Questions That Plague Physics

Lawrence M. Krauss speaks about unfinished business

Chair of the physics department at Case Western Reserve University, Lawrence M. Krauss is famed in the research community for his prescient suggestion that a still mysterious entity called dark energy might be the key to understanding the beginnings of the universe. He is also an outspoken social critic and in February was among 60 prominent scientists who signed a letter entitled "Restoring Scientific Integrity in Policymaking," complaining of the Bush administration's misuse of science. The public, though, might know him best as an op-ed writer and author of books with mass appeal. His 1995 work, *The Physics of Star Trek,* became a best-seller, translated into 15 languages. He is now finishing his seventh popular title, *Hiding in the Mirror: The Mysterious Allure of Extra Dimensions,* which he describes as "an exploration of our long-standing literary, artistic and scientific love affair with the idea that there are hidden universes out there." Krauss recently discussed his many scientific and social passions with writer Claudia Dreifus.

SCIENTIFIC AMERICAN: What are the top questions bedeviling physicists today?

LAWRENCE KRAUSS: Three that I find fascinating are: What is the nature of dark energy? How can we reconcile black hole evaporation with quantum mechanics? And, finally, do extra dimensions exist? They are all connected. And they are all going to require some new insights into quantum gravity. But someone is going to have to come up with a totally new and remarkable idea. And it's hard to predict when that is going to happen. In 1904 you couldn't have predicted that Albert Einstein would come up with a remarkable idea in 1905.

I think the resolution to these problems is likely to be theoretical and not experimental. This is because direct experimental signatures that might point us in the right theoretical directions in these areas probably lie beyond the realm of current experiments. I'd also bet that the solution to these problems is not going to resemble anything being done now, including string theory.

SA: Is string theory the physics equivalent of The God That Failed, as some people used to say about communist ideology?

LK: Not exactly. But I do think its time may be past. String theory and the other modish physical theory, loop quantum gravity, both stem from one basic idea: that there's a mathematical problem with general relativity.

The idea is that when you try to examine physical phenomena on ever smaller scales, gravity acts worse and worse. Eventually, you get infinities. And almost all research to find a quantum theory of gravity is trying to understand these infinities. What string theory and what loop quantum gravity do is go around this by not going smaller than a certain distance scale, because if you do, things will behave differently. Both these theories are based on the idea that you can't go down to zero in a point particle, and that's one way to get rid of mathematical infinities. The main difference, I think, between the two theories is that string is intellectually and mathematically far richer.

String theory hasn't accomplished a lot in terms of solving physical problems, but it's produced a lot of interesting mathematical discoveries. That's why it fascinates. Loop quantum gravity hasn't even done that, at least in my mind.

SA: Are you saying that string theory hasn't really gotten us anywhere?

LK: Neither string theory nor loop quantum gravity has told us much about the key unsolved physical problems—most important, why does the universe have dark

energy? That's the biggest question right now. One thing that has come out of string theory is the idea of plural universes or extra dimensions, and that's because string theory is based on extra dimensions. The only consistent string theory originally had 26 dimensions, and then it got lowered to 10. But the universe we live in is four-dimensional [three spatial plus time]. A lot of talk went into explaining how all these extra dimensions were invisible. Recently some people have been trying to turn that defect into a virtue by suggesting that the extra dimensions might actually be detectable.

SA: You've just finished writing a book about parallel universes. Do you think they're real?

LK: Let me answer you this way: it's an exciting area, and it's wonderful for graduate students. One of my former Ph.D. students is largely responsible for the recent surge of interest in this idea. But I think these extra dimensions smell wrong. What we are learning from elementary particle physics about the unification of all the forces in nature tends to point in a direction that is not the direction these large parallel universe models suggest. As beautiful and as sexy as they are, if I had to bet, I'd bet that these large extradimensional ideas are probably not right. We'll see.

SA: How did you come to write *The Physics of Star Trek?*

LK: Actually, it began as a joke, probably sometime in 1993. I had just finished *Fear of Physics* for Basic Books. I was chatting with my editor about what I might do for them next. Somewhere in the conversation, she mentioned something about her daughter's being a Trekker. "How about *The Physics of Star Trek?*" she laughed.

