

IS THERE A THEORY OF EVERYTHING?

Strung together

By Matt Crenson ■ Illustration by Nicolle Rager Fuller

Physics is really two sciences. There's quantum mechanics, the weird tumultuous world where particles pop into and out of nothingness and cats can be simultaneously living and dead. And there's general relativity, Einstein's majestic vision of massive objects bending space and time.

Ever since these two very different views of the universe emerged early in the 20th century, generations of physicists have tried to unite them in a single theory that would ideally describe all four of nature's basic forces to boot. Even Einstein tried, and failed. Now, after an especially frustrating few decades with little new evidence to guide them, today's physicists may be about to get some tantalizing hints about how the forces fit together.

The clues are expected to come from the Large Hadron Collider, a ring of superconducting magnets in the Alps designed to smash protons together at energies never before seen on Earth. The collider began operating in March 2010 and is expected to reach full power in 2014, when it will attempt to smash its protons together with double the violence it does today.

Even then, the LHC will be far from powerful enough to re-create the single, unified force that physicists believe existed for a fraction of a second after the Big Bang—you'd need a collider as big as the universe itself for that. But the LHC might be able to test some of the predictions made by the leading theory that joins gravity and the other forces.

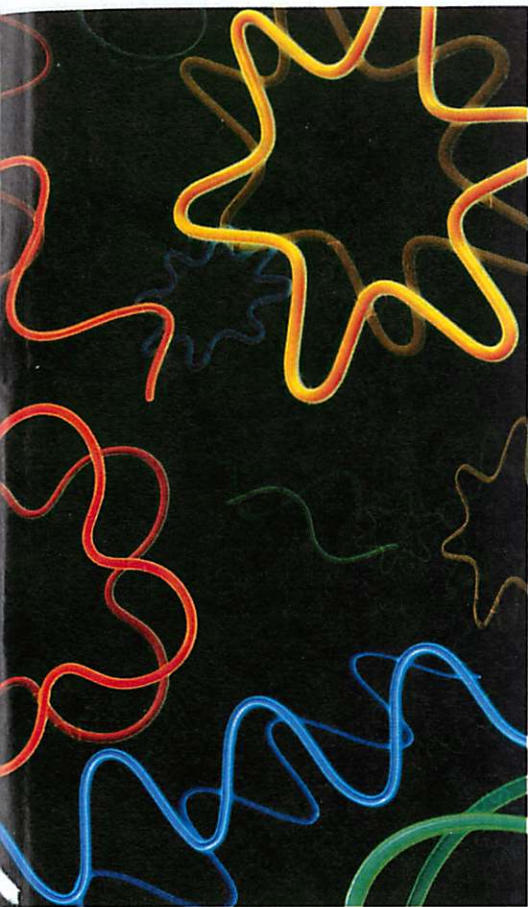
Superstring theory—string theory

for short—ties all of physics into one neat package by reducing the bewildering taxonomy of particles in the current bestiary of physics, the Standard Model, to identical snippets of string, each less than a billionth of a billionth of a billionth of a centimeter long. According to string theory, the particles that carry the three forces included in the Standard Model—the photon (electromagnetism), the gluon (strong force) and the W and Z bosons (weak force)—are all just the same tiny dancers each following their own distinct rhythms.

And unlike the Standard Model, string theory has room for gravity.

Though proposals besides string theory attempt to explain how all the forces of nature might fit together, most of those other theories come with major flaws. Some predict the existence of particles that can't exist, for example.

String theory's primary drawback is that it requires there be much more to the universe than physicists can probe, making the theory very difficult to test.



Superstring theory attempts to unify gravity with quantum mechanics by describing particles and forces as tiny vibrating strands and loops.

For string theory to say anything about how the forces arise, physicists have to figure out how all those extra dimensions roll up, or “compactify,” into the four familiar ones.

String theory also conjures up a shadow population of partner particles for all of the ones currently known to exist — a notion called supersymmetry. In fact, supersymmetry may be necessary to join the strong, weak and electromagnetic forces, so it is important even if string theory isn’t correct.

When forces collide

Many physicists have high hopes that the LHC will find evidence for both supersymmetric particles and extra spatial dimensions.

“Even if we don’t go out to the other dimensions, in some sense the other dimensions can come to us,” says Harvard physicist Lisa Randall.

Working in the 1990s with colleague Raman Sundrum, now at the University of Maryland in College Park, Randall showed that it might be possible to detect the decay of a gravity-carrying particle coming from an extra dimension. Finding such a particle at the LHC would both verify the existence of extra dimensions and suggest why gravity is much weaker than the other three forces.

“I think it would be somewhat surpris-

ing,” Randall says. “But this is one of the things we could find, and this is one of the things they should be looking for.”

Most physicists think it’s more likely that the LHC will find evidence for supersymmetric partners of the particles in the Standard Model. Which partners appear, and their properties, would put some helpful constraints on how the universe compactifies the 11 dimensions predicted by string theory.

For example, if the lightest superparticle turned out to be the wino, the superpartner of the weak force-carrying W boson, that would be consistent with a version of string theory known by the pithy moniker “M-theory compactified on 7-D manifold of G_2 holonomy.”

Such supersymmetric particles may already have been observed, in fact — not on Earth, but in space. Some of the dark matter that is thought to make up more than 80 percent of the matter in the universe could be composed of supersymmetric particles left over from the universe’s earliest moments (see Page 24). In the last few years two space-based instruments, the Fermi Gamma-ray Telescope and the Italian-led PAMELA mission, have seen evidence of dark matter in the Milky Way in the form of gamma rays and antimatter that could have been produced by supersymmetric particles colliding.

Because the LHC and any future colliders can carry physicists only so far back toward the moment just after the Big Bang, science’s understanding of a unified theory is ultimately going to have to come from exploring the vastness of the universe. Some physicists wonder if such a strategy, which relies on finding and interpreting clues left behind by nature, can produce results comparable to the high-precision experimental data that led to the Standard Model during the 20th century.

But string theory is not 20th century science — in fact, string theorist Edward Witten has described it as “21st century physics that fell accidentally into the 20th century.” Now that the 21st century has arrived, it’s string theory’s time to be put to the test. ■

For example, most versions of string theory require that the universe have 10 or 11 dimensions — nine or 10 of space and one of time, rather than the four that people experience: up-down, front-back, left-right and past-future.

“The forces are unified in 11 dimensions, but they split apart when you go to four dimensions,” says Gordon Kane, a physicist at the University of Michigan in Ann Arbor.

Back to one

One of the enduring puzzles in physics is why gravity—which guides matter on the scale of planets and galaxies—is so much intrinsically weaker than the other three forces. In the moments just after the Big Bang, some researchers think, the forces may have been united as one, separating into forces with differing strengths as temperatures decreased.

Strength of the four forces back in time

