Will the Large Hadron Collider Explain Everything?

By JIM HOLT
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Lisa Randall is a professor of physics at Harvard and one of the more original theorists at work in the profession today. In the fancifully titled "Knocking on Heaven's Door," her second book for a popular audience, she has two avowed aims: first, to explain where physics might be headed now that the Large Hadron Collider — the enormous particle accelerator on the Swiss-French border — is finally up and running; and second, to air her views on the nature of science, its fraught relations with religion, and the role of beauty as a guide to scientific truth. Her book thus alternates between the nitty-gritty of particle physics and meditations of a more rarefied sort. Stitching the whole thing together are passages recounting the author's globe-trotting adventures: accepting the key to the city from the mayor of Padua, chatting up a scientifically curious actor on a flight to Los Angeles, attending the Barcelona premiere of an opera about physics for which she had written the libretto.

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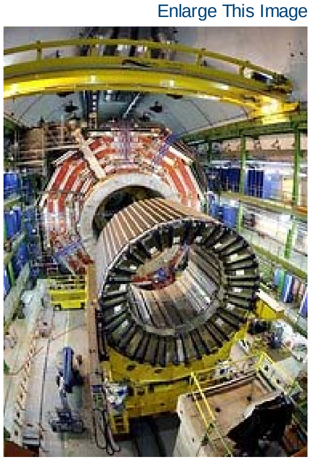

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The magnet core of a particle detector on the Large Hadron Collider. "The L.H.C. belongs to a world," Randall writes, "that can only be described with superlatives."

KNOCKING ON HEAVEN'S DOOR

How Physics and Scientific Thinking Illuminate the

So where is physics headed? Before grappling with this question, it might be wise to ask first where physics is. And the cynical answer is, about where it was in the 1970s. That was when the finishing touches were put on the so-called Standard Model of particle physics. The Standard Model describes, in a single mathematical framework, the basic constituents of nature and three of the four known forces that govern their interactions: electromagnetism; the "strong" force, which holds the nucleus of the atom together; and the "weak" force, which causes radioactive decay. The Standard Model is not particularly elegant; indeed, it's something of a stick-and-bubble-gum contraption. But in the decades since it was formulated, it has predicted the result of every experiment in particle physics, and with terrific accuracy.

There is one obvious problem with the Standard Model. It leaves out the fourth force of nature, the earliest one to be discovered and the one with which we're most familiar: gravity. Nobody has yet figured out how to describe gravity in the same language — the language of quantum mechanics — the Standard Model uses to describe the other

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Universe and the Modern World
By Lisa Randall
Illustrated. 442 pp.
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three forces. So we need a separate theory for gravity: Einstein's general relativity theory.

Some physicists of a conservative kidney, like Freeman Dyson, are reasonably content with this division of labor. Let the Standard Model handle the small stuff (atoms on down), they say, and general relativity handle the massive stuff (stars on up). Never mind that the two theories give inconsistent answers at extreme energies, where very small things can also be very massive; we can't observe such energies anyway.

But other physicists insist that an entirely new framework must be found, one that would transcend the Standard Model by putting all four forces on the same theoretical footing. Only then, they argue, will we understand how nature behaves at energies like those that prevailed at the Big Bang, when the four forces acted as one. The best candidate for such a unifying framework seems to be string theory.

String theory is a top-down approach to progress in physics — total revolution from above. Once you find the right principles to describe nature at the very highest energies, all else follows. The problem with string theory is that so far at least, it makes no testable predictions. Since string theorists are working in the dark, experimentally speaking, some say they are not really doing science, but rather pure mathematics.

The alternative is a bottom-up approach — gradual reform from below. And this brings us back to Lisa Randall. She knows as well as her string-theorist colleagues do that the Standard Model can't be the whole story. At best, it's a low-energy approximation of the Truth. But she prefers to hew closely to the available experimental data, using those data to resolve puzzling features of the Standard Model and to guess how it might be extended to energies just beyond its ken — the sort of energies that, she hopes, will be attainable soon in the Large Hadron Collider.

This is not to say that Randall has no truck with string theory. Indeed, she has exploited one of its central ideas — that space might have extra, hidden dimensions — as part of an ingenious bottom-up proposal (worked out with Raman Sundrum) to resolve a longstanding mystery about the Standard Model, known as the hierarchy problem: Why do the elementary particles it describes have such wildly arbitrary masses? Related to this is a second mystery: Why do these particles have any mass at all?

