

ATOMS FOR PEACE + 50

Nuclear Energy & Science for the 21st Century

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Panel Chairman:

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Superconductivity

ORBACH: It is my great pleasure to introduce to you one of the new, newest, Nobel Laureates in physics, Alexei Abrikosov. All of us who have studied superconductivity learned from the very beginning the Abrikosov lattice. His contributions to that field and many others are immense and we are indebted to him for his contribution to our understanding of nature. Dr. Abrikosov.

ABRIKOSOV: Thank you for your applause. I will try to be as short as possible. I'm also going to speak about science but much more to earth I will say than what we have heard. We have heard today a lot about various sources of energy. I am going to discuss another question, namely, the saving of energy. You see, I have in mind, not switching off of unnecessary appliances, but much more from the metal(?) things, namely a huge loss of energy due to the resistance of wires through which the ...(inaudible) electric energy is transferred.

And so, therefore, that of course, loss would be completely absent if we could use superconductivity, which Ray mentioned. So, what is the problem of using superconductivity? The main problem is, of course, is that this phenomenon exists only at low temperatures. These low temperatures actually increase very much in the last year and now their highest critical temperature is 135 Kelvins. That means higher than the boiling temperature of liquid nitrogen and so, therefore, liquid nitrogen can be used in cryos ...(inaudible) instead of liquid helium and that, of course, is a great progress.

However, the materials which have these properties, layer cuperides(?), they unfortunately are brittle and therefore they are inconvenient for technical applications. Despite that, they are really applied and much more projects are existing with application of these materials and so on. So the need is very strong. So, therefore, the question is, what is the future? What can we say about the future? Is there any possibility to increase the critical temperature or bring it even higher than room temperature?

Of course, if that would be possible, there would be a revolution comparable to the discovery of fission of uranium. Because in every household there would be in the devices used there, there would be superconductors. And in order to do that, we must analyze, how actually the discovery of new superconductors with higher critical temperatures, how did it happen? And I had a very interesting discussion once with Alex Muller who was the person who discovered the copper oxides, the layer of copper oxides, which are responsible for the most(?) high critical temperatures.

So Alex Muller was fascinated by the fact that some chemical compounds, consisting of barium, lead, and bismuth and oxygen, that such an oxide had a rather high critical temperature for those days, 14 Kelvins and, at the same time, they electron density in this substance, was two orders of magnitude less than in conventional superconductors. According to the existing ...(inaudible) Theory, the higher density would enhance the critical temperature. And so, therefore, it was not understandable how just the opposite led to a pretty high critical temperature.

So then Alex Muller, since his whole life he studied this ferro electrics of ...(inaudible) structures, he had a guess how this could happen. In order to check it, he had to find another substance of this kind and try to change it and so on in order to get the higher critical temperature. He was extremely lucky because in France a chemist, Bernard DaVau(?) has discovered such a basic substance, which could be useful for Alex Muller's intentions and that was lanthanum(?)₂, copper O₄.

So Alex replaced part of lanthanum by barium and got the critical temperature of 30 Kelvins. This opened the field of layer of copper oxides and led to this high critical temperature. But I believe that nowadays these substances have exhausted their potential and one cannot expect radical increase of critical temperature with these substances. So the question is how to move further and, you see, I think that many people have some ideas in this respect. I, personally, have one also. How to reach even higher critical temperatures, for example, ten times higher? So, that, of course, it is simply an idea, a dream, which of the type, what Alex Muller had. But he was lucky that there was DaVau who discovered a suitable substance.

Now in order, actually, to follow this, we must analyze what is happening. Scientists nowadays want to have fast results. It is the same, except maybe elementary particle physicists and astrophysicists. They are not limited in time. But other people are really limited. They are in rush all the time. And, of course, the rush does not stimulate such kind of search for new substances. Even if you have some idea, you have to search quite a lot.

And so, therefore, I think that this question is very important for practical applications. So, I would suggest the following, since we have Dr. Ray Orbach, yes, so I would suggest the

following, maybe it could be the initiative of the office of basic research in the DOE or maybe they should-- But anyhow they should somehow call for the project.

