Ghosts, Aliens, Quantum Gravity, Extra Dimensions, Sci Fi--and the Rules of Science

In this excerpt from the new book *Knocking on Heaven's Door: How Physics and Scientific Thinking Illuminate the Universe and the Modern World* (Harper Collins, 2011), you'll learn why, although it's true that scientists sometimes have been wrong, that doesn't mean there are no rules--or that everything is possible

By Lisa Randall | September 22, 2011 | 22

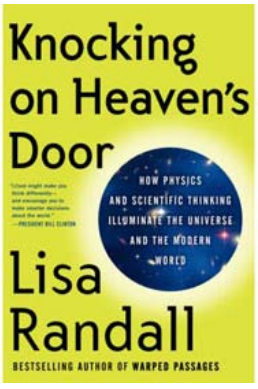

Image: HarperCollins Publishers

Among the many reasons I chose to pursue physics was the desire to do something that would have a permanent impact. If I was going to invest so much time, energy and commitment, I wanted it to be for something with a claim to longevity and truth. Like most people, I thought of scientific advances as ideas that stand the test of time.

My friend Anna Christina Büchmann studied English in college whereas I majored in physics. Ironically, she studied literature for the same reason that drew me to math and science. She loved the way an insightful story lasts for centuries. When discussing Henry Fielding's novel *Tom Jones* with her many years later, I learned that the edition I had read and thoroughly enjoyed was the one she helped annotate when she was in graduate school.

Tom Jones was originally published 250 years ago, yet its themes and wit resonate to this day. During my first visit to Japan, I read the far older *Tale of Genji* and marveled at its characters' immediacy, too, despite the thousand years that have elapsed since Murasaki Shikibu wrote about them. Homer created the *Odyssey* roughly 2,000 years earlier than *Genji*. Notwithstanding its very different age and context, we continue to relish the tale of Odysseus's journey and its timeless descriptions of human nature.

Scientists rarely read such old—let alone ancient—scientific texts. We usually leave

Latest Headlines

Natural Gas Firm Says Shale Fracking Caused UK Earthquakes
Reuters | 26 minutes ago | 1

Can Climate Science Predict Extreme Weather?
News | 54 minutes ago

The Fabric of the Cosmos: A Q&A with Brian Greene, November 2, 10:00 - 11:00 PM ET [Live Stream]
Features | 2 hours ago | 1

Show Most Read
Show Most Commented

Latest Posts by SA Editors

The Scientific Paper: past, present and probable future
STAFF A Blog Around The Clock | 4 hours ago

that to historians and literary critics. We nonetheless apply the knowledge that has been acquired over time, whether from Newton in the 17th century or Copernicus more than 100 years earlier still. We might neglect the books themselves, but we are careful to preserve the important ideas they may contain.

Science certainly is not the static statement of universal laws we all hear about in elementary school. Nor is it a set of arbitrary rules. Science is an evolving body of knowledge. Many of the ideas we are currently investigating will prove to be wrong or incomplete. Scientific descriptions certainly change as we cross the boundaries that circumscribe what we know and venture into more remote territory where we can glimpse hints of the deeper truths beyond.

The paradox scientists have to contend with is that, while aiming for permanence, we often investigate ideas that experimental data or better understanding will force us to modify or discard. The sound core of knowledge that has been tested and relied on is always surrounded by an amorphous boundary of uncertainties that are the domain of current research. The ideas and suggestions that excite us today will soon be forgotten if they are invalidated by more persuasive or comprehensive experimental work tomorrow.

When the 2008 Republican presidential candidate Mike Huckabee sided with religion over science—in part because scientific "beliefs" change whereas Christians take as their authority an eternal, unchanging God—he was not entirely misguided, at least in his characterization. The universe evolves and so does our scientific knowledge of it. Over time, scientists peel away layers of reality to expose what lies beneath the surface. We broaden and enrich our understanding as we probe increasingly remote scales. Knowledge advances and the unexplored region recedes when we reach these difficult-to-access distances. Scientific "beliefs" then evolve in accordance with our expanded knowledge.

Nonetheless, even when improved technology makes a broader range of observations possible, we don't necessarily just abandon the theories that made successful predictions for the distances and energies, or speeds and densities, that were accessible in the past. Scientific theories grow and expand to absorb increased knowledge, while retaining the reliable parts of ideas that came before. Science thereby incorporates old established knowledge into the more comprehensive picture that emerges from a broader range of experimental and theoretical observations. Such changes don't necessarily mean the old rules are wrong, but they can mean, for example, that those rules no longer apply on smaller scales where new components have been revealed. Knowledge can thereby embrace old ideas yet expand over time, even though very likely more will always remain to be explored. Just as travel can be compelling—even if you will never visit every place on the planet (never mind the cosmos)—increasing our understanding of matter and of the universe enriches our existence. The remaining unknowns serve to inspire further investigations.

