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Scientist At Work | Lisa Randall

On Gravity, Oreos and a Theory of Everything

By DENNIS OVERBYE

The portal to the fifth dimension, sadly, is closed.

There used to be an ice cream parlor in the student center at the Massachusetts Institute of Technology. And it was there, in the summer of 1998, that Lisa Randall, now a professor of physics at Harvard and a bit of a chocoholic, and Raman Sundrum, a professor at Johns Hopkins, took an imaginary trip right out of this earthly plane into a science fiction realm of parallel universes, warped space and otherworldly laws of physics.

They came back with a possible answer to a question that has tormented scientists for decades, namely why gravity is so weak compared with the other forces of nature: in effect, we are borrowing it from another universe. In so doing, Dr. Randall and Dr. Sundrum helped foment a revolution in the way scientists think about string theory - the vaunted "theory of everything" - raising a glimmer of hope that coming experiments may actually test some of its ineffable sounding concepts.

Their work undermined well-worn concepts like the idea that we can even know how many dimensions of space we live in, or the reality of gravity, space and time.

The work has also made a star and an icon of Dr. Randall. The attention has been increased by the recent publication to laudatory reviews of her new book, "Warped Passages, Unraveling the Mysteries of the Universe's Hidden Dimensions," A debate broke out on the physics blog Cosmic Variance a few weeks ago about whether it was appropriate, as a commentator on NPR had said, to say she looked like Jodi Foster.

"How do we know we live in a four-dimensional universe?" she asked a crowd who filled the Hayden Planetarium on a stormy night last week.

"You think gravity is what you see. We're always just looking at the tail of things."

Although it is the unanswerable questions that most appeal to her now, it was the answerable ones that drew her to science, especially math, as a child, the middle of three daughters of a salesman for an engineering firm, and a teacher, in Fresh Meadows, Queens. "I really liked the fact that it had definite answers," Dr. Randall said.

At Stuyvesant High School, where she was in the same class as Brian Greene, the future Columbia string theorist and best-selling author, she was the first girl to serve as captain of the school's math team, and she won the famous Westinghouse Science Talent Search competition with a project about complex numbers. She went on to Harvard where she stayed until 1987 when she emerged with a Ph.D. in physics.

Those were heady times in physics. Fired by the dream of a unified theory of everything, theorists flocked to string theory, which envisioned the fundamental elements of nature as tiny wriggling strings.

Dr. Randall, however, resisted this siren call, at least for a while. For one thing, physicists thought it would take a particle accelerator 10 million billion times as powerful as anything on earth to produce an actual string and test the theory.

String theory also stubbornly requires space-time to have 10 dimensions, not the 4 (3 of space and 1 of time) that we experience. Preferring to stay closer to testable reality, Dr. Randall was drawn to a bottom-up approach to theoretical physics, trying to build models that explain observed phenomena and hoping to discover principles with wider application. But Dr. Randall and string theory had their own kismet.

In the mid-90's, theorists discovered that the theory was even richer than its founders had thought, describing not just strings but so-called branes, as in membranes, of all dimensions. Our own universe could be such a brane, an island of three dimensions floating in a sea of higher dimension, like a bubble in the sea. But there could be membranes with five, six, seven or more dimensions coexisting and mingling like weird cosmic soap bubbles in what theorists sometimes call the multiverse.

"The stuff we're really famous for was really lucky in a way," Dr. Randall said.

In the summer of 1998, after postdoctoral stints at Harvard and the University of California, Berkeley, she was a tenured M.I.T. professor ready to move to Princeton. She wondered then whether parallel universes could help solve a vexing problem with a favorite theories of particle physicists.

That theory, known as supersymmetry, was invented in turn to solve another problem - the enormous gulf known as the hierarchy problem between gravity and the other forces. Naïve calculations from first principles suggest, Dr. Randall said, that gravity should be 10 million billion times as strong as it is. You might find it hard to imagine gravity as a weak force, but consider, says Dr. Randall, that a small magnet can hold up a paper clip, even though the entire earth is pulling down on it.

But there was a hitch with the way the theory worked out in our universe. It predicted reactions that are not observed.

Dr. Randall wondered if the missing reactions could be explained by positing that some aspects of the theory were quarantined in a separate universe.

She called up Dr. Sundrum, who was then a fellow at Boston University and happy to collaborate, having worked with her before. A lot of physics is taste, he explained, discerning, for example, what is an important and a potentially soluble problem. Dr. Randall's biggest strength, he said, is a kind of "unworldly" instinct. "She has a great nose," Dr. Sundrum said.

"It's a mystery to those of us - hard to understand, almost to the point of amusement - how she does it without any clear sign of what led her to that path," he continued. "She gives no sign of why she thinks what she thinks."

They began by drawing pictures and making crude estimates over ice cream and coffee in that ice cream parlor, which is now a taqueria. What they drew pictures of was a kind of Oreo cookie multiverse, an architecture similar to one first discovered as a solution of the string equations by Edward Witten of the Institute for Advanced Study and Petr Horava, now at Berkeley. Dr. Randall and Dr. Sundrum's model consisted of a pair of universes, four-dimensional branes, thinly separated by a five-dimensional space poetically called the bulk.

When they solved the equations for this setup, they discovered that the space between the branes would be warped. Objects, for example, would appear to grow larger or smaller and get less massive or more massive as they moved back and forth between the branes.

Such a situation, they realized to their surprise, could provide a natural explanation for the hierarchy problem without invoking supersymmetry. Suppose, they said, that gravity is actually inherently as strong as the other forces, but because of the warping gravity is much much stronger on one of the branes than on the other one, where we happen to live. So we experience gravity as extremely weak.