The project should have no promise that they will indeed discover such a high temperature superconductor. And the judgments have to be done by the idea, whether it is reasonable or it is absolutely fantastic. So, reasonable project of this kind should be funded and supported. And maybe in this way we can go to high temperature superconductors, really high temperature, because nothing limits the critical temperature. There is no principal limitation. So that was what I wanted to say. Thank you.

[applause]

Questions and Answers:

ORBACH: The floor is now open for questions.

QUISH: My name is Alan Quish. I'm a physics professor at the University of Michigan. One important benefit of the Atoms for Peace Proposal was the start of exchange visits between Russian and American scientists and students, especially in high energy and nuclear physics. This seemed an excellent and successful example of what Susan Eisenhower this morning mentioned as her father's hope that the Atoms for Peace Program would build good relations between scientists and students who would later become scientific leaders and help this, to have better relations between the two sides of the Iron Curtain. I think this had worked.

I've been involved in this program since the late 1960s. Unfortunately, this mutually beneficial exchange was significantly reduced when the now expired Department of Energy "Min(?) Atom Peaceful Use of Atomic Energy, Memorandum of Cooperation" was not signed when it was expired in February 2002. Has any progress been made in getting this signed again so this can continue.

ORBACH: I think the question was addressed at me and not the panel. Would any members of the panel like to respond to that? (laughter) Yes there is progress made and, in fact, in today's newspaper you will see one of the reasons why that progress will now accelerate. Thank you.

Are there other questions addressed to the panel?

GERKY: Bob Gerky, INNEL, to one of the three panelists. We've heard a lot about, where did the water come from on earth. And I'd be curious as to what the latest thinking is. There are some who have said the water on earth has come from comets. Does that hold any water?

ORBACH: Michael?

TURNER: I'm looking for an astronomer or planetary side on my left side here but I don't see one. Well, it certainly came from the quarks (laughter) in the Big Bang and it went through the Big Bang nucleus synthesis. I cannot tell you what the best idea for where the water on earth came from. I can only tell you the early origin of water, which is extremely exciting.

___: Is there any reason that it should have come from any different than all the rest of the elements that we have here on earth?

TURNER: Well, chemistry plays an important role in the formation of the solar system because some of the elements are more volatile than other elements. So, here on earth we don't see the primordial mix. Most of the universe is-- Most of the atoms in the universe are hydrogen. We certainly don't see that here on earth. But the earth's gravity isn't strong enough to hold the hydrogen and the helium, whereas in the sun and in the giant planets it's possible. So, chemistry plays a very important role in what we see here.

ORBACH: Questions? As Chairman, then, I am going to take the liberty of asking my own, which has been driving me nuts for five years. I would like to ask the panel to speculate on just what this dark energy is.

TURNER: Well, I think my son's idea's pretty good.

ORBACH: Are we really that bereft of ideas?

TURNER: No, I think we are at the phase right now where we need a really crazy idea. One of the exciting things about science is that when you get the very toughest problems, they involve some creative break, thinking outside of the box and so I tell this to graduate students and undergraduates and I also put a footnote saying, "Not every crazy idea is a solution to a profound problem. Some of them are just crazy ideas."

The range of things that we're thinking about run from something as mundane as the energy of the quantum vacuum. The problem there is that Jonathan and his friends can't calculate how much the quantum vacuum weighs. When they try to calculate it they get an absurdly large number before they say it must be zero.

(Laughter) It could be-- I describe very, very briefly inflation, speed up in the early universe. Maybe this is a milder form of inflation. And an idea that I really, really like, because it seems crazy enough to be correct is that there is no dark energy; we just don't understand gravity. And that a theme, again, that Jonathan was talking about, was that this marriage between gravity and quantum mechanics will require a modification of general relativity. If you'd ask Jonathan and his colleagues five years ago where that modification would be, they would say, "Oh, it is going to be at very, very short distances. It's not going to affect the cosmos."

But you never know where the clues are going to come from and this could be the clue that tells us about how we have to modify general relativity. And so I think that the solution to this problem that we go back and look at Jonathan's paper and find in page five that there is a two that should have been a 1.5. I think it's that we find something out very profound about matter, space, time and energy.

BAGGER: Mike is completely right about that. I showed a graph, which showed quarks and leptons and so forth, but that is really just a schematic for a whole structure which allows you to do calculations that are tested at experiments to better than a tenth of a percent level. And that

whole structure completely breaks down on the subject of dark energy. As Mike was saying, if you use that, basically, you calculate that the dark energy should be infinite and in particle theory if it is infinite, well, maybe it's zero; you missed something.