My own research field of particle physics investigates increasingly smaller distances in order to study successively tinier components of matter. Current experimental and theoretical research attempt to expose what matter conceals—that which is embedded ever deeper inside. But despite the often-heard analogy, matter is not simply like a Russian matryoshka doll, with similar elements replicated at successively smaller scales. What makes investigating increasingly minuscule distances interesting is that the rules can change as we reach new domains. New forces and interactions might appear at those scales whose impact was too tiny to detect at the larger distances previously investigated.

The notion of scale, which tells physicists the range of sizes or energies that are relevant for any particular investigation, is critical to the understanding of scientific

#scio11 - Perils of Blogging as a Woman under a Real Name
STAFF A Blog Around The Clock | 5 hours ago

Sun Time is the Real Time
STAFF A Blog Around The Clock | 6 hours ago

#SciAmBlogs Tuesday - cycads, lancelets, robots and loving eyes...
STAFF The Network Central | 12 hours ago

#scio11 - Blogging on the Career Path
STAFF A Blog Around The Clock | Nov 1, 2011

Show Latest from SA Blog Network

Science Jobs of the Week

progress—as well as to many other aspects of the world around us. By partitioning the universe into different comprehensible sizes, we learn that the laws of physics that work best aren't necessarily the same for all processes. We have to relate concepts that apply better on one scale to those more useful at another. Categorizing in this way lets us incorporate everything we know into a consistent picture while allowing for radical changes in descriptions at different lengths.

Partitioning by scale—whichever scale is relevant—helps clarify our thinking—both scientific and otherwise—and why the subtle properties of the building blocks of matter are so hard to notice at the distances we encounter in our everyday lives. In doing so, we can also elaborate on the meaning of "right" and "wrong" in science, and why even apparently radical discoveries don't necessarily force dramatic changes on the scales with which we are already familiar.

It's Impossible

People too often confuse evolving scientific knowledge with no knowledge at all and mistake a situation in which we are discovering new physical laws with a total absence of reliable rules. A conversation with the screenwriter Scott Derrickson during a recent visit to California helped me to crystallize the origin of some of these misunderstandings. At the time, Scott was working on a couple of movie scripts that proposed potential connections between science and phenomena that he suspected scientists would probably dismiss as supernatural. Eager to avoid major solecisms, Scott wanted to do scientific justice to his imaginative story ideas by having them scrutinized by a physicist—namely me. So we met for lunch at an outdoor café in order to share our thoughts along with the pleasures of a sunny Los Angeles afternoon.

Knowing that screenwriters often misrepresent science, Scott wanted his particular ghost and time-travel stories to be written with a reasonable amount of scientic credibility. The particular challenge that he as a screenwriter faced was his need to present his audience not just with interesting new phenomena, but also with ones that would translate effectively to a movie screen. Although not trained in science, Scott was quick and receptive to new ideas. So I explained to him why, despite the ingenuity and entertainment value of some of his story lines, the constraints of physics made them scientifically untenable.

Scott responded that scientists have often thought certain phenomena impossible that later turned out to be true. "Didn't scientists formerly disbelieve what relativity now tells us?" "Who would have thought randomness played any role in fundamental physical laws?" Despite his great respect for science, Scott still wondered if—given its evolving nature—scientists aren't sometimes wrong about the implications and limitations of their discoveries.

Some critics go even further, asserting that although scientists can predict a great deal, the reliability of those predictions is invariably suspect. Skeptics insist, notwithstanding scientific evidence, that there could always be a catch or a loophole. Perhaps people could come back from the dead or at the very least enter a portal into the Middle Ages or into Middle-earth. These doubters simply don't trust the claims of science that a thing is definitively impossible.

Despite the wisdom of keeping an open mind and recognizing that new discoveries

await, however, a deep fallacy is buried in this logic. The problem becomes clear when we dissect the meaning of such statements as those above and, in particular, apply the notion of scale. These questions ignore the fact that although there will always exist unexplored distance or energy ranges where the laws of physics might change, we know the laws of physics on human scales extremely well. We have had ample opportunity to test these laws over the centuries.

When I met the choreographer Elizabeth Streb at the Whitney Museum, where we both spoke on a panel on the topic of creativity, she, too, underestimated the robustness of scientific knowledge on human scales. Elizabeth posed a similar question to those Scott had asked: “Could the tiny dimensions proposed by physicists and curled up to an unimaginably small size nonetheless affect the motion of our bodies?”

