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AUTHOR



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## When Particles Collide

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**Harvard physicist Lisa Randall talks about particles colliding, high energy, and the recent revelations that might upend Einstein's theory. Alexander Fabry unravels her new book, "Knocking on Heaven's Door."**

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Lisa Randall, theoretical particle physicist at Harvard, explained the strange physics of string theory and tiny extra dimensions in her first book, *Warped Passages*. She met The Daily Beast for a cappuccino at L.A. Burdicks to discuss how scientific progress happens, the largest particle accelerator ever made, the origin of mass, the future of physics, and her most recent book *Knocking on Heaven's Door*.

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One of the central motifs of Randall's book is the sometimes messy process of scientific discovery. The world looks fuzzy at the far boundaries of scientific knowledge. On the ordinary scale of everyday life we have enormous amounts of data that confirm our understanding of physics. But on unfamiliar scales, like the extremely small or the very high energy, we bump against the limits of experience. This doesn't mean that we should distrust physics—far from it, as modern physics has made and verified some astoundingly accurate predictions—but it introduces both scientific uncertainty and the potential for incredible new discoveries.

The Large Hadron Collider (LHC) in Switzerland, the most complicated machine every built and the most powerful particle accelerator in the world, now places us on this boundary of knowledge. In her book, Randall manages to transform these experiments at distant and unfamiliar scales into crucial acts in a cosmic drama.

There has been some buzz recently from CERN—which houses the Large Hadron Collider—about an experiment that seemed to find faster-than-light neutrinos, something I thought was impossible. What do physicists think about this?

Most people suspect the measured speed of these neutrinos is wrong— due to an experimental error or an incorrect interpretation of results. Nonetheless it is not impossible that we will eventually measure such a violation of one of the underlying assumptions of the theory called special relativity.

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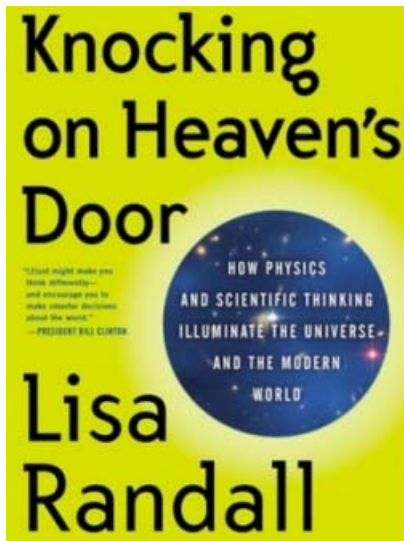
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It could be that the underlying symmetry that is assumed is somehow violated. One way this might happen is with an extra dimension, and a warped extra dimension of the sort I've thought about in particular. It doesn't necessarily occur but it is possible.

This is challenging science in action. We want to test our fundamental assumptions as precisely as possible. Even if they work in regimes we've already measured, a violation could be a sign of a deeper underlying theory. Theories build on each other. This is one of the key elements of science that I discuss in my book.

#### What happens inside the LHC?

First of all you have to know, what's happening is protons are colliding together. At these energies, it's actually not the protons themselves that collide together en masse, but ingredients inside the protons. It's quarks, which are inside, or gluons, which are particles associated with the strong force that holds it together. So these particles collide and they then turn into pure energy.  $E=mc^2$ —Einstein's famous equation. And that energy can then turn into new particles. It can turn into what we call standard model particles, and that describes everything we've seen so far, in fact. Or it could be some new particles. So what the experiments try to do is report what came out of the collision.

#### One of the particles the LHC is looking for is something called the Higgs boson, right? What is this?

In some sense, there are two main goals at the LHC. One is the Higgs boson, which we'll go into in a minute. And the other, we're not just looking for the Higgs boson, there's another very exciting idea of why particles have the mass they do, which could involve these very exotic ideas about space-time symmetries or dimensions of space or very exotic things, and we want to learn both. What makes the Higgs so interesting is that we really think it should show up. These other ideas, might be just beyond the energy reach of the LHC, or they might be there. But the Higgs really should be there.

So let me tell you about the Higgs. The Higgs has to do with how particles acquire their mass. That might sound like an odd concept, particles and mass. I should say how fundamental elementary particles acquire their mass. Shouldn't particles just have mass? But it turns out, according to actually the symmetries in

the standard model, according to the fundamental principles involved in the field there underlying it, unless there's some extra mechanism, they won't, it would just be an inconsistent theory. So you need this new mechanism. This mechanism is called the Higgs mechanism. And it involves the idea that particles are part of their mass in some sense by scattering against charges spread throughout the universe. It's called a Higgs field, not a Higgs particle, a Higgs field. It's a different type of charge that in some sense exists throughout the universe. And particles acquire their mass in some sense by scattering off that charge. So basically, particles that scatter more are heavier. Now if the Higgs mechanism is right, and I think most particle physicists think it is right, there should be direct experimental evidence. You might say the fact that particles have mass is in some sense evidence. What we really want to know is, what is the model underlying this Higgs mechanism? What is it that gives you this charge spread throughout the universe?

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