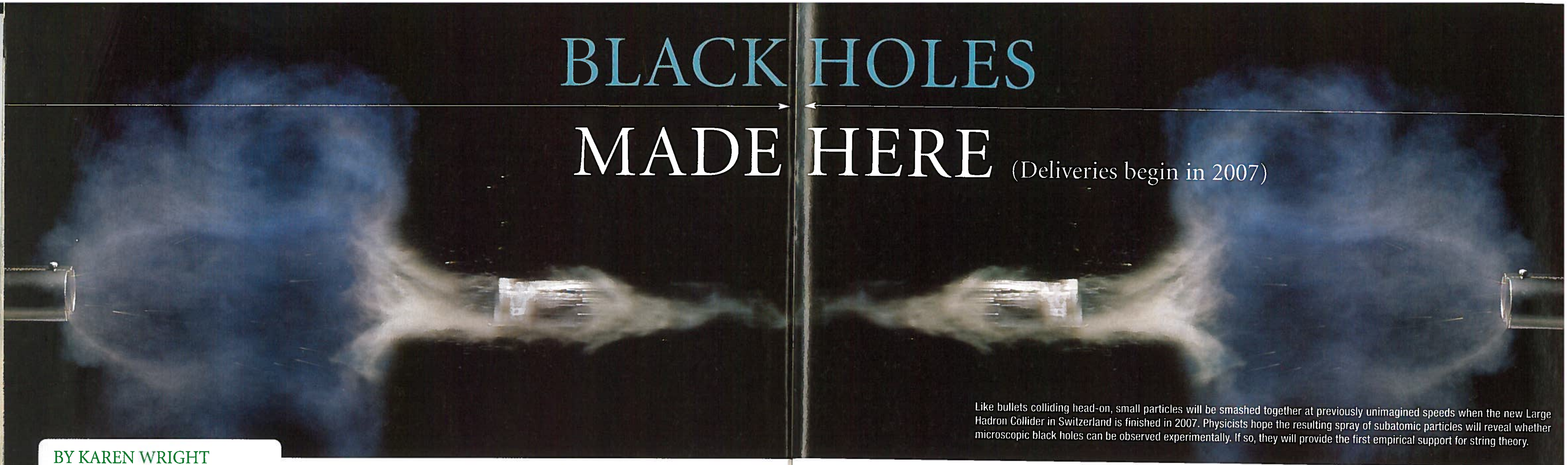
BLACK HOLES MADE HERE

(Deliveries begin in 2007)



Like bullets colliding head-on, small particles will be smashed together at previously unimagined speeds when the new Large Hadron Collider in Switzerland is finished in 2007. Physicists hope the resulting spray of subatomic particles will reveal whether microscopic black holes can be observed experimentally. If so, they will provide the first empirical support for string theory.

PHOTOGRAPH BY STEPHEN DALTON/PHOTO RESEARCHERS.

BY KAREN WRIGHT

BLACK HOLES ARE THE bogeymen of the modern imagination. Their sinister name and scary reputation are well earned. Formed by the collapse of massive stars, they exert a gravitational force so strong it traps light as well as matter. They can last for an eternity and can weigh more than millions of suns.

"When people think of black holes, they think of *big* black holes, like on *Star Trek* or something," says physicist Jonathan Feng of the University of California at Irvine.

Feng has something else in mind. He envisions objects so small they are difficult to imagine—roughly 10^{-17} of an inch across. And they don't hang around very long either—about 10^{-25} of a second. His microscopic black holes weigh just a thousand times the mass of a proton. They share the same physics as the *Star Trek*–size ones, but if they exist, they are probably harmless. No one has ever observed them. But experiments starting later this year could be the first capable of detecting them.

Microscopic black holes could provide a window into the quantum world, the subatomic realm where the most intractable puzzles of physics remain. They could be the first proof of dimensions beyond the three of height, width, and depth. They could help us find an elusive theory of everything that combines observations of the quantum world with the large-scale world of gravity. They could also help solve one of science's most vexing scientific riddles: "They'd explain why gravity is so weak," says Feng.