That night I started thinking about the transporter, a *Star Trek* device that disassembled your atoms, moved them almost instantaneously to somewhere else and reassembled them in that place. What might it take to build one? That led to my making a list of all these neat *Star Trek* phenomena that one could use to hook people into thinking about physics. If people loved this imaginary stuff, I thought, why couldn't they love real science, which is a thousand times more amazing?

I was blunt about *Trek* things that wouldn't work. But I also pointed readers toward more fascinating possibilities in the real universe. Real science comes up with ideas that no fiction writer would have the temerity to suggest. Think about cosmic antigravity, something I work on at my day job: no one understands why empty space should have energy. It's the weirdest idea in the world!

SA: Why?

LK: If you asked a child how much energy there is in empty space, he'd say "none," because that's the sensible answer. But what we've learned is that's not true: if you take everything away, there's still something there.

What's worse is: if you put a little amount of energy into empty space, then everything we know about the laws of physics says you should be able to put a tremendous amount of energy into it. Once you open the dam and allow empty space to have energy, you ask how much it should naturally have. Our current understanding of gravity and quantum mechanics says that empty space should have about 120 orders of magnitude more energy than the amount we measure it to have. That is 1 with 120 zeroes after it! How to reduce the amount it has by such a huge magnitude, without making it precisely zero, is a complete mystery. Among physicists, this is considered the worst fine-tuning problem in physics.

When we solve this problem, we're going to have to explain why the number that we measure is 120 orders of magnitude smaller than we would expect it to be. No

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LAWRENCE M. KRAUSS is a man of many opinions. One is that string theory has failed to shed light on the nature of dark energy.

one has an idea how to do that. And that's why it's the most exciting thing in physics. Because weird makes things exciting.

SA: You are one of the few top physicists who is also known as a public intellectual. In the middle of the past century, that kind of activity by scientists was much more common. Albert Einstein, in fact, was an international celebrity, whose private views of everything from nuclear disarmament to Zionism were solicited by the press. Why do you think you're such a rare bird that way now?

"I'm not against teaching faith-based ideas in religious classes; I'm just against teaching them as if they were science."

LK: I can't speak for others. Besides my own research, I see part of my mission as trying to close the disconnect between science and the rest of the culture. We live in a society where it's considered okay for intelligent people to be scientifically illiterate. Now, it wasn't always that way. At the beginning of the 20th century, you could not be considered an intellectual unless you could discuss the key scientific issues of the day. Today you can pick up an important intellectual magazine and find a write-up of a science book with a reviewer unashamedly saying, "This was fascinating. I didn't understand it." If they were reviewing a work by John Kenneth Galbraith, they wouldn't flaunt their ignorance of economics.

SA: How did science illiteracy become socially acceptable?

LK: We all know how badly science is taught in many schools. So many middle school and even some high school teachers have no background in science. When my daughter was in the second grade and I went to her school, I was stunned by how her teacher seemed incredibly uncomfortable with having to teach even the simplest scientific concepts. I think this is common. And there is the reality that science has grown increasingly esoteric, making it more difficult for laypeople to grasp.

The truth is—and I'm hardly the first to say this—after World War II, American scientists became an isolated elite. The secrets that allowed them to change the world also allowed them to shirk responsibility for citizenship. Scientists became a class above society, rather than a part of it.

And so for the longest time, certainly until the 1970s, many American scientists just didn't believe that reaching the public was important. Those were good times, with lots of money coming in. The wake-up call came in 1993, when Congress killed the Superconducting Super Collider. That was a real signal physicists were doing something wrong.

We hadn't convinced the public—or even all of our colleagues—that it was worth billions to build this thing. And since then, it has become clear: to get money for what we do, we're going to have to explain it to the public. *My* predilection is to try to connect the interesting ideas in science to the rest of people's lives.

SA: The big public issue you've been identified with is fighting against creationist teachings in the schools. For the past couple years, you've spent your time traveling, debating creationists on proposed curriculum changes for Ohio's high schools. Was that fun?

KRAUSS (*standing*) spoke to the Ohio State Board of Education Standards Committee on March 11, 2002, in an effort to keep religious teachings out of the public school science curriculum. The board agreed, although creationists have not given up the fight.

