thereafter all sorts of scientific facts that seemed unusual appealed to me. But through the years that I was in elementary school and high school, I never thought I would necessarily be a scientist. I was interested in all sorts of things, history and music and literature.

So when did I decide to become a physicist? Well, it was by default. I was in my second year of college. I went to Virginia Tech, and I was thinking that I might like to be a chemist. I was taking a course called quantitative analysis, and that particular course in laboratory the idea was to identify exactly the components in an unknown specimen and what their fraction was. In order to do this, there's a procedure called titration. You use phenolthaline [phonetic], and you would dribble it into a solution, and right at the exact point it would let you determine the concentration, the solution would change from pink to blue, or blue to pink, depending on which way you're going. I'm colorblind, so I'd have to go eight or ten drops past that to see when the end point of the titration came.

I fell way behind in the course, and I knew I understood the underlying idea. I just couldn't see it. So I went to the professor and explained that I was colorblind, and could I please use a pH meter. This was in 1955, I guess that was. The professor said no, that "If you can't see the end point of this titration, that's just tough luck, kid. You better be thinking about some other profession." And so I did. So then, fortunately, all the introductory courses for chemistry and physics are the same, so I took physics courses.

[Taping interruption]

HOLLANDER:

Can you go back to the story, when you were in high school.

RICHARDSON:

So when I changed from being a major in chemistry to physics, and that was because I was advised that being colorblind was a sufficiently severe handicap that I could not be a very good professional chemist. So I went into physics, and I liked it very much because I could have lots of liberal electives as well as take physics. I could take math and English literature and courses like that, which I thought, and still think, that majoring in physics or mathematics can be one of the most liberal of all university studies, because there's room to take other things and think about the arts and humanities as well.

HOLLANDER:

Is there any particular book or person during that period [inaudible]?

RICHARDSON:

Not really. I had some very excellent teachers that kind of guided me and had good mentorship in making the things like calculus and the introductory physics courses seem simple and—

HOLLANDER:

None of them particularly stand out?

RICHARDSON:

Nope. I also had summer jobs when I was an undergraduate in college at what was then called the National Bureau of Standards, and I enjoyed that a great deal. I worked in the division calibrating electrical standards. Power companies from all over the United States would send up things like their standard resisters to be calibrated every six years, and my job was seeing if the resistance had changed in the last six years since they'd sent it in to have a certificate made for it.

But I think that made me very comfortable with things in laboratories, and I essentially assumed, okay, I can do whatever I want to. I found that it was easy to understand and pick up the experimental techniques, especially the ones that were used there then.

HOLLANDER:

Can you explain what is it you've done to win the Nobel?

RICHARDSON:

Well, I was a collaborator with Doug Osheroff and Dave Lee, and we discovered a very unusual state of matter. It was the super fluid phase of liquid helium-3. Now, what's unusual about it is that it's a state that's very similar to the most common type of superconductivity in metals, although this is a state in liquid. The reason superconductivity takes place in most metals is that a short-lived pairing, almost like a molecular formation, takes place in the electrons and metals, and the electrons join up with their atomic moments. They're not atoms. Their electric moments, their magnetic moments, rather, opposed to each other, one this way and one that way. The electron has a magnetic moment, and the pairs are formed with the cancellation of the net magnetic moment of the two.

In helium-3, a similar pairing takes place, but the magnetic moments go this way, and those nuclear magnetic moments. First, it's a different kind of symmetry for what is basically the same phenomenon underlying, but this symmetry with the spin equal to one has three possible spoon states. This one's always zero. Then in quantum mechanics, when they have net spin of one, we can have plus one, minus one, and then zero, goes like that, up, up, down, up, like that for the middle one.

Another consequence of that is that if the pairs are formed in that state, they have a different spatial arrangement, and they have an angular momentum. That is, they have an angular rotation of the two atoms around each other, whereas in superconductor there is no net angular momentum. So this gives the material a whole set of new properties that are unique to super fluid helium-3, of things that had been measured so far on Earth.