The fact that it's not zero and it's not infinite, is something that is just completely beyond anything that we can understand and so something brand new has to happen and we just don't have a clue what it is.

ORBACH: Are there other questions?

___: Well, it is sort of a comment. I'm an experimenter so I don't really believe much of anything that can't be measured. There was an article in Scientific American within the last year and I'm bad with names so I forget the guy's name but he proposed a good solution would be to have a very small extra term to Newton's Law that deviated from it at large distances. As far as I know there is no direct experiment that shows that you can't have something which would only cause 1020 deviations from Newton's Law nearby.

And a bunch of my theory colleagues dumped on me and started explaining why that couldn't work but I think it is something to look at.

___: The problem is that the violence that you have to do to the theory has to be consistent with that suite of precisions measurements that you have made so far. And so that imposes constraints. You have to be consistent. Yet, I agree. The answer has got to be crazy. So there is not much wiggle room but there is a hole somewhere and we have to find it.

ORBACH: I think one has to be careful of empirical fits. I mean you can play games with the laws but why, and are the microscopies behind them was my response with I read the article. It was certainly a clever argument but it doesn't answer anything. In the same way that the cosmological constant can change the sign and it gives you expansion, it doesn't tell you where it comes from and that is what these gentlemen have been struggling with. But you actually said something, Michael, that was quite, and, again, Jonathan, quite extraordinary. You believe that the structure of general relativity may be inaccurate.

TURNER: Well, certainly in science we know that in any give point in time, our description of the natural world is just an approximation and what's exciting about the scientific process is that it is never over. Newton wasn't wrong; he just didn't get the whole story. Einstein's theory encompasses-- In science successive theories eat their predecessors whole if we are doing our job right. And so, Einstein just didn't get the whole story. He got a big, big, chunk that we're still trying to swallow. We're still trying to understand black holes and their meaning and we're still trying to understand the Big Bang.

But I think if you took a poll among physicists, I think most of us would say, Einstein didn't get it all. He did not have the last word on gravity and we have more to learn and we're looking for clues and maybe the cosmic speed-up is a clue to tell us which direction to go.

BAGGER: Also it's quite possible, that because ...(inaudible) constant is related to the extra dimension, because it's a question of how our four-dimensional world is embedded in this higher dimensional space, it could be just related to that as well. Again, we don't know.

ORBACH: In the spirit of experiment, can you give us some clues as to how these extra dimensions might actually be observed?

__: Well, in particle physics, everything is a particle. So, actually, if they are the right size, they could be seen as a set of new particles that-- New accelerators like the LHC, or they could be seen through deviations from Newton's Laws and table top experiments, depending exactly on what variety of new dimensions we are talking about or they might be so small that they are only seen indirectly here or there. We don't know.

The great advance in the last few years-- Previously, people thought that these extra dimensions had to be so small that, well, you basically can't see them. But recently theorists have figured out how they can be infinitely large and you still wouldn't know that they're there. And so the story is wide, wide open.

ORBACH: Further questions? Yes.

DOWNEY: Jim Downey, again, at Harvard. And I would have to say I'm not much of a string theorist except for what it involves in tying my shoes. My question is a follow-on to that. It seems from what I have read about string theory that one of the flaws is that it's heavily on the word theory and that experiments to validate it are extremely limited. I'm wondering if we have to find multiple universes or if we can be comfortable at some point with the fact that this may, in fact, be the only universe that ever was.

__: String theory is, at this point, so-- It's so early in the development of string theory that one can't even say, really, what it predicts. How it connects to experiments, we don't know. It's more of also a paradigm at this point, than an actual precise theory with predictions. We'll have to see. Time will tell how it fits in, how it is detected, if it's detected.

__: To comment on your multi-verse possibility, I think what intrigues people are the questions that string theory addresses and the mathematical beauty. Then if you marry string theory with this idea of inflation that I was talking about, you could have had multiple Big Bangs and the rules, what we call the laws of physics, the local bylaws of physics, could be different in the different inflationary events and so the universe could have a structure that is infinitely larger than we can imagine and, if this is so, this would be a breakthrough on the same level of Copernicus getting us out of the center of the universe and the idea that there a multi-verse structure would bring us back down to earth.