JAY LAPRETE *AP Photo*

LK: It was the least fun of anything I've ever done. Convincing people of the excitement of science is fun; trying to stave off attacks on science feels like the most incredible waste of time, even if necessary.

I got drafted after several creationists were appointed to the Standards Committee of the Ohio State Board of Education. They were proposing new standards to create false controversy around evolution by introducing an ad hoc idea called intelligent design into high school science classes.

For nearly a year, I found myself in the middle of what was almost the equivalent of a political campaign.

When it was over, we won and we lost. We won because we had kept intelligent design out of science classes. We lost because in the spirit of "fairness," the board added a sentence to the standards saying, "Students should learn how scientists are continuing to critically examine evolutionary theory." I strongly opposed this. I wanted them to say that scientists are continuing to critically examine everything.

As I feared, this sentence opened the door for the creationists' claiming that there is controversy about the accuracy of evolutionary theory. And it's come back to haunt us. Just the other week, I had to put everything I was doing aside because the creationists were back at their old games again in Ohio. One of the model lessons that came out was an intelligent-design diatribe. Basically, they snuck the whole thing in again, through the back door. This becomes so tiresome that you just want to say, "Forget about it, go on." But then you realize that this is exactly what Phillip Johnson, this lawyer who first proposed the intelligent-design strategy, proposed when he said something like, "We'll just keep going and going and going till we outlast the evolutionists."

SA: Do scientists trap themselves when they try to be "fair" and "give equal time" in their debates with the anti-Darwinists?

LK: Yes. Because science isn't fair. It's testable. In science, we prove things by empirical methods, and we toss out things that have been disproved as wrong. Period. This is how we make progress.

I'm not against teaching faith-based ideas in religion classes; I'm just against teaching them as if they were science. And it disturbs me when someone like Bill Gates, whose philanthropy I otherwise admire, helps finance one of the major promoters of intelligent design by giving money to a largely conservative think tank called the Discovery Institute. Yes, they got a recent grant from the Gates Foundation. It's true that the almost $10-million grant, which is the second they received from Gates, doesn't support intelligent design, but it does add credibility to a group whose goals and activities are, based on my experiences with them, intellectually suspect. During the science standards debate in Ohio, institute operatives constantly tried to suggest that there was controversy about evolution where there wasn't and framed the debate in terms of a fairness issue, which it isn't. [*Editors' note: Amy Low, a media relations officer representing the Bill and Melinda Gates Foundation, says that the foundation "has decided not to respond to Dr. Krauss's comments."*]

SA: Why do you find this grant so particularly disturbing that you single it out here?

LK: Because we're living in a time when so many scientific questions are transformed into public relations campaigns—with truth going out the window in favor of sound bites and manufactured controversies. This is dangerous to science and society, because what we learn from observation and testing can't be subject to negotiation or spin, as so much in politics is.

The creationists cut at the very credibility of science when they cast doubt on our methods. When they do that, they make it easier to distort scientific findings in controversial policy areas.

We can see that happening right now with issues like stem cells, abortion, global warming and missile defense. When the testing of the proposed missile defense system showed it didn't work, the Pentagon's answer, more or less, went, "No more tests before we build it."

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SA: Between your popular writing and your political work, when do you do science?

LK: In the quiet hours of the night, in between those things. I do it then—or when I have the opportunity to sit down with students and postdocs. It's amazing to me, when we do that, how much we can accomplish. I rely on that a lot lately.

There can be months when I'm working on other things, and I get very, very depressed. Talking about science is important, and it may be the most important thing that I do. But if I'm not actually doing science, I feel like a fraud. On the other hand, if I don't do the public stuff, I also feel like a fraud.

SA: Why a fraud?

LK: Because science is not done in a vacuum. It is done in a social context, and the results of science have important implications for society, even if it is simply providing a general understanding of how we humans fit into the cosmos.

Thus, simply producing new knowledge, without making any attempt to help disseminate it and explain it, is not enough. I think one cannot expect every scientist to spend time on the effort to explain science. But in a society in which the science is of vital importance and also in which many forces are trying to distort the results of science, it is crucial that some of us speak out. SA