There's also a speculation that—actually astronomers think that they've proven it, but they can't do the measurements—that distant objects called neutron stars have a similar state of matter in the interior. That is, that the neutrons are close enough that they form these paired states, and that in neutron stars the state is like that in helium-3, with the magnetic moments of the neutrons parallel to each other in the pairs. You can do experiments on super fluid helium-3, but neutron star matter is another question.

HOLLANDER:

Aside from the astronomical implications of [inaudible], is there any line that you can think of that you can draw to some practicality in something we could use now or in the future?

RICHARDSON:

No. [Laughs] It is just one of these things that is an important piece of missing information in the kind of underlying structure of physical phenomenon, and understanding the physical phenomenon. But it's no more useful than knowing that there are distant objects out there called pulsars that send signals to the Earth, or lots of things that we see in astronomy. It's interesting phenomena that had never been seen before.

HOLLANDER:

Doctor, [inaudible]. What kind of metaphysical [inaudible]?

RICHARDSON:

It's not my style. [Laughs] I'm more of a pragmatic person than metaphysical.

HOLLANDER:

I just mean your world perspective.

RICHARDSON:

You know, my world perspective and metaphysical one is—I mean, I think this is an amazing time, by the way, in astrophysics and cosmology. The evidence for the Big Bang is overwhelming. The recent—I won't say recent. The results from the COBE satellite experiment, Cosmic Background Explorer of radiation, looks at the infrared microwave radiation all over the sky, measures it and looks for little places where there might be strong concentrations, with the average temperatures fits the planet radiation law with tremendous precision. Temperature of the universe is 2.72 degrees, and it's just absolutely clear that everything out there started from a single point 15 billion years ago or so. That has pretty significant metaphysical implications, I think.

HOLLANDER:

What I was also trying to ask you, [inaudible] do you think beyond that? Do you ever think beyond that? Do you ever think why is this here? Why out of all of this?

RICHARDSON:

I ask why, but I don't know why, and I don't know that there's any answer to it. That's one of the things that's just one of life's most important—I mean, it's a deep mystery.

HOLLANDER:

Even though you've been playing with it?

RICHARDSON:

Well, I wasn't playing with that, but I mean, you know.

HOLLANDER:

Jumping to [inaudible], has the Nobel changed your life?

RICHARDSON:

The first year after the Nobel Prize, I traveled a great deal giving public lectures all over the world. I did that not only because it was flattering to be recognized and asked, but I think it's also important to try to communicate what the basic ideas and excitement of science is to the broadest general audience possible. Then for the past two years I've been involved in a number of national science and professional society, government and profession society, advisory committees. I had not done that quite as much before the

Nobel Prize, although I was pretty active in activities of the National Academy of Science and the American Physical Society. I maintain those activities.

HOLLANDER:

What do you think is the significance of the Nobel? Did you always want to win a Nobel before? Had it been in the back of your mind, ever?

RICHARDSON:

I think everybody would love to have a Nobel Prize, but it wasn't a consuming thing. I didn't wake up at night dreaming about it or yearning for it or anything like that. When it was announced, it was a surprise. We knew that when we did the research that it was very significant, but the question was, would other people understand how significant it was? We were in a relatively small research field, with only a couple hundred people in the world, really, working directly in that research field, so that it wasn't clear that it's implications for other areas of science would become apparent.

HOLLANDER:

Yourself apart, do you feel that the Nobel is justly given out, that the prizes are justly awarded [inaudible]?

RICHARDSON:

Sure. They're very, very thoughtful and very careful. I don't have any complaints about that.

HOLLANDER:

Are the right people getting the Prizes?

RICHARDSON:

Yes. Frequently, it takes twenty or thirty years, but I think that's also a reasonable thing, too, because the sometimes it takes a long while to fully appreciate where the work fits in the context of other science that's going on. There are many other deserving people, so that there's maybe a shortage of Nobel Prizes. But then the value of it becomes less so that if there are too many, or something. The fields I know about are physics and chemistry. I certainly have no problems about that, the people that have been selected since I've been aware of the Prize.

HOLLANDER:

If I were to come to you as a student and say to you, "Doctor, what do you think I should do? What do you think I should study? What books do you think I should read?"

RICHARDSON:

I have lots of students. I mean, I advise students.