The idea of wee black holes may not sit well with readers raised on sci-fi scenarios. But the laws of physics don't limit the size of black holes. To make one, you need to cram either a lot of mass or a lot of energy into a very small space. Big black holes are spawned when a dying star collapses, packing so much mass into such a small space that gravity becomes overwhelmingly powerful. In theory, the same effect could occur when two very energetic particles collide—a sudden compression of really high energy into a negligible volume. High-*mass* black holes have big, long-lasting effects. High-*energy* black holes would evaporate almost instantly because they leak energy in a way that massive black holes don't.

Their very existence, however fleeting, could hint at extra dimensions. "If you smack together two particles at high enough energies, you can make a black hole," says Feng. "And if there are extra dimensions, the energies don't even have to be that high."

Physicists first realized this in the late 1990s. Even within the most powerful accelerators on Earth, the high-energy collisions required to produce microscopic black holes in just three spatial dimensions are so rare as to be nonexistent. But increasing the number of dimensions would increase the likelihood of such collisions, simply because there's more area to collide in. Collisions between very energetic particles would then be much more likely than a 3-D analysis would predict, and the creation of microscopic black holes could be within reach of the latest technology.

Theorists have been banking on the existence of extra dimensions for years. It's their best shot at unifying the four fundamental forces: the electromagnetic, strong, and weak, as well as gravity. The first three control the interactions of minute particles at minuscule distances; they rule the subatomic domain. Gravity, however, operates predominantly on macroscopic scales. It may rule the realm of the stars, but its effect on particles is weak. Physicists call this conundrum the hierarchy problem.

"There exists in physics this overwhelming question: Why is the characteristic mass at which gravity becomes very strong so much higher than the mass at which other forces are strong?" says particle physicist Haim Goldberg of Northeastern University in Boston.

The most viable answer so far is proposed by string theory, a model dating to the mid-1970s. String theory explains all forces and particles as vibrating, one-dimensional loops of energy, and it proposes the existence of multiple dimensions—10 to be exact, including time—hidden within the apparent 3-D fabric of space. In this model, gravity alone of the four forces operates in all the dimensions. It's as strong as the other three forces, but because its effects extend undetected into hyperdimensional space, it appears to be attenuated. The apple falling from the tree, the moon circling Earth are just the tip of the iceberg. "What we feel in our paltry three dimensions is a weakened version of gravity," says Goldberg.

String theory works pretty well on paper, but physicists have struggled to identify experiments or observations to test it. The detection of microscopic black holes would shore up the theory by showing that gravity can act at the quantum level, as the model predicts. A Swiss particle accelerator called the Large Hadron Collider, due to be completed in 2007, could produce them. By hurling protons together at 14 trillion electron volts, it will create the kinds of high-energy collisions that are supposed to generate microscopic black holes. "If [black holes] are there, the LHC is going to see them," says particle physicist Luis Anchordoqui, also of Northeastern University. Anchordoqui's latest calculations predict that the collider could generate a black hole every few months or so. If it does, "you have to think of our entire universe floating in dimensions that only gravity can penetrate," Anchordoqui says.

A new Argentinian observatory might get the goods even sooner. The Pierre Auger Cosmic Ray Observatory is netting signals from the most energetic particles in the universe: ultrahigh-energy cosmic rays, which slam into the atmosphere at speeds no accelerator can match, sparking air showers of subatomic particles and ultraviolet light. A fraction of those collisions could generate microscopic black holes, which Goldberg and Anchordoqui think would produce a unique brand of particle showers. "You could say not just that this is anomalous but that it has the signature of a black hole," says Goldberg.

Feng and theoretical physicist Alfred Shapere of the University of Kentucky estimate that the Auger observatory could detect up to 10 such showers a year—"black holes appearing over your head, for free," says Feng.

Shapere, like many string theorists, is excited by the mere prospect of actual data. "This is the first time I've been involved in a project that had experiments going on right now," he says. "It could be longer than my lifetime before we have experimental proof that string theory is right or wrong. If we could observe it in action experimentally, we'd be back to the good old days, when experiments led theory."

Yet detecting microscopic black holes can take string theory only so far. They will prove the presence of extra dimensions, but those extra dimensions may not behave according to string theory. And quantum gravity could still exist at much higher energies that cannot be produced experimentally, so the absence of microscopic black holes won't discount the theory either. But at the very least, the upcoming experiments should establish boundaries on the size and energy level of hidden dimensions. "The scientific community will be more willing to accept us if we're setting limits on our theories and ruling some out than if we're jumping up and down saying we've proved string theory," says Shapere. ☒