THE DISCOVER INTERVIEW
LISA RANDALL

Physics' rising star ventures into 11 dimensions, visits other universes, explains gravity, and keeps her sense of humor

INTERVIEW BY **COREY S. POWELL** PHOTOGRAPHY BY **GERALD FORSTER**

Lisa Randall laughs.

That may not seem at all remarkable until you consider what's on her mind right now. She is out to liberate humanity from the pervasive but quite possibly mistaken assumption that we live in a three-dimensional world. "The disinformation campaign began in the crib, which first introduced you to three spatial dimensions," she warns in her recent book, *Warped Passages: Unraveling the Mysteries of the Universe's Hidden Dimensions.*

Starting in earnest a couple of decades ago, a group of physicists began seeking deeper truth in string theory, which holds that the fundamental particles of nature consist of minuscule vibrating strands of energy. Problem is, the theory works well only if the strings vibrate in more than three dimensions. Randall, a theoretical physicist at Harvard University, is a leading light of a second generation of researchers who are taking that idea to an even grander level, envisioning not just tiny strands but huge territories of higher dimension, called branes. She thinks this approach could revolutionize our understanding of gravity and uncork the deepest workings of the universe.

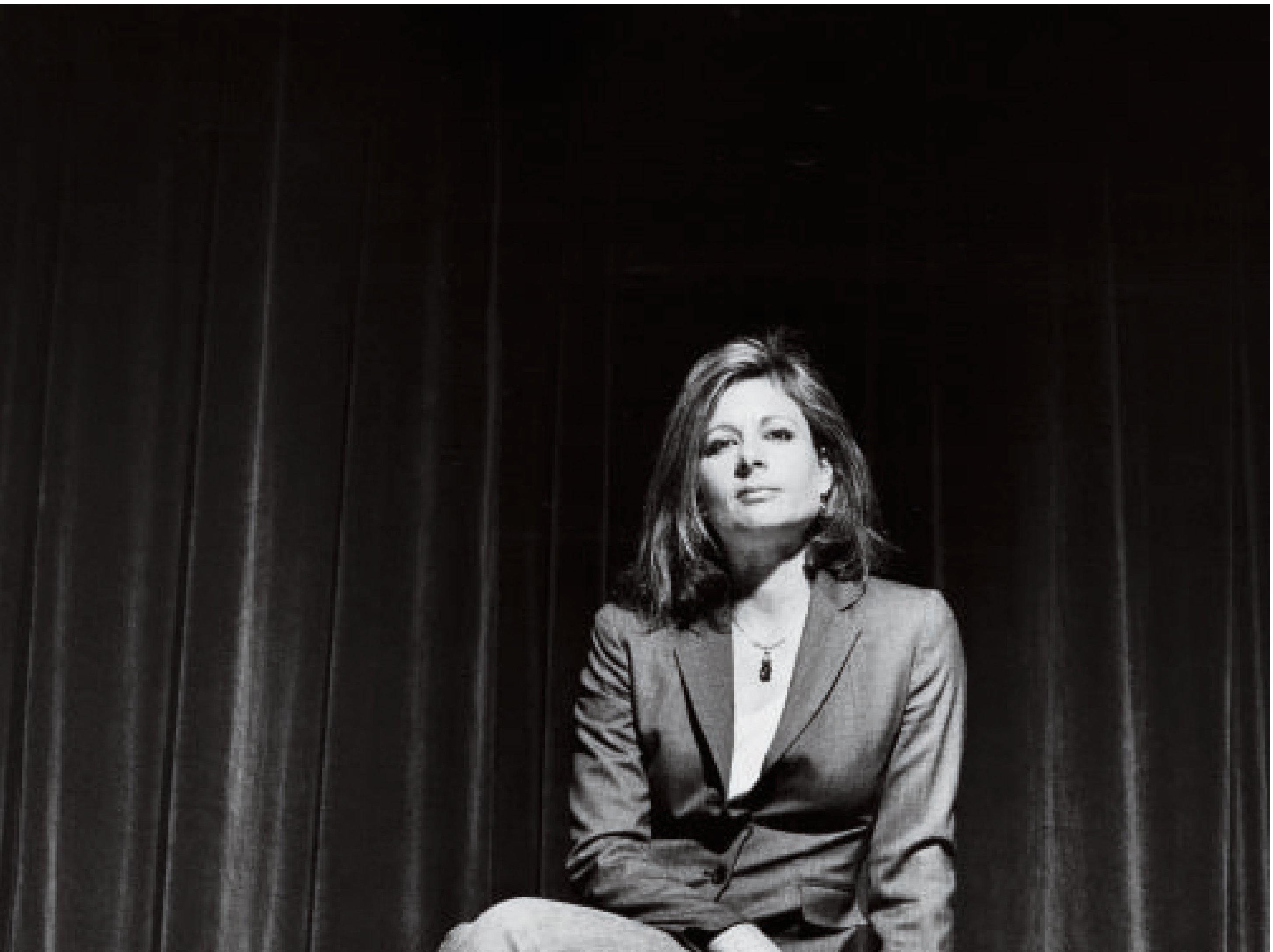
Yet Randall is resolutely down to earth. She chafes at the thought that her ideas should be restricted to the confines of academia, she both respects and swats aside her importance as a woman in a male-dominated field—and then there is that laugh, hearty and throaty, that erupts repeatedly during our conversation. She finds this world rich and comforting and funny. She just wants to give it a little more dimension.

