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Physicist Lisa Randall talks about hidden dimensions - and the importance of visible women in the field

By Peter Dizikes | September 4, 2005

WHATEVER YOUR MANNER of repose while reading this article--sitting, standing, lying down--you most likely feel firmly anchored to the earth. The force of gravity, as you experience it, seems impressively strong.

That is not exactly how Lisa Randall, a theoretical physicist at Harvard, views the matter. Like many other scientists, Randall thinks of gravity as a profoundly weak thing--"feeble," as she puts it. Indeed, particle for particle, as it were, gravity is the puniest of the fundamental forces governing the activity of matter in the universe, by a staggering margin.

In recent years, Randall has shot to science stardom thanks to her proposed explanation about why this is so. We are living, Randall has suggested, in a universe containing at least one extra dimension beyond those we can perceive. Gravity, she argues, is weak because it has been diluted into this extra space. Moreover, the universe's center of gravity, so to speak, may lie elsewhere; what we feel is just a small spillover of this force.

"Imagine a warped universe where we're just sitting some place off-center," Randall says, explaining her work at a cafe near Harvard Square on a recent afternoon. "We're not exactly where gravity peaks." And don't squint if you can only see three dimensions. Randall suggests we may be living in an isolated neighborhood of the cosmos, with fewer dimensions than exist in other parts of the universe.

Granted, these days, exotic-sounding theories about the cosmos are seemingly a dime a dimension. String theorists insist we live in a 10-dimensional universe--the extra ones are very, very small--while cosmologists ponder "multiverses" in which our own universe is but one of many that have existed. Still, because of the compelling logic of her theory and the suggestive cosmic structure it contains, Randall's papers on the subject (some of which she produced with colleagues Raman Sundrum and Andras Karch) are among the most-cited in contemporary physics, the equivalent of chart-topping hits.

"Her work is very original, very significant," says Mark Wise, a professor of physics at Caltech who has studied problems relating to Randall's theories. "She is one of the very top researchers of her generation."

And should the idea of, say, a five-dimensional universe still seem a bit outlandish to nonscientists, they can explore matters further in Randall's new book, "Warped Passages: Unraveling the Mysteries of the Universe's Hidden Dimensions," published by Ecco Press this month. "Warped Passages" is by turns engrossing and demanding, as Randall outlines her own ideas and details the impasses in physics which have given rise to mind-bending theories like her own. "The cosmos could be larger, richer, and more varied than anything we imagined before," writes Randall.

She hopes her book shows that scientists are a more varied bunch than is usually imagined, too. "I wanted to dispel some of the standard images people have," says Randall--namely, that physicists are men. While Randall--the first woman tenured in the physics department at Princeton, and the first tenured in theoretical physics at both MIT and Harvard--cites no particular female role models or mentors who sparked her own career, she believes a visible female presence in physics can overthrow stereotypes. "One of the reasons I thought it was important for me to write this book is so people could see that there are women like me out there doing this work, who are central to the field," she notes.

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Theoretical physics, as practiced by Randall and her colleagues, requires understanding the universe on both its smallest and largest scales. For decades, physicists have been producing and cataloging an array of subatomic particles--quarks, leptons, bosons, and more--in high-energy particle colliders. Theorists analyze the results and ask a question: What might be the structure of a universe containing these constituent parts?

Physicists would like that structure to neatly link the four fundamental forces regulating the interactions of matter: Gravity, electromagnetism, the strong nuclear force (which binds the components of protons and neutrons, within the atom) and the weak nuclear force (which governs the decay of some atoms). Immediately after the Big Bang, many physicists suspect, the fundamental forces may have been the same, but became differentiated and fixed into place as the universe expanded, cooled, and took its current form.

Physicists have been able to align, in theory and experiments, electromagnetism and the weak force, and have also, but less definitively, connected them with the strong force in the "Standard Model" of particle physics. Gravity, however, is so much weaker that it exists on an energy scale 10 million billion times different in magnitude than the other forces, constituting what particle physicists call the "hierarchy problem." That a tiny refrigerator magnet can by itself counteract the gravitational force of the entire earth--by sticking to the refrigerator door instead of falling to the floor-- shows the superior short-range power of electromagnetism.

To explain gravity's feebleness, Randall and Sundrum took some already existing concepts about space from theoretical physics and put them to new use. Their theory suggests that different regions of the universe have different properties: There is a "brane" (short for membrane) comprising the area on which we live, and a "bulk" space with a higher number of dimensions that surrounds or borders it. Gravitons, the particles to which the transmission of gravity is attributed, can travel between the two, even if we cannot.

In their breakthrough paper, published in 1999, Randall and Sundrum proposed that gravity's dilution can be accounted for in a specific cosmic configuration featuring two branes, separated by a higher-dimensional bulk space. One brane, the "Gravitybrane," Randall writes, "experiences a large gravitational force." Some gravity leaks out of this brane, through the bulk, and onto the other brane, which they call the "Weakbrane." We live on the Weakbrane.