Her work is wonderful, and her inquiries into the basic assumptions about dance and movement are fascinating. But the reason we cannot determine whether new dimensions exist, or what their role would be even if they did, is that they are too small or too warped for us to be able to detect. By that I mean that we haven’t yet identified their influence on any quantity that we have so far observed, even with extremely detailed measurements. Only if the consequences of extra dimensions for physical phenomena were vastly bigger could they discernibly influence anyone’s motion. And if they did have such a significant impact, we would already have observed their effects. We therefore know that the fundamentals of choreography won’t change even when our understanding of quantum gravity improves. Its effects are far too suppressed relative to anything perceptible on a human scale.

When scientists have turned out to be wrong in the past, it was often because they hadn’t yet explored very tiny or very large distances or extremely high energies or speeds. That didn’t mean that, like Luddites, they had closed their minds to the possibility of progress. It meant only that they trusted their most up-to-date mathematical descriptions of the world and their successful predictions of then-observable objects and behaviors. Phenomena they thought were impossible could and sometimes did occur at distances or speeds these scientists had never before experienced—or tested. But of course they couldn’t yet have known about new ideas and theories that would ultimately prevail in the regimes of those tiny distances or enormous energies with which they were not yet familiar.

When scientists say we know something, we mean only that we have certain ideas and theories whose predictions have been well tested *over a certain range of distances or energies* . These ideas and theories are not necessarily the eternal laws for the ages or the most fundamental of physical laws. They are rules that apply as well as any experiment could possibly test, over the range of parameters available to current technology. This doesn’t mean that these laws will never be overtaken by new ones. Newton’s laws are instrumental and correct, but they cease to apply at or near the speed of light where Einstein’s theory applies. Newton’s laws are at the same time both correct and incomplete. They apply over a limited domain.

The more advanced knowledge that we gain through better measurements really is an improvement that illuminates new and different underlying concepts. We now know about many phenomena that the ancients could not have derived or discovered with their more limited observational techniques. So Scott was right that sometimes scientists have been wrong—thinking phenomena impossible that in the end turned out to be perfectly true. But this doesn’t mean there are no rules. Ghosts and time-travelers won’t appear in our houses, and alien creatures won’t suddenly emerge from our walls. Extra dimensions of space might exist, but they would have to be tiny or warped or otherwise currently hidden from view in order for us to explain why they have not yet yielded any noticeable evidence of their existence.

Exotic phenomena might indeed occur. But such phenomena will happen only at

difficult-to-observe scales that are increasingly far from our intuitive understanding and our usual perceptions. If they will always remain inaccessible, they are not so interesting to scientists. And they are less interesting to fiction writers, too, if they won't have any observable impact

Weird things are possible, but the ones non-physicists are understandably most interested in are the ones we can observe. As Steven Spielberg pointed out in a discussion about a science fiction movie he was considering, a strange world that can't be presented on a movie screen—and which the characters in a film would never experience—is not so interesting to a viewer. Only a new world that we can access and be aware of could be. Even though both require imagination, abstract ideas and fiction are different and have different goals. Scientific ideas might apply to regimes that are too remote to be of interest to a film, or to our daily observations, but they are nonetheless essential to our description of the physical world.

ABOUT THE AUTHOR(S)
Lisa Randall is a Frank B. Baird, Jr., Professor of Science at Harvard University. She studies theoretical particle physics and cosmology. In addition to her research, she has written a popular book, Warped Passages: Universe's Hidden Dimensions, as well as a libretto for Hypermusic: A Projective Opera in Seven Planes. She is a member of Scientific American's board of advisors.

22 Comments

1. gongniu
02:51 PM 9/22/11

I clicked through to the article because of the buzzwords in the headline ... and several paragraphs in it's still about college memories. Well shame on me for following the buzzwords, but could you at least make the titles relate to the article more? It undermines your credibility to trick us readers like that.

2. lyellr
05:26 PM 9/22/11

Excuse the rest of us for not having your level of ADD. Interesting writing generally takes a couple paragraphs to introduce itself, maybe if you kept at it for more than 30 seconds you'd get a little more out of it.

Loved the article, keep 'em coming!

3. timbo555
10:54 AM 9/24/11

"You'll learn why, although it's true that scientists sometimes have been wrong, that doesn't mean there are no rules--or that everything is possible".

Sometimes? All scientists have been wrong 99% of the time. The modern light bulb was a success only after Edison FAILED over one thousand five hundred times. That's a pretty impressive ratio.

Human knowledge is finite. Human ignorance is nearly infinite. Pride and arrogance complicate matters considerably.