[Taping interruption]

RICHARDSON:

So the first thing I advise students is make sure that you, if you really want to be successful and happy, that you pick something that is interesting to you. If it is not interesting to you after giving it a fair test, move while you still have time, to something that is more interesting. This is particularly important in sort of the balance of research fields that one can select and whether one wants to go through the sometimes painful and long training ordeal of being a scientist rather than being, say, an attorney or a businessman or something.

If the goal is to go into it to make a lot of money, I don't think being a research scientist is a very good path for that, that one, really, by all means, ought to be a businessman or a stockbroker or in some other field. That's important, because in just making a decision about what type of science, what to do, I think it has to fit the personality of the individual. If you can't attack it with a certain amount of passion and, in times, even consuming passion, it's unlikely that they'll be very successful. On the other hand, there are works in the areas of applied science that can lead to a lot of wealth and satisfaction, but it doesn't require the same type of burning passion.

All right, so now, you say what field to work on. That one is a really important question, but there's almost an uncertainty principle in the answer. If you tell a whole lot of people to study one thing, that makes that a very, over the long term, a much less-promising area to study, because there will be too many people in it all doing the same thing and competing. So that my advice is to look for something that not everyone else is doing so there's lots of room to express one's own individual creativity.

But that's kind of a matter of scale, so there's a general area of physics or biology. In fact, one of my favorite areas right now is a hybrid between the two, the applications of physical ideas and principles and techniques to biological problems, and the reverse, looking at how nature's used 4 billion years of evolution to optimize everything, and then take objects apart and study them at their microscopic level to understand the physics and chemistry of how, I don't know, grasshopper legs work or something like that, and see if we can't plagiarize nature to make a unique new device that can be applied.

HOLLANDER:

This is a general question, which I hope you will answer specifically. Has physics made you happy?

RICHARDSON:

Yes. Now, how can I answer it specifically? I can't say how it made me happy. I have—

HOLLANDER:

[inaudible]

RICHARDSON:

I'm intrinsically a content person, so the times when I'm most happy, I guess, and most excited is while we were doing the experiments on super fluid helium-3 and every few days some very new and exciting result we would obtain. We'd think, "Well, what happens if we do this and move it a little bit," especially in the days when we got surprises and got a result that was not intuitive. That was a particularly wonderful time because it was an accidental discovery, and we didn't know what we were going to find and do the measurements.

But there are lots of other times when we've had—my students and I have been able to do things that seemed to be particularly elegant after we learned how to do it the right way. Typically in science, one makes many mistakes before learning how to really make the right measurement on a phenomenon. So that's been fun.

Teaching has been fun. I enjoy both undergraduate and graduate teaching, so I found that that was a very aesthetically pleasing thing. As a cultural matter, this is a very, very exciting time in which to be living. There are lots of rather amazing things that are discovered each year, and I find it very exciting just to be able to understand what those things are and what their implications are for the future of our culture.

HOLLANDER:

Could you give us some details of how that accidental discovery happened [inaudible]?

RICHARDSON:

Well, there's never a moment; it's just a realization of it. And we were doing experiments, and the graduate student who had developed the apparatus for doing this was Doug Osheroff, who's here right now, and he was doing some experiments, testing the cooling efficiency of this crazy-sounding technique of squeezing liquid helium-3 to make it into a solid. And what he observed was that the cooling rate always slowed down at a particular pressure of the liquid helium-3. At first, it seemed kind of impossible that it could be so precisely at the same pressure.

Well, the pressure turns out to correspond to an exact temperature, and that meant there was a phase transition, after we thought about it and looked at it. We thought at the time that it was a phase transition in the solid helium-3 that was in the chamber with the liquid helium-3. We even published a paper claiming that we had found the long sought-after nuclear magnetic ordering transition in solid helium-3, and that was wrong. As we did more experiments, we discovered that it was in the liquid helium-3, and then found that the liquid helium-3 had unusual magnetic properties that could be attributed to this pairing transition like that found in superconductors.

Well, okay, so that when did it become exciting? Well, after Doug was able to reproduce the exact pressure at which the slowing down occurred, then we knew that it was reproducible, whatever it was. That was a very intriguing sighting, because it was something new in that temperature range.