"You can be only a modest distance away from the gravity brane," Dr. Randall said, "and gravity will be incredibly weak." A result was a natural explanation for why atomic forces outgun gravity by 10 million billion to 1. Could this miracle be true? Crazy as it sounded, they soon discovered an even more bizarre possibility. The fifth dimension could actually be infinite and we would not have noticed it.

In this case, there would be only one brane, ours, containing both gravity as we know it and the rest of nature. But it would warp space in the same way as in the first model, trapping gravity nearby so that we would experience space-time as four-dimensional. This new single brane model did not solve the weak gravity problem, Dr. Randall admitted, but it was a revelation, that an infinite ocean of space could be sitting next to us undetected.

"So when we wrote this paper, what we were concentrating on was this amazing fact that really had been overlooked for 100 years - well, years, whatever - that you can have this infinite extra dimension," she said. "I mean it was quite wild."

This was not the first time that theorists had tinkered with the extra dimensions of string theory, dimensions that had been presumed to be coiled out of sight of experiment, into tight loops so small that not even an electron could enter. In 1998, three theorists - Nima Arkani-Hamed of Harvard, Gia Divali of New York University and Savas Dimopoulos of Stanford (a group known in physics as A.D.D.) - had surprised everybody by suggesting that if one or two of the curled-up extra dimensions had sizes as big as a tenth of millimeter or so (gigantic on particle physics scales), gravity would be similarly diluted and weakened.

When Dr. Randall and Dr. Sundrum published their first paper, describing the two-brane scheme, in 1999, she said that many physicists did not recognize it as a new idea and not just an elaboration on the large extra dimensions of the A.D.D. group. In fact, she said, the extra dimensions don't have to be very large in the two-brane theory, less than a millionth of a trillionth of a trillionth of an inch.

When they published their second paper, about the infinite dimension, she said, even some of their best friends, reserved judgment.

But by the time a long-planned workshop on strings and particle physics at the Kavli Institute for Theoretical Physics in Santa Barbara rolled around that fall, string theorists were excited about the Randall-Sundrum work and the earlier A.D.D. proposal.

The reason was simple: If they were very lucky and one of these versions of string theory was the one that nature had adopted, it could actually be tested in the Large Hadron Collider, the giant particle accelerator due to go into operation at CERN near Geneva in 2007. Colliding beams of protons with a combined energy of 14 trillion electron volts, the collider could produce particles like gravitons going off into the fifth dimension like billiard balls hopping off the table, black holes or even the illusive strings themselves.

"If this is the way gravity works in high-energy physics, we'll know about it," Dr. Randall said.

Although physicists agree that these theories are a long shot, the new work has captured their imaginations and encouraged them to take a fresh look at the possibilities for the universe and their new accelerator.

Dr. Greene of Columbia said, "Sometimes it takes an outsider to come into a field and see what is being missed, or taken for granted." At first the idea that extra dimensions could be bigger than any of us had thought was shocking, he said.

Andrew Strominger, a Harvard string theorist, said: "Before A.D.D. we believed there was no hope of finding evidence for string theory at the Large Hadron Collider, an assumption that was wrong. It shows how unimaginative and narrow-minded we are. I see that as cause for optimism. Science and nature are full of surprises, we never see what's going to happen next."

It was shortly before a conference that Dr. Randall had organized during the Kavli workshop that she had her own experience with gravity: she fell while rock climbing in Yosemite, breaking several bones. Only a day before, she said, she had completed a climb of Half Dome and was feeling cocky.

Another symptom of gravity's weakness is that a rope is sufficient to hold a human body up against earth's pull, but Dr. Randall was still on the first leg of her climb and hadn't yet attached it to the rock.. She woke up in a helicopter. For a long time, she said, new parts kept hurting as old ones healed. "I was very much not myself. I didn't even like chocolate and coffee."

Since she was the conference organizer, her ordeal was more public than she would have liked. "In some ways you sort of want to do this in private," Dr. Randall said. "On the other hand people were really nice."

After two years at Princeton, Dr. Randall returned to M.I.T. in 2000, but then a year later moved to Harvard, by then a powerhouse in string theory. She was the third woman to get tenure in physics there.

Dr. Randall, 43 and single, prefers not to talk about "the women in science thing," as she calls it. That subject that gained notoriety earlier this year when Harvard's President Larry Summers famously ventured that a relative lack of women in the upper ranks of science might reflect innate deficiencies, but Dr. Randall said it had been beaten to death.

Asked if she would rather be a woman in science than talk about women in science, Dr. Randall said, "I'd rather be a scientist."

She did say that part of the reason she had written her book was to demonstrate that that there were women out there doing this kind of science. "I did feel extra pressure to write a good book," she said, adding that the response in reviews and emails from readers had been much greater than she had expected.

She was particularly pleased that some of her readers were attentive and studious enough to catch on to various puns and games she had inserted in the book, like the frequent references to Alice in Wonderland, which, she said, is a pun on "one-d-land."

Dr. Randall is intrigued by that fact that her results, as well as other results from string theory seem to paint a picture of the universe in which theories with different numbers of dimensions in them all give the same physics? She and Andreas Karch of the University of Washington have found, for example, that the fifth dimension could be so warped that the number of dimensions you see would depend on where you were. Our own universe might just be a three-dimensional "sinkhole," she says.

"It's not completely obvious what gravity is, fundamentally, or what dimensions are, fundamentally," she said over lunch. "One of these days we'll understand better what we mean, what is the fundamental thing that's given us space in the first place and dimensions of space in particular."

She held out less hope for time, saying, "I just don't understand it.

"Space we can make progress with."

Is time an illusion?

"I wish time were an illusion," she said as she carved up the last of her chocolate bread pudding, "but unfortunately it seems all too real."