Why string theory requires extra dimensions

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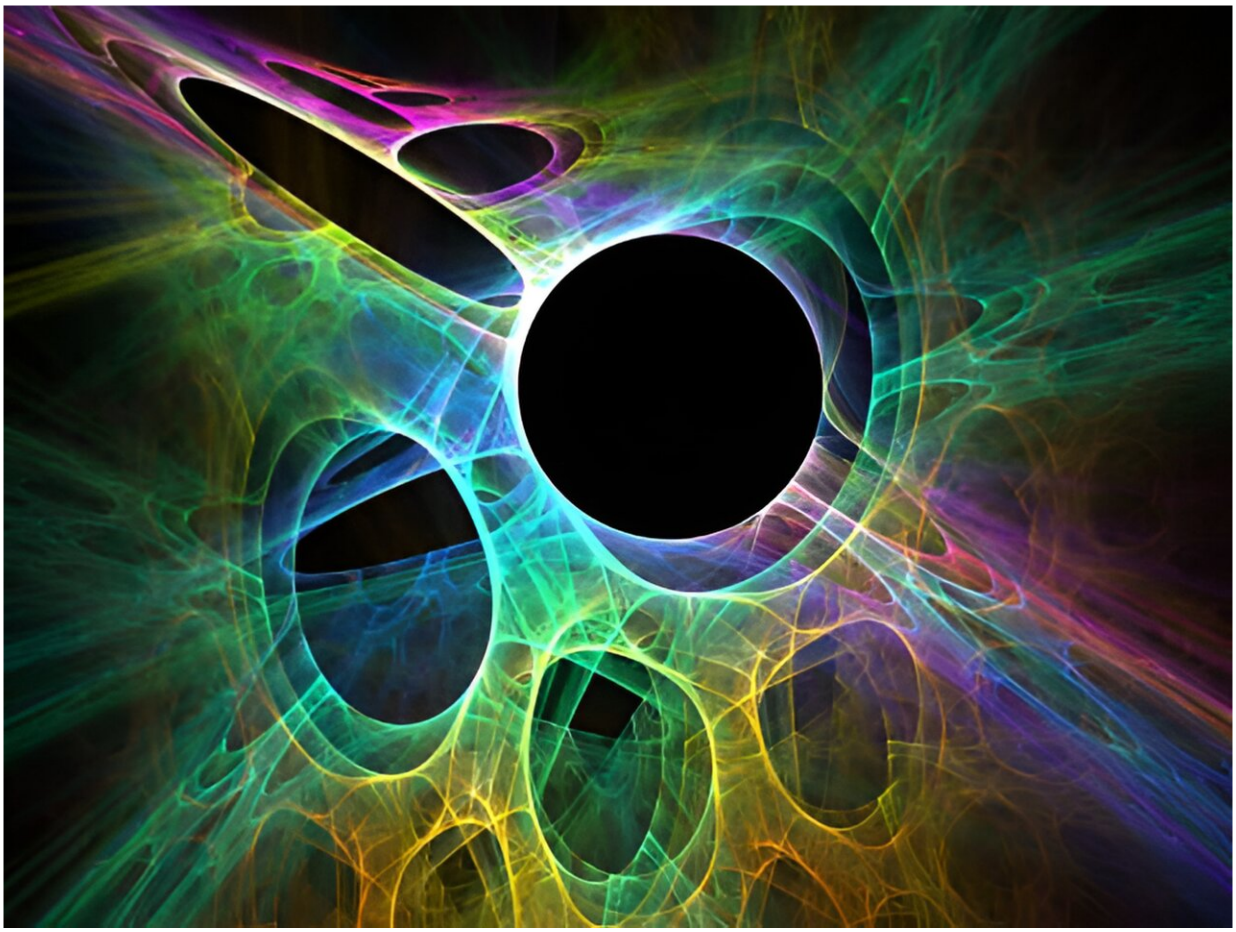

Superstrings may exist in 11 dimensions at once. Credit: National Institute of Technology Tiruchirappalli

String theory found its origins in an attempt to understand the nascent experiments revealing the strong nuclear force. Eventually another theory, one based on particles called quarks and force carriers called gluons, would supplant it, but in the deep mathematical bones of the young string theory physicists would find curious structures, half-glimpsed ghosts, that would point to something more. Something deeper.

String theory claims that what we call particles—the point-like entities that wander freely, interact, and bind together to make up the bulk of material existence—are nothing but. Instead, there is but a single kind of fundamental object: the string. These strings, each one existing at the smallest possible limit of existence itself, vibrate. And the way those strings vibrate dictates how they manifest themselves in the larger universe. Like notes on a strummed guitar, a string vibrating with one mode will appear to us as an electron, while another vibrating at a different frequency will appear as a photon, and so on.

String theory is an audacious attempt at a theory of everything. A single mathematical framework that explains the particles that make us who and what we are along with the forces that act as the fundamental messengers among those particles. They are all, every quark in the cosmos and every photon in the field, bits of vibrating strings.

String theory remains the most promising avenue toward a quantum theory of gravity. It can claim this ultimate title because it incorporates all the forces of nature under its banner, potentiality fulfilling the unification dreams of the past half-millennium of physical exploration of the cosmos, and because the theory naturally includes a new particle (or rather, particular vibration of string) that has all the right properties to serve as the quantum force carrier of gravity, the gravitational analog to the photon.

String theory has not been tested, has not been verified, and is not yet even complete. Indeed, despite its enormous promise and potential, the mathematics that underpin the theory are so difficult to solve that nobody has yet come to a solution, let alone a prediction that can be predicted against experiment. It seems that nature is set to tease us again and again. The original attempts to fold gravity into a quantum framework collapse on themselves under the weight of irreducible infinities. And now the most promising solution around those infinities, to replace the point-like particles of old quantum theory with loops of strings, is so unworkable that the infinities sometimes seem preferable.

Despite its shortcomings, theorists have managed to make some headway into the deepening forests of the strings, and in their searching—which sometimes looks more like bold wishes that we hope someday may be proven true—they have struck on something unexpected.

Dimensionality plays a critical role in string theory. The tiny vibrating strings are tasked with the monumental effort of explaining all of creation—every kind of particle to ever have existed, to ever have been discovered, and all the more that we have yet to find. But early on string theorists discovered that the meager three dimensions of space were not enough; confined to our usual and familiar spacetime, strings cannot support enough different kinds of vibrations to explain the full panoply of particles.

And so string theorists came up with an elegant solution. If the universe does not have enough dimensions to give strings the freedom they need to explain all of physics, then we must add most dimensions to the universe. Modern versions of string theory state that we have either ten or eleven spatial dimensions (the difference comes from different formulations of the theory).

To explain why these extra dimensions have escaped our notice thus far in our experiences living in this universe, the dimensions in addition to the familiar three must be curled up on themselves to those same ultra-tiny scales as the strings themselves, shoving them into the hidden corners of perception and experiment. Even our ability to probe the constituents of atoms themselves is far too clumsy to pierce into this string-dominated realm.

We do not need to concern ourselves with the structure or properties of these hidden dimensions, because what matter to us is that string theory, which claims to be a successor in the unbroken chain of unification spanning five hundred years, and claims to one day blossom into a full theory of quantum gravity, admits the possibility, by very nature of mathematical necessity, that our universe has a different number of dimensions than what we may naively assume.

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