As you say, we can't test that yet. So it's this intriguing idea because the hallmark of science is testability. And so I think even you find the string theorists who are desperate to find little ways to test the theory because you have to test these ideas in science.

___: Is that idea giving up this universe-- There are billions of universes and this one is the way it is just because it is? Are we giving up to say that?

___: Well, you're talking about the anthropic principle, which I'm not a fan of--

___: Well, it's related to what you are saying.

___: If the universe has this multi-universe structure that you asked about, and we're very far from saying that, then it's a fact of nature that we have to accept. So, let's wait and see if we have to accept that fact.

ORBACH: There's a book by Martin Reese called The Six Numbers that Determine the Universe, which raises this question, pointing out that these six number, which are the cause for existence, are accurate to an incredible limit for us to exist. And, therefore, why those six, which forms the basis for the second book that he wrote, and I refer you to that.

Burt--

RHICHTER: Burt Richter from Stanford. The whole history of physics is the history of metaphysics turning into physics because of experiments. And right now what we are suffering from is a dearth of experiments because the experiments are getting more complicated, bigger, and more expensive. My poor theory colleagues don't have any data to anchor them and so they are floating in the ether multi-verses and strings and all the rest of that sort of thing.

But sitting up there is one person controlling the budget of the Department of Energy, another person controlling the budget in certain areas of the National Science Foundation and what we've got coming along now are not only things like the LHC, this great accelerator, but we're going to have new telescopes, we're going to have new X-Ray satellites. And I think in the next ten or 15 years, I wish it were faster, we're going to have some new facts and new facts are going to bring some of theory friends back from floating around in the ether to having to make contact, once again, with the real world and then we're going to start to move to a new concept.

___: I hate to dispute. I hate to disagree with Burt Richter. You're absolutely right. We have wonderful possibilities in front of us and we have a plate that is very, very full and we will have a hard time getting everything done. But I think what's very exciting in this connection between the quarks and the cosmos, is that this astronomical fact that the universe is speeding up is not just of interest to astronomers but it's of great interest, as you well know, to your theorists and it may be--

Maybe it's not the clue that they wanted. Maybe they wanted the Hink's particle first but science is always orderly and so we've got other clues coming in, the dark matter, the dark energy. But I take you point on the possibilities before us and finding a way to carry out the experiments and realize our dreams.

ORBACH: I'm going to have Rob Goldsten ask the last question.

GOLDSTEN: Since some areas of particle physics are deferring from making predictions yet and there are these 17 or 19, depending on how you want to count them, basic numbers that are behind the standard theory, we had Roger Penrose come to Princeton to take the occasion to go after string theory as being irrelevant. That was kind of an interesting experience at Princeton. But I asked him this question and his answer-- And I'm curious how your response is, what your answer is-- Since we can't have a prediction, how about a meta-prediction, so to speak, a prediction about the predictions. When will one of these numbers come out of string theory? The first one?

[pause]

ORBACH: Would you like me to predict when Jonathan will answer this question? (Laughter)

___: So to speak, a meta, meta-prediction.

BAGGER: To be honest, I'm not a string theorist. I'm backpedaling fast. I actually believe in effective field theory. I'm more like a condensed matter physicist, mucking around with my effective Hamiltonian of the standard model and I can look further and see that either great things coming in the next factor ten in energy. To get all the way to the string theory scale, is more than I can imagine. But I can use string theory for inspiration and to take the big picture of string theory and use it as a guide, but actually detailed calculations, it's like trying to drive, perhaps chemistry from first principles of quarks and leptons. There are many steps in between. It may be very hard.

ORBACH: As one of those guys who mucks around with materials, let me thank the members of the panel and all of you in the audience. I think Burt Richter's plea, that this will come faster than 15 years, is upon us. We have four to five more years of operation of Fermilab. These issues, these new particles, the experiments that have been called for may well emerge from that. One has, as you saw the large hadron collider at Cern, the possibility of the linear collider in parallel. We have in front of us machines and theories that address the very fundamentals of our existence. It's an exciting time to be alive and I thank you all for joining us this afternoon.

[applause]

END OF SESSION 4