As a consequence of this uneven cosmic geometry--in mathematical terms, it is "warped," giving Randall's book its title--the hierarchy problem can be radically reduced. There is plenty of gravity in the universe, but we are only exposed to a small bit of it. And while Randall and Sundrum have since found that their concept is also theoretically consistent with a one-brane configuration, Randall hopes evidence supporting the two-brane model could appear within a decade, after a new Swiss particle collider, the Large Hadron Collider, starts operating. "The universe is about to be pried open," she suggests in a burst of optimism at the end of "Warped Passages."

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If so, the reading public may wonder, how much of it will they be able to comprehend? Popular science books aim to make the complex appear simple. But the cutting-edge concepts Randall trades in often resist reduction to formulas, phrases or images, while unification theories such as hers require background knowledge covering virtually all of physics.

Randall sensibly begins her book trying to make readers feel comfortable about their impending intellectual discomfort. Take the notion of a higher-dimensional world, long a part of mathematics even though, as Randall writes, "we are not physiologically equipped to envision more than three dimensions of space." But, Randall adds, readers need not imagine a dimension only in spatial terms. Think of buying a house. The factors you might consider include its size, price, location, appearance, and more. The number of dimensions in your house search simply equals "the number of quantities you find worth investigating."

Besides, we already use a supple notion of dimensions. Albert Einstein famously posited that our three dimensions of space and one of time form a four-dimensional fabric of "spacetime." Indeed, when we refer to an event, we habitually specify its placement in both space and time.

Randall also notes that we can infer the way familiar physical effects might operate in higher-dimensional spaces. In a new popular-physics image, Randall compares the gravity emanating from an object like a planet to the water shooting from a circular sprinkler, which becomes less dense farther from the source: "Gravity, like water, is more widely distributed when it is further away." Because the Theory of General Relativity, Einstein's description of gravity, is mathematically consistent with a higher-dimensional universe, Randall here also foreshadows the unveiling of her own theory later in the book.

"I could have written a simpler version of it," acknowledges Randall. To make sure lay readers could still follow the text, she had nonscientist friends and acquaintances review chapters; novelist Cormac McCarthy, a Visiting Researcher at the Santa Fe Institute in New Mexico, commented on the whole manuscript. Ultimately, Randall says, she wanted to display the "real richness" of modern physics and highlight the intellectual struggles that animate physicists: "Why do scientists think about these things? What is it like to do science?"

Among other things, doing science can mean tackling problems for weeks, months or years. Reading "Warped Passages" does not take that long, of course, but the book will appeal especially to readers willing to live with unresolved problems instead of just being fed neat solutions. "I don't pretend that we've now discovered all the answers," says Randall. "Who wants to think that all the problems have been solved? Where's the fun in that?"

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Randall, 43, grew up in Queens and attended Stuyvesant High School in Manhattan, as a classmate ("literally--we had all our classes together") of string theorist-to-be Brian Greene, whose 1999 book "The Elegant Universe" was a huge popular-science success. Randall received both her bachelor's degree and doctorate in physics at Harvard, then spent several years as a professor at MIT before moving to Princeton in the late 1990s, briefly returning to MIT, and accepting her current position at Harvard in 2001.

Harvard has been a good fit for Randall, although she could not have been expecting university president Lawrence Summers, in January, to suggest that women may collectively have a lesser "availability of aptitude at the high end" of science, limiting the number who might become, in his words, "physicists at a Top 25 research university" (a category in which Summers would presumably place Harvard). Inevitably Randall has spent a fair amount of 2005 fielding questions about women and science, although she tends to deflect queries about the Summers controversy itself.

"This is an issue that goes beyond Harvard," Randall asserts. For female scientists, she thinks, "there's always that extra little hurdle to overcome" to have work taken as seriously as that of male scientists. Even as an established physicist, Randall says, she has had occasion to ask herself a question shared by many women in academia: "Are you getting the same benefit of the doubt?"

Randall also possesses a true physicist's impatience with social-scientific studies claiming to identify the reasons fewer women than men participate in the sciences. "At this point things are so poorly understood, it's almost the wrong question to ask why things are they way they are," she says. "The question is, what can we do to improve them?"

In that vein, Randall served on Harvard's Task Force on Women in Science and Engineering, created in the aftermath of the Summers furor, and favors practical measures to provide equal opportunities for women in academia, like steps ensuring fairness in faculty searches. Ultimately, Randall seems to prefer leading by example. Sometimes, she claims, "the way to make changes is just to be doing things, and the world eventually changes."

That attitude seems related to the way Randall approaches physics itself. In "Warped Passages," she claims she would sooner be remembered "for imagining new truths than for insisting on the status quo" in science. But Randall does not think of herself as a science revolutionary, just a practical-minded "model builder," as she calls herself in the book.

As Randall sees it, she's just responding to the facts on the ground--or floating somewhere in spacetime--that have not yet been straightened out, like the mysterious weakness of gravity. "Facts so bizarre cry out for a deeper explanation," Randall states in "Warped Passages."

And should it be necessary for scientists to build models representing the form of the entire universe, just to explain the behavior of matter at the smallest scales, so be it. "It's easier to imagine big things rather than small things," says Randall, answering a question about dimensions, but, as it happens, summarizing her ongoing adventures in physics.

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