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Jim Holt's new book, "Why Does the World Exist?," will be published next spring.

A version of this review appeared in print on October 9, 2011, on page BR14 of the Sunday Book Review with the headline: Disturbances in the Field.

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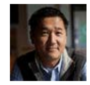

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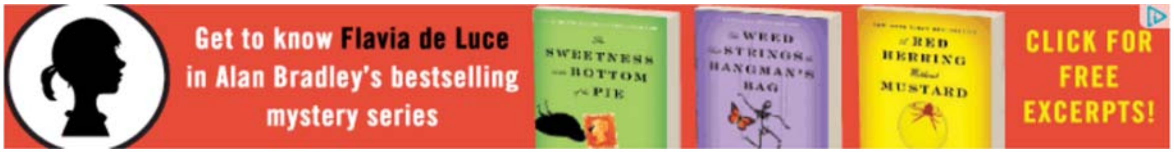

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And here's where the Large Hadron Collider had better help. At the very least, this magnificent machine — the biggest ever built, and quite possibly the most picturesque (rating a photo spread in Vanity Fair) — is expected to blast into existence the Higgs boson. This is the long-sought missing ingredient of the Standard Model, the one that (if it really does exist) would be the key to understanding how asymmetries arose between forces that ought to look the same.

KNOCKING ON HEAVEN'S DOOR

How Physics and Scientific Thinking Illuminate the Universe and the Modern World

By Lisa Randall

Illustrated. 442 pp. Ecco/HarperCollins Publishers. $29.99.

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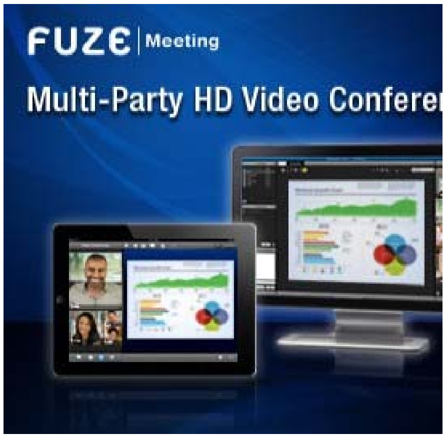
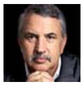
Randall strives conscientiously to explain this Higgs business, as well as the hierarchy problem and her own arrestingly subtle way of dealing with it (which involves gravity "leaking" through warped dimensions). Such matters, it must be said, are among the very hardest to get across to non-physicists. If you don't have the math under your belt, the right metaphors can sometimes give you the agreeable feeling that you are "almosting it" (as Stephen Dedalus says to himself in "Ulysses"). Randall does manage to deliver such moments, if not as consistently as other physics-popularizers (notably Steven Weinberg, Brian Greene and Lawrence Krauss).

Her philosophical ruminations are more uneven. She gives a fine analysis of the affinity between scientific and artistic beauty, comparing the broken symmetries of a Richard Serra sculpture to those at the core of the Standard Model. Elsewhere, though, she is guilty of what might be called premature intellectual closure. Can a scientist be religious? Only at the price of inconsistency, she argues, because scientific determinism is not compatible with belief in a deity who can willfully intervene in the world. Sympathetic though I am to her conclusion, I would point out that scientific determinism is equally incompatible with free will and moral responsibility.

It is interesting to consider the Large Hadron Collider itself in this light. Here we have a gigantic and complex physical object that was consciously created by humans motivated by the desire to obtain, in Randall's words, "a more comprehensive picture of the nature of reality." But this physical object, like the scientists who planned it, ultimately just consists of elementary particles bumping around. It came together through interactions that, in principle at least, could be entirely accounted for by the laws of physics, without any





reference at all to human will or purpose. Seen in this non-anthropocentric way, the Large Hadron Collider looks like the physical universe's bid for a kind of self-awareness. Its existence is a sign that the laws of physics mandate their own discovery.

To me that's a breathtaking thought (even if it's a little woolly and Hegelian), and I am grateful to Randall for putting it into my head — where, also thanks to her, a certain Bob Dylan song has been reverberating for the last three weeks.

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