Astrophysics

Where No One Has Gone Before

"Wormhole!" cried Captain Kirk with alarm during a tense moment in the first *Star Trek* movie. The famous commander of the *Enterprise* has just realized that his spaceship was plunging into a harrowing warp in space and time.

While *Star Trek* is fiction, wormholes are not—at least in theory. And new calculations by a team of Caltech theorists playfully suggest that a sufficiently advanced civilization might be able to create and maintain wormholes for interstellar travel, perhaps even as time machines.

Along with the black hole, a wormhole is one of the more bizarre solutions to the equations that describe Einstein's theory of general relativity. Essentially it's a tunnel that punches through the very fabric of space. Once open, this passage would link different, widely separated regions of our universe.

While wormholes have long been handy plot devices for science-fiction writers—a shortcut means of traveling from star to star in days or weeks instead of centuries—physicists never worried too much about them. The equations of general relativity indicated that the tiniest bit of matter flung into a wormhole would pinch off the wormhole's throat within the blink of an eye, too little time for any spacecraft to pass through. Nature alone, in other words, seems to abhor a wormhole.

Could Wormholes Be Real?

But Michael Morris, Kip Thorne, and Ulvi Yurtsever wondered whether such constraints hold true for an arbitrarily advanced civilization with nearly-unlimited powers. Their musings were sparked a few years ago when Carl Sagan, then working on his novel *Contact*, asked Thorne how the book's extraterrestrial characters might easily dart about the Milky Way through wormholes without violating any laws of physics.

The three researchers figured that one way to set up such an interstellar bus line would be to place identical, highly charged spheres in front of each of the two "mouths"—the entrance and exit, so the speak—of the wormhole. According to quantum field theory, the laws of physics at the level of an atom, the presence of the electrically charged spheres would change the vacuum within the tunnel in such a way as to allow the wormhole to remain passable.

"But this is not the complete solution," cautions Morris. The extraterrestrials will also have to find a way to prevent any spacecraft, plunging through the hole, from getting crushed by the intense electromagnetic field generated by the spheres. Keeping the wormhole throat open requires a tension comparable to the pressures found in the center of neutron stars, the densest celestial objects known in the cosmos. Morris and company leave it up to the brainy E.T.'s to figure out how to achieve this formidable feat, not to mention assembling the wormhole itself.

Theorists currently picture wormholes spontaneously appearing and disappearing in empty space like a frothy foam, but the size of these wormholes is exceedingly tiny, trillions of times smaller than an atomic particle. In a paper on the subject, Morris and Thorne write that one has to imagine "an exceedingly advanced civilization pulling a wormhole out of this submicroscopic, quantum mechanical, spacetime foam and enlarging it and moving its openings around the universe until it has assumed the size, shape, and location required for some specific interstellar travel project."

"But if such wormholes can be built," says Morris, "then they might also be used as time machines." This could be done by moving one of the wormhole mouths at near-light speed, then returning it just as quickly to its original location. According to the theory of special relativity, the portal that was rapidly moved will end up younger than the other opening. With each mouth opening onto a different epoch, a trip through the wormhole would then provide a means of roaming through time.

This intriguing capability, however, also raises some serious paradoxes: Could a daughter go back in time and kill her father before she was born? "Either we've made a mistake," says Morris, now with the University of Wisconsin at Milwaukee, "or some deeper understandings will come along to show us how to prevent this." Morris suspects that the laws of physics will not allow the universe (or devious daughters) to get into trouble, a general rule often referred to as "cosmic censorship."

Morris and his colleagues have yet to prove, for example, that moving a wormhole around won't cause it to fall apart, making time travel impossible. But then again, some future engineering genius, akin to *Star Trek*'s Scotty, may yet find a way around that problem.

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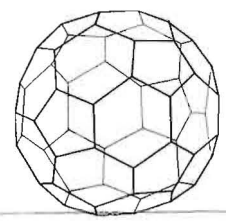
Chemistry

Soccer Ball Carbon—From Space To Soot



Because carbon is at the core of the chemistry of living things, its molecular arrangements have been studied more than that of any other element. Thus it is with considerable surprise that chemists have recently discovered evidence of a novel arrangment of carbon atoms—60 in all—that has the shape of a soccer ball and may be one of the most stable of all molecules. Moreover, this new molecule and related molecules seem to form readily under extreme conditions—both in combustion and in outer space.

That clusters of 60 carbon atoms are uniquely stable was first discovered by Exxon researchers in the course of vaporizing carbon with a laser. Further investigation by chemists at the University of Sussex in England and at Rice University in Texas showed that the most likely shape was that of an icosahedron—a hollow, chicken-wire cage analogous to the markings on a soccer ball. The chemists named the molecule buckminsterfullerene, after the builder of the similarly shaped geodesic domes.

They soon discovered that the process of growing a molecule from vaporized carbon leads almost inevitably to a whole family of closed shapes. When a rapidly growing molecule does not close, however, it is likely to keep on growing—wrapping layer upon layer of carbon atoms—to form a giant particle. The researchers propose that is exactly what happens when wood burns to form soot, and when carbon atoms ejected from a star condense to form interstellar particles. And while the scientists caution that the soccer ball structure has not been completely confirmed, they believe it is the key to a whole new branch of organic chemistry. *Science*, vol. 242, p. 1017 and 1139.