American Scientist online
THE MAGAZINE OF SIGMA XI, THE SCIENTIFIC RESEARCH SOCIETY

see list of all reviews from this issue: November-December 2005

Dimensions Demystified

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Warped Passages: Unraveling the Mysteries of the Universe's Hidden Dimensions. Lisa Randall. xii + 500 pp. Ecco Press, 2005. $27.95.

Parallel Worlds: A Journey Through Creation, Higher Dimensions, and the Future of the Cosmos. Michio Kaku. xviii + 428 pp. Doubleday, 2005. $27.95.

The fact that space has three dimensions would seem to be one of the most obvious and indisputable features of our world. Ever since Einstein proposed his theory of general relativity, however, it has been possible to imagine the existence of extra, somehow hidden, dimensions—new directions in which material objects could extend in space. Their existence is often considered in the context of a desire to unify gravitation with other forces, a goal that continues to be important. String theory, the leading candidate for reconciling quantum mechanics with general relativity, actually requires the existence of extra dimensions. Over the course of the last few decades, theoretical physicists have invested great effort in exploring the different ways in which such dimensions could be hidden from view and what effect they might have on the physics we directly observe.

Lisa Randall, who has been one of the most influential researchers in this area, has written a book aimed at sharing the excitement of recent discoveries with a general audience. *Warped Passages: Unraveling the Mysteries of the Universe's Hidden Dimensions* follows in the footsteps of popular accounts of cutting-edge physics by the likes of Stephen Hawking, Kip Thorne, Alan Guth and Brian Greene, who helped create the ideas they are explaining. Part of the role of such books is to provide an expert's view of the current situation in fundamental physics. Equally important, however, is the insight they give into the thought processes of working scientists.

The simplest way to hide extra dimensions from view is to imagine that they are "compactified"—curled up into a tiny ball (or other geometrical configuration) with an extent much smaller than what can be probed by current experimental apparatus. In the 1990s, however, a new possibility arose, as scientists came to appreciate the role of "branes" in higher-dimensional physics. A brane, generalizing the concept of a membrane, is simply an extended object: A string is a one-dimensional brane, a membrane is a two-dimensional brane, and so on, up to however many dimensions may exist. A remarkable feature of such objects is that particles may be confined to them, unable to escape into the surrounding space. We can therefore imagine that our visible world is a three-dimensional brane, embedded in a larger universe into which we simply can't reach.

Gravity, as the curvature of spacetime itself, is the one force that is hard to confine to a brane; the extra dimensions must therefore have some feature that prevents gravity from appearing higher-dimensional. (For example, in four spatial dimensions, the gravitational force would fall off as the distance cubed, rather than the distance squared.) One possibility, proposed by Nima Arkani-Hamed, Savas Dimopoulos and Georgi ("Gia") Dvali, is that the extra dimensions curl up into a ball that is small without being too small—perhaps as large as a millimeter across in each direction. Randall, in collaboration with Raman Sundrum, showed that an extra dimension could be *infinitely* big, if the higher-dimensional space was appropriately "warped" (hence the title of her book). These scenarios, and others that followed, launched a renaissance in the study of extra dimensions. Most intriguingly, these theories made specific predictions for the outcome of experiments that could be done in the near

future. (Already, the "millimeter" of the original proposal of Arkani-Hamed and colleagues has been reduced to less than a tenth of a millimeter by experimental progress.)

Building up to these developments requires a good deal of background, and Randall's book provides it in great depth. She begins with an extended introduction to the idea of extra dimensions itself, including the inevitable invocation of Edwin Abbott's classic 1884 novel *Flatland,* which describes a two-dimensional universe whose inhabitants can't imagine a third dimension. But then Randall backs up a bit, to launch a detailed survey of 20th-century physics, covering relativity, gravitation, quantum mechanics, particle physics, the Standard Model and extensions thereof, such as supersymmetry and string theory. She makes a concerted effort to keep the presentation lively and entertaining—by, for example, quoting from popular music and featuring fictional characters, Athena and Icarus, in certain narrative digressions. A distinctive feature of *Warped Passages* is the discussion of two different ways of extending physics beyond the Standard Model: the bottom-up, model-building "Harvard" approach; and the top-down, string-theory "Princeton" approach. Both philosophies are interesting and important, and the study of extra dimensions has brought them into close collaboration. The perspective of someone who has been immersed in the details makes the discussion of this dichotomy an especially valuable feature of the book.

Michio Kaku's *Parallel Worlds: A Journey Through Creation, Higher Dimensions, and the Future of the Cosmos,* although superficially similar to Randall's book, actually differs significantly from it. Although Kaku worked on string theory in its early days, he has become well known more recently as a popularizer of physics, and this is evident from the text. *Parallel Worlds* is not written from the viewpoint of an insider relating developments as they occurred. It is telling, for example, that the bibliography consists solely of other books for a general audience, with no citations of the primary literature. Nonetheless, the presentation is extremely polished, and the discussion is invigorated by the inclusion of numerous interesting and revealing anecdotes about the participants.

Kaku is also very attuned to the fact that what interests the general reader is not always what interests the professional physicist. He is quite willing to discuss the possibility of life on other planets, or even the religious implications of the work he describes. Statements such as "If true, [the multiverse] would unify two of the great religious mythologies, Genesis and Nirvana. Genesis would take place continually within the fabric of timeless Nirvana" are made as straightforwardly as comments on the cosmic microwave background.

The book deals with "parallel worlds" in a somewhat generalized sense; brane-world scenarios are discussed, but so are the "many worlds" of the Everett interpretation of quantum mechanics, as well as the "pocket universes" implied by inflationary cosmology. Kaku also discusses the recent astronomical discovery that the expansion of our universe is accelerating, and the implied existence of dark energy. The notion that galaxies are flying away from one another at increasing rates as the universe grows increasingly empty propels the narrative: Can we use other worlds as a possible escape hatch from this desolate future? The accompanying discussion, invoking wormholes and baby universes, goes a step or two beyond established physics. By itself this sort of speculation is okay, but it blurs an important line. The branes and extra dimensions of Randall's book, although they seem far-fetched, arise out of a sober and systematic exploration of the possibilities opened up by string theory; thus they are concepts that experimentalists take very seriously. Wormholes connecting different universes sound no more speculative than extra dimensions but are actually not nearly as grounded in well-established physics. Nonexperts may not be able to make these sorts of distinctions.

Both of these books do an excellent job of explaining very esoteric concepts. As a theoretical physicist myself, I would be cheered to notice someone sitting at my local coffee shop engrossed in either book. *Parallel Worlds* is somewhat easier to dip into and provides a nice overview of many interesting ideas in modern physics. *Warped Passages,* however, is useful and important both as an introduction to some key ideas in modern physics and as a window onto the way that physics is really done. Let us hope that the tradition of accessible books written for the general public by accomplished scientists continues to thrive.

Reviewer Information

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