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Meeting the Multiverse

A theoretical physicist brings her bewildering science down to earth.

by Marcia Bartusiak

It began with Isaac Newton. With the publication of his *Principia* in 1687, Newton became the first scientist to demonstrate that nature's actions, from the path of a cannonball to the moon's orbit about the earth, could be described by distinct mathematical laws. Mathematics became the key to unlocking the secrets of the heavens.

Continuing along this path, the Scottish theorist James Clerk Maxwell in the 1860s devised a concise set of eminently beautiful equations that united the forces of electricity and magnetism, showing them to be different sides of the same coin. Several decades later, Albert Einstein, spurred by his superb physical intuition but also by an astute mathematical rigor, extended Newton's laws and showed that gravity was a geometric manifestation. Space-time became a palpable item — a flexible sheet — and objects that appear to be under a gravitational force are actually following the geometric curves that matter impresses upon this rubbery mat of space-time. Even before tests confirmed this view, Einstein was sure his theory was right because of what he called "its incomparable beauty."

Lisa Randall, *Warped Passages: Unraveling the Mysteries of the Universe's Hidden Dimensions*, (Ecco, $27.95).

Mathematical beauty is a potent lure to physicists. In 1963, Murray Gell-Mann looked at the bewildering array of ephemeral particles discovered by physicists and found order by imagining a more fundamental group of building blocks called quarks, which combined by specific rules to generate the many particles. At that time, theoretical physicists were generally working side by side with experimentalists, but, encouraged by their successes, the theorists began to race ahead into unknown territory. The most ambitious, guided solely by the beauty and power of their mathematics, built a construct known as superstrings. This theory suggests that all the forces we experience and the particles we detect result from infinitesimally small strings vibrating within a space-time composed of 10 or 11 dimensions.

The story of superstrings was skillfully told in Brian Greene's best-selling *The Elegant Universe* (see "One Stuff," July-August 1999, page 25), but there's another aspect to this tale that Greene kept in the background. Not all theoretical physicists are happy with this dependence on mathematical splendor. Some are worried that the notorious celebrity of superstrings has diverted many of the best and brightest in physics from their science's more traditional (and successful) strategy: teaming up with experimentalists. Just as journalists Bob Woodward and Carl Bernstein were advised in the movie *All the President's Men* to "follow the money" to reach their goal — exposing the Watergate scandal — superstring critics would like to see theorists once again follow the data.

Superstring mavens are the top-downers. They sped to the ethereal heights and are now looking back down at the real world, hoping to find experimental evidence for strings below them. But, as Harvard professor of physics Lisa Randall asks in *Warped Passages*, have they now found themselves "at the edge of a precipitous, isolated cliff, too remote for them to find their way back to base camp"?

Randall represents the other faction of theorists: those whose feet are firmly planted near an atom smasher and who make predictions that will be either accepted or rejected as particles are slammed together and the resulting debris sifted through. They are the "model builders," who offer a healthy dose of caution to the grander claims of superstring theory. "So far," writes Randall, "...all attempts to make string theory realistic have had something of the flavor of cosmetic surgery. In order to make its predictions conform to our world, theorists have to find ways to cut away the pieces that shouldn't be there, removing particles and tucking dimensions demurely away....String theory is captivating at first, but ultimately string theorists have to address these fundamental problems." She says the model builders, on the other hand, are the "trailblazers who are trying to find the path that connects the solid ground below...to the peak....They yield definite predictions for physical phenomena, giving experimenters a way to verify or contradict a model's claims."

The two camps are not totally at odds. Indeed, Randall acknowledges that the inroads made by string theorists have been inspirational in part for her and her colleagues. "String theory introduces new ideas, both mathematical and physical, that no one would otherwise have considered, such as...extra-dimensional notions," she notes.

String theory brought to the forefront the idea that there may be more to the universe than just three spatial dimensions — height, width, length — plus time. There could be six more dimensions that we fail to perceive, possibly because they are so tiny and curled up and hidden from view, or perhaps because some are infinite in extension. These new spatial directions are the "warped passages" of the book's title: a concept that has dominated Randall's thinking during the last several years. This book is a chronicle of her theoretical adventures within this brave (and strange) new world.

At first, theorists postulated that it was the strings themselves that oscillated within these many dimensions, allegedly creating the various particles found in the cosmos. More recently, that idea has expanded to include membranes, or "branes" for short. A brane is essentially a slice out of that multidimensional world. According to this view, we might be living on a four-dimensional brane (space + time), which itself is immersed inside the full dimensional realm known in its entirety as the "bulk." Such entities as light waves, electrons, and protons are confined to our specific brane, according to Randall, much like water droplets trapped on a shower curtain.