Then the next exciting thing was when we were doing magnetic resonance experiments and carefully studying the magnetic resonance signals in the solid helium-3, and totally unexpectedly found that the liquid helium-3 was the one that had the change in the magnetic resonance signal or the liquid part, rather than the solid part. And that was a very big surprise and an amazing result.

HOLLANDER:

Where do you think we're going from here? What do you think [inaudible]?

RICHARDSON:

Well, where we need to go is—those are two different classes of questions, because if you look around and see what the societal needs are, the things that can help mankind or can lead to devices that might make an individual either a small or a large profit, that's one class of strategies that might be used. Those are easier to answer, because you can see that in the electronics industry the Moore's Law [phonetic], that is the doubling of a density of logic elements on a chip that increasing every two years or so requires certain technologies to improve at a certain rate in order to achieve that. By the way, in that field, though, decreasing the size of the elements as a strategy will run out within the next decade, because the size of the elements will be too small. So somebody has to think of something new. So that's one class of questions there.

Similarly, in life sciences, what is interesting to do is to understand the millions and millions of proteins that are expressed by the genes when they send out little signals to make cells do their things. That's a wonderful research field with possibilities for countless thousands of people to be working on it for a century and finding very interesting results and new science.

So that's kind of an answer to the question of what do we need to do.

Now, the other question is, what is the new science that we would like to see discovered, and there are questions in cosmology and astrophysics that are quite remarkable. We know the exact temperature of the universe, that it is the residue of the Big Bang, and that fits very, very well, but there are other pieces of what we observe that do not fit into what we can account for with our existing body of physical theories. Or if they do, there are some tremendous mysteries about what's called the missing matter.

Let me be more specific. If you look at the distribution of stars out in the far distance or the distribution of stars within a galaxy, the spacing cannot be accounted for if you use only the objects that you can see light coming from and estimate the mass of those objects and then say that the forces that keep all of those pieces bound together are just the forces of gravity. There's not enough mass there to be able to make that work. On those considerations alone, we need almost twice as much mass as we can see in the universe for things to be held together the way they are. But there's even more difficult problem that seems to be coming from more recent observations of the most distant objects, and that's that the rate of expansion of the universe at the beginning was faster than it is now.

If you just have as a model, there was an instantaneous bang and a huge amount of energy was converted into, first, dense matter, and then matter that coalesced to form stars, the changes in the rate of expansion cannot be easily understood in terms of what we know about general relativity and the force of gravity without introducing other things. So the current model used by the theoretical astrophysicists, and I'm not one of them, but I've been very interested in the result, is that half of the total amount of energy in the universe is in something called just dark energy. It almost sounds like the ether that was rejected a hundred years ago. Then in the other half of the matter and energy in the universe, one portion of it is that which we can see, and the other portion of it is this invisible dark matter.

HOLLANDER:

[inaudible]

RICHARDSON:

That might or might not be, but I think there might be some new physics.

[Taping interruption]

HOLLANDER:

If I were to come to you and ask you what book should I read, what should I do to [inaudible] in the right direction [inaudible], where would you point me?

RICHARDSON:

It depends on your age and—

HOLLANDER: I'm eighteen.

RICHARDSON:

Okay, but let me go back a step, because let me think of my own life and what really mattered to me and what I really enjoyed, and then put myself at those different ages right now.

When I first learned to read and could do it with confidence, say, by the time of the second or the third grade—this is in the 1940s—I developed a passion for the Oz books. I really loved that whole series, and it captured my imagination, not because I believed in magic, but I could suspend disbelief. Then I became addicted to reading. Almost all of my life, I've read one or two books every week, either fiction or nonfiction. I found that that was just very important to me, first, recreational, to give me ideas about life. It's sort of a quiet soul so that's there's sometimes peace to think about other things and other pieces of inspiration comes out. So that for me there is no one thing to read.

I know you're asking now what one scientific thing would lead one in the right path. But my answer really is that I think one needs to read a great deal to understand lots about the world around you. I like to read things from great pieces of literature to junk novels on the airplane, and have for years, and I like science fiction.