Where did your interest in physics begin?

When I was in school I liked math because all the problems had answers. Everything else seemed very subjective. The teachers in English class would say, "What is the reason that this is an important book?" They'd look for the three good reasons, whereas you might think of some other one. I didn't like the arbitrariness of that. Later I decided that just doing math would drive me crazy. I'd be up all night working on a problem, and I thought, "I can't live the rest of my life like this." [Laughs] I wanted something more connected to the world.

Speaking of staying connected to the world—in your work you imagine extra dimensions, but you still have to live on the same planet as the rest of us. Do you carry around the image of other dimensions in your mind?

It's momentary. In my book I describe a time walking over the Charles River and thinking, "You know, I really do believe there are extra dimensions out there." Sometimes I have a sense of what I'm seeing being a small fraction of what's there. Not always there, but probably more often than I realize. Something will come up, and I'll realize I'm thinking about the world a little differently than my friends.



Science is not going to be able to answer the "why" questions, but that's not to say we can't go further.

So you intuitively believe higher dimensions really exist?
I don't see why they shouldn't. In the history of physics, every time we've looked beyond the scales and energies we were familiar with, we've found things that we wouldn't have thought were there. You look inside the atom and eventually you discover quarks. Who would have thought that? It's hubris to think that the way we see things is everything there is.

If there are more than three dimensions out there, how does that change our picture of the universe?
What I'm studying is branes, membranelike objects in higher dimensional space. Particles could be stuck to a three-dimensional brane, sort of like things could be stuck to the two-dimensional surface of a shower curtain in our three-dimensional space. Maybe electromagnetism spreads out only over three dimensions because it's trapped on a three-dimensional brane. It could be that everything we know is stuck on a brane, except for gravity.

Yet we very clearly see only three dimensions when we look around. Where could the other dimensions be hiding?
The old answer was that the extra dimensions were tiny: If something is sufficiently small, you just don't experience it. That's the way things stood until the 1990s, when Raman Sundrum and I realized you could have an infinite extra dimension if space-time is warped. Then with Andreas Karch, I found something even more dramatic—that we could live in a pocket of three dimensions in a higher-dimensional universe. It could be that where we are it looks as if there's only three dimensions in space, but elsewhere it looks like there's four or even more dimensions in space.

And there could be a whole other universe set up that way?
Possibly. It would be a different universe because, for example, bound orbits [like Earth's path around the sun] work only in three dimensions of space. And the other universe could have different laws of physics. For example, theycould have a completely different force that we are immune to. We don't experience that force, and they don't experience, say, electromagnetism. So it could be that we're made of quarks and electrons, while they're made up of totally different stuff. It could be a completely different chemistry, different forces—except for gravity, which we believe would be shared.

What is so special about gravity?
In string theory there are two types of strings, open ones with ends and closed ones that loop around. Open strings are anchored to the surface of the brane, so the particles associated with them are stuck on the brane. If you have a string associated with the electron, for example, it's on a brane. Gravity is associated with a closed string. It has no end, and there is no mechanism for confining it to the brane. Gravity can spread out anywhere, so it really is different. It can leak out a little into extra dimensions. That can explain why gravity is so weak compared with the other forces: A little magnet can lift a paper clip against the pull of the entire Earth.

Some of these ideas sound, frankly, a bit crazy to the average person. Where do they come from?
The idea of extra dimensions comes from string theory, the hypothesis that fundamental particles are actually oscillations of tiny strands of energy. String theory gives you a way to combine two very different models of the world, quantum mechanics and general relativity. Basically, quantum mechanics applies on atomic scales, and general relativity applies on big scales. We believe there should be a single theory that works over all regimes. String theory does that, but only in a universe that has more than three dimensions of space. More generally, there's stuff we don't understand if there are only three dimensions of space, and some of those questions seem to have answers if there are extra dimensions. Also, no fundamental physical theory singles out three dimensions of space. The theory of gravity allows any number. So it's logical to think what the world would look like if extra dimensions are there.