Given this setup, Randall offers a new and mind-blowing take on the universe — or "multiverse," as we may be residing amid other branes, other parallel universes, within this complex higher-dimensional domain. "Thinking about branes makes you aware of just how little we know about the space in which we live," she writes. "The universe might be a magnificent composition linking intermittent branes." If there is life on those other branes, they likely experience different forces and possibly even different forms of matter. Randall stresses that, despite the science-fiction quality to this notion, evidence for these higher dimensions might actually be obtainable in the foreseeable future. “Experimental tests of competing hypotheses are near at hand, and within a decade,” she predicts, “there should be a dramatic revision in our understanding of fundamental physical laws that will incorporate whatever is discovered....”

For the last few decades, many theorists have been focused on unifying the four forcesof nature — gravity, electromagnetism, and the strong and weak nuclear forces. Just as Maxwell showed that electricity and magnetism were different features of the same force — electromagnetism — so, too, do theorists suspect that all the forces at some time were united, likely in the first moment of the Big Bang. As the primordial universe cooled and expanded, each force took on its own identity. But Randall believes there are more important questions to answer first. Why are the masses of the elementary particles — such entities as the electrons, protons, and neutrons that make up atoms — so low (theory alone would predict masses much higher) and why is the force of gravity so weak, compared to the other forces? A toy magnet, for instance, can lift a paper clip off the ground, despite the entire Earth gravitationally pulling back on it.

Randall’s investigations of higher dimensions are centered upon these conundrums, and she discusses several schemes (some developed by her, others by colleagues) for possible testing. In one model, for example, every particle we know and see around us has a partner in higher dimensional space — a KK particle (named after Theodor Kaluza and Oskar Klein, two physicists who first toyed with the idea of higher dimensions in the early twentieth century). According to Randall, these particles originate in the extra dimensions but make an appearance in our universe with measurable properties. In a way, they cast a three-dimensional “shadow” upon our world, much as an object would cast a two-dimensional shadow on a wall on a sunny day.

Finding a ghostly KK particle would not only be evidence of the higher dimensions, but would also provide an answer to gravity’s frailty. Whereas electromagnetism and the nuclear forces are confined to our brane, and so remain fairly strong, gravity is the lone force that spans all the dimensions and, as a consequence, gets diluted.

Or maybe, posits Randall, we live near a brane where gravity is intensely strong, but by the time the gravitational field extends through a fifth dimension, it arrives on our brane of space-time much weakened.

As you read along, branes, strings, and higher dimensions start resembling a set of LEGO blocks, to be arranged and rearranged to match our world and our cosmology. Which model will survive, if any, is hard to predict. More exciting for Randall and her colleagues is that testable predictions can be made, renewing the exhilarating time in particle physics of the late 1960s, when quarks were first detected at the Stanford Linear Accelerator as electrons slamming into protons revealed that the protons were built out of three smaller particles (as Gell-Mann had surmised).

CERN, the European particle-physics center situated on the Swiss-French border, is now installing the most powerful instrument ever built to investigate the properties of elementary particles. Within two years, its Large Hadron Collider is scheduled to smash two beams of protons together at energy levels so high that the resulting impact might nudge some KK particles into plain sight (or at least allow them to leave their calling cards within the collision debris). What is more, infinitesimally tiny black holes might form as well, quickly evaporating in a hail of energy. There’s even a small chance that strings themselves might be amplified and detected. Any of these occurrences would be evidence of higher dimensions. Such are the very real, daily concerns of contemporary theoretical — and, soon, experimental — physicists.

Be warned: this book can be tough going at times. "I wanted to let the fascination of theoretical physics speak for itself without over-emphasizing personalities and without simplifying the subject deceptively," cautions Randall. "... I truly believe that there are many people who are smart, interested, and tough enough to want more of the real thing." There's not an equation in sight, but readers should be prepared to learn about renormalizations, gauge bosons, and symmetry transformations, with insightful illustrations provided for assistance. Those who stick with it are rewarded with a realistic peek at physicists at play, seeing how they can absorb a new concept and fashion potential solutions to long-held mysteries. *Warped Passages* is more challenging than most popular science works, but highly accessible to the physics-minded because of Randall's lucid explanations. It's quirky and rambling, but somehow always intriguing.

How seriously should we take all this talk of vibrating strings and parallel universes? Hypotheses in high-energy physics rise and fall on the Internet these days, sometimes in a matter of hours. But I can imagine getting comfortable with branes and higher dimensions, as some of us are already accustomed to black holes, relativity, and particle/wave dualities. To get ready for that day, aspiring theoretical physicists are encouraged to buy a copy, for there's much inspiration to be found here.

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