Right now I'm reading *Huckleberry Finn* for the first time again in fifty years, and I recommend it to everyone. There's a tremendous piece of literature because of its insight, especially for Americans, into the American culture and traditions. But also Mark Twain had a terrific sense of irony that I think is important to everyone who might be a scientist one day, too, that you can't take yourself too seriously, and you have to enjoy the fact, and especially enjoy the fact that when you perform an experiment and get a result that might be the exact opposite of what you thought you were going to get based upon your model of how the universe ought to work, that those are the best times. Even though it might be disappointing right at first when it didn't work, there's a reason behind why it didn't work.

I can think of no nonfiction sort of instructional book that would necessarily be the key to taking someone along the right path that I would recommend. There are books written by famous scientists, and they're all interesting, but I've never found that any of those was a work that would give me, or would have given me, I don't think, a new eighteen-year-old, insight into the keys to a successful scientific career.

I've enjoyed the Feynman books, both the textbooks and the books about him. I've enjoyed Freeman Dysen's books, you know, the *Keys To The Universe.* Feynman would say, "Surely you're joking, Mr. Feynman." Those are entertaining, but I don't think that they necessarily are a keystone or the launching point for success in science.

HOLLANDER:

[inaudible]. What brought you to *Huckleberry Finn*?

RICHARDSON:

Well, that was just a fluke. I was looking on the web and noticed that there was a website that had a lot of novels and literatures that you could download free to load into your palm pilot. So I loaded it, I transferred it over and loaded it into my palm pilot, and I read it on the airplane coming over here. I find myself being appalled about some of the cruder aspects of life in America in the 1840s, but the tremendous wit and humor of Mark Twain, and the interaction between Jim and Huckleberry Finn is very poignant. It ought to be reread by every American at least every fifteen, twenty years, because it really reminds us a lot about our origins.

HOLLANDER:

[inaudible] what's the next thing [inaudible]?

RICHARDSON:

I can't predict that. Oh, I know what I'm going to read. The next one I can't wait to read is *Harry Potter* four. I love those Harry Potter books, and I'm astonished by the imagination and insight of Rowling. She's just terrific.

HOLLANDER:

One last question. Do you have a favorite physics joke, science joke?

RICHARDSON:

I'm not good at calling them up that way. [Laughs] Most of mine are sort of short, quiet jokes that are spontaneous rather than—

HOLLANDER:

Let me ask you this thing differently then. What [inaudible] to you professionally?

RICHARDSON:

I would have to think about that, too, because there are lots of things, both amusing and embarrassing and everything.

HOLLANDER:

[inaudible]

RICHARDSON:

Nothing occurs to me right now. I'll have to think a little bit. Betty said, well, getting the Nobel Prize is very amusing. [Laughs]

HOLLANDER:

[inaudible]

RICHARDSON:

There are lots of small amusing things that happened. What Betty was referring to was the day the Nobel Prizes in our year were announced, I was in Washington participating in a National Academy of Sciences panel. I was in a small hotel there. I got a phone call at five o'clock in the morning, and first that terrified me because nobody calls you at five o'clock in the morning with good news in a hotel room. But after it dawned on me in a few minutes that the man was talking about something about the Nobel Prize, I said, "Wow, this is pretty good." He said, well, they'd be sending a fax and it would have details. I said, "Thank you," and hung up.

Then I had some phone calls from people in the press that had heard about it and asking me, "Well, how does it feel?"

I said, "Yes, it feels wonderful."

Meanwhile, Betty who was at home, had been called up at four-thirty, promised not to call me before the Nobel Prize Foundation had called up, and they said they were going to call at five. So she started trying to call me at five and couldn't get through because the phone line was busy all the time. So eventually she found out that that was going to be too difficult. She wanted to leave a message. There was a night clerk in the hotel, so she said to him, "Well, when you see him, please tell him congratulations."

The night clerk said, "Why? Did he win the lottery?"

Betty said, "No, he won the Nobel Prize."

He said, "Well, what's that?"

Then she explained a little bit, and he could compare it with the lottery and decided it was probably pretty good and okay. So he said, "All right, okay." And that was it.

[End of interview]