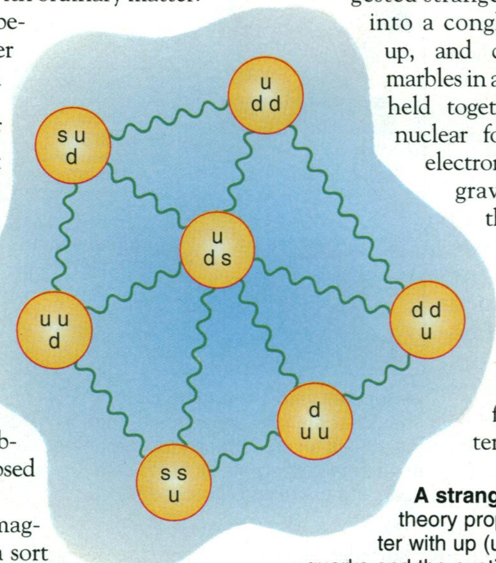
PARTICLE PHYSICS

A New Form of Strange Matter And New Hope for Finding It

Deep in the dense cores of collapsed stars even atoms don't survive. The force of gravity crushes them into particle mushes weighing megatons per teaspoon. But even these alien forms of matter don't hold a candle to another possible end product of a collapsing star: something physicists justifiably call "strange matter."

This strangeness comes from an exotic particle not associated with ordinary matter: the strange quark. It belongs to a six-member quark family, along with up, down, charm, top, and bottom, each of which carries a different combination of charge and mass. The only ones that make up matter as we know it are up and down quarks, but in theory, matter could form out of strange quarks as well. In nature, it would turn up most probably in interiors of collapsed stars.



A strange matter. A new theory proposes a form of matter with up (u) and down (d) quarks and the exotic and elusive strange quark (s). In theory this strange nucleus could become as big as the sun.

SOURCE: C. DOVER ILLUSTRATION: DAN REBEIZ

Scientists originally imagined strange matter as a sort of disorganized mixed bag of strange quarks, but this summer a group proposed that the quarks could form a sort of mutant atomic nucleus that could conceivably grow to the size of a star. For the moment this is speculation, but it may not be theoretical musing for long. Physicists are preparing to try making strange matter here on Earth, in experiments at Brookhaven National Laboratory in New York and Switzerland's CERN, next summer.

It hasn't been easy to find out much about strange matter until now, because it's not only strange, it's elusive. One reason is that its constituents, the strange quarks, are themselves hard to pin down. They can be made in accelerators, and have been glimpsed there occasionally since the late 1960s, but only rarely. They are related to the basic building-blocks of earthly matter—the up and down quarks—but strange quarks have more mass, which means they take more energy to make. They were abundant during the first fraction of a second after the Big Bang but went nearly extinct when the universe cooled below a few trillionths of a degree. Accelerators can produce two- and three-quark combinations that include strange quarks, but these decay quickly to more mundane, lower mass particles.

But in the mid-1970s Massachusetts Institute of Technology's (MIT) Arthur Kerman and his colleagues suggested that if strange quarks were produced in sufficient quantities, some of the particles could stick together. While quarks in ordinary nuclear matter stay tied into triplets, Kerman suggested strange quarks might mix into a conglomerate of strange, up, and down quarks, like marbles in a bag. They would be held together by the strong nuclear force which, unlike electromagnetism or gravity, gets stronger as the quarks move further apart, pulling them back like balls on springs. Kerman argues that this model is the most stable form of strange matter: "Strange matter wants to be a plasma." His proposed strange matter would come in the form of large droplets of quarks made up of about two-thirds strange ones and one-third ups and downs.

Kerman's "traditional" model of strange matter is, to be sure, exotic, but the strange nuclei proposed by Brookhaven's Carl Dover and colleagues, in the 30 August *Physical Review Letters* are perhaps even more unusual. Dover's idea is that stranger quarks could substitute for the ordinary up and down quarks of regular matter. Everything would still be bound in triplets, but some would have one, two, or occasionally three strange quarks. Dover and his colleagues have done calculations based on the current theory of particles and forces and shown that such triples, once brought together, would stick together like the protons and neutrons in an atomic nucleus.

The experiments scheduled for next summer at Brookhaven and at CERN could give the thumbs up to one of these two models—a prospect that is sending a ripple of excitement through the physics community. "It was all theory before," says Yale experimental physicist Jack Sandwise. "Experiments are just—at this very minute—getting under way." Investigators are busy setting up the complex apparatus they will use to accelerate and collide gold nuclei in an attempt to drum up enough concentrated energy to create a blob of strange matter. Sandwise is one of a group collaborating at Brookhaven, and they've been buoyed by advances in accelerator and detector technology that allow them to track the complex debris that shoots out from each collision.

In Brookhaven's Alternating Gradient Synchrotron, or AGS, they plan to smash these gold nuclei at jolting energies of several hundred Giga electron volts. The researchers hope to yield a critical number of strange quarks in the debris. If strange matter results, it would leave a definite signature in a detector because a large conglomerate of such particles would register a very high mass when compared to the rest of the particle spray.

Though a machine like the one at Brookhaven can only make the equivalent of a small atomic nucleus, Dover says it's theoretically possible for there to be a conglomerate the size of the sun. But that would require the immense amount of matter available inside the collapsing core of a dying star. What will happen inside the accelerator, says Dover, is that strange matter will probably last about 10 to the -10 seconds, which is plenty of time to leave a definitive track in a detector.

But that doesn't mean it's a sure thing. The problem is that strange quarks come out of such collisions with an equal number of their antimatter counterparts, antistrange quarks, and to avoid mutual annihilation a number of strange ones must fly out of the collision on a tangent, away from their antistrange kin. That's what makes it a dicey proposition, and what makes some physicists highly skeptical that the accelerators will produce results. Says MIT's Robert Jaffe, who has also done work on strange matter, "It's like flinging two bicycles together and expecting to find all the chain links fly off in the same direction.'

Sandwise and Dover concede the chances of any one collision creating enough quarks that travel off in just the right direction is minuscule, but the odds go up with time, as the machine will make thousands of collisions per second. If not there, then strange matter might form at Europe's CERN, where a similar experiment will also start next year. And even those who are skeptical concede that the venture is worth the risk. "Chances of finding strange matter are slim," says physicist Edward Farhi of MIT. But he adds that "it would be very exciting if they do find it. It's a longshot with a high payoff." And stranger things have happened.

–Faye Flam