One of the amazing things about your work is that so much of it comes straight from your imagination, not from rooting around **in the laboratory. It seems very much like chalk-and-blackboard research.**
Right, the blackboard. Those are the things that seem to strike people, that we have blackboards with equations all over them and that we are talking to each other a lot; we're not just going into our offices and ignoring the rest of the word. But we do just go and think sometimes. Once you're really focused, if you get jogged out of it, you have to go back and really reestablish that. It's like Fred Flintstone and his bowling ball: You don't want to interrupt someone when they're in that state. Then again, sometimes we're just talking and writing together on a piece of paper, and sometimes we're at that blackboard putting ideas back and forth. Our work is all those things. It's reading what other people have done, trying to puzzle through something, getting stuck, getting unstuck, trying to find different ways around a problem.

How will we know if your ideas are right?
We'll look for what are called Kaluza-Klein particles, which are associated with the hidden dimensions [CK]. The Large Hadron Collider [a particle accelerator on the French-Swiss border that will begin operating in 2007] could have enough energy to produce these particles. In our theory, Kaluza-Klein particles will decay in the detector—you find the decayed product and you can reconstruct what was there. That would be very strong evidence of extra dimensions. Maybe within five years we'll know the answers.

These are costly experiments. Do you worry about the public's willingness to support such purely theoretical research?
I'm really concerned about it. If we don't do it now, we'll probably never do it. We've built up the technology; we're at a point where

if we don't continue, we'll lose that expertise, and we'll have to start all over again. True, it's expensive, but at the end of the day it will be worth it. It makes a difference in terms of who we are, what we think, how we view the world. These are the kinds of things that get people excited about science, so you have a more educated public.

You don't exactly fit the image of the graying, tweedy professor. Does being a young woman in a male-dominated field carry special responsibilities?
If only I was still young! [Laughs] I thought maybe I'd make it all the way through an interview without having to talk about this. But, yeah, I think it does. I'm probably more careful, and probably I spend more time on this particular issue. Also, in writing my book, I felt it had better be good, because there aren't that many women in the field, and I thought it would be subject to extra scrutiny. So there is extra responsibility; the flip side is that potentially there's extra reward.

Outside your own field, where do you see the most vibrant things happening in science today?
Neuroscience is exciting. Understanding how thoughts work, how connections are made, how the memory works, how we process information, how information is stored—it's all fascinating. Experimentally, though, we're still rather limited in what we can do. I don't even know what consciousness is. I'd like someone to define consciousness.

Many people would say physics has a long way to go too. Does it bother you that the things you're excited about now may seem quaint as soon as someone comes up with a better theory?
True, we haven't found all the answers, but we've found some and we're finding more. The fact that we don't know everything doesn't mean we know nothing. People have asked me, "Why bother, if you don't get final answers?" I said, "If someone gave me a dessert, and I knew it wasn't the best dessert ever, I would still be really happy to eat it and wait for the next one."

Will physics ever be able to tackle the biggest questions—for instance, why does the universe even bothers to exist?
Science is not religion. We're not going to be able to answer the "why" questions. But when you put together all of what we know about the universe, it fits together amazingly well. The fact that inflationary theory [the current model of the Big Bang] can be tested by looking at the cosmic microwave background is remarkable to me. That's not to say we can't go further. I'd like to ask: Do we live in a pocket of three-dimensional space and time? We're asking how this universe began, but maybe we should be asking how a larger, 10-dimensional universe began and how we got here from there.

This sounds like your formula for keeping science and religion from fighting with each other.
A lot of scientists take the Stephen Jay Gould approach: Religion asks questions about morals, whereas science just asks questions about the natural world. But when religion addresses the natural world, science pushes back on it, and religion has to accommodate it. Can you tell people not to ask questions because it will interfere with their beliefs? Personally, if I find out my belief is wrong, I change my mind. I think that's a good way to live.

So does your science leave space for untestable faith? Do you believe in God?
There's room there, and it could go either way. Faith just doesn't have anything to do with what I'm doing as a scientist. It's nice if you can believe in God, because then you see more of a purpose in things. Even if you don't, though, I think that there's a virtue in being good in and of itself. It doesn't mean that there's no purpose. It doesn't mean that there's no goodness. I think that one can work with the world we have. So I probably don't believe in God. This will earn me a lot of enemies probably, but—in some ways, it's more moral. If you do something for a religious reason, you do it because you'll be rewarded in an afterlife or in this world. That's not quite as good as something you do for purely generous reasons. I think it's a problem that people are considered immoral if they're not religious. That's just not true.