SEARCHING FOR STRANGE MATTER

The quest extends from neutron stars to monstrous isotopes and compact energy sources

By IVARS PETERSON

Strange matter is strange indeed. Unlike ordinary atomic nuclei, which contain only "up" and "down" quarks, this hypothetical form of matter is made up of roughly equal proportions of "up," "down" and "strange" quarks. Moreover, if enough of these fundamental particles could agglomerate into a single lump of strange matter, they would form a monstrous nucleus visible to the naked eye.

"We don't know if strange matter can exist," says Charles R. Alcock of the Lawrence Livermore (Calif.) National Laboratory. But evidence for its existence would have intriguing consequences in astrophysics and important implications for the understanding of fundamental forces and particles in physics. That possibility makes strange matter worth pursuing.

In fact, physicists have been playing with the notion of strange matter for more than a decade. In 1984, Edward Witten of Princeton (N.J.) University was the first to suggest that drops of quark matter might be stable, perhaps even more stable than ordinary matter. Subsequent calculations by Edward H. Farhi and Robert L. Jaffe of the Massachusetts Institute of Technology showed that Witten's argument was plausible.

Those results prompted a variety of proposals and experiments designed to sift out, detect or create strange matter. One recently suggested scheme for producing, collecting and growing the stuff goes so far as to hint that such matter could be harnessed as a new type of compact energy source. However, despite this flurry of attention, many basic questions – both theoretical and experimental – remain unanswered.

According to what physicists call the "standard model" of the universe, particles such as protons and neutrons are themselves made up of even more basic particles called quarks. Quarks are thought to come in six different "flavors" carrying the somewhat arbitrary labels "up," "down," "strange," "charm," "top" and "bottom." A proton can be imagined as a bag containing two "up" quarks and one "down" quark. A neutron is made of one "up" quark and two "down" quarks. When neutrons and protons combine to form an atomic nucleus, they remain separate particles. In other words, the quarks stay in their bags.

In contrast, the recipe for strange matter calls for a mixture of "up," "down" and "strange" quarks, which are not confined to separate particles, or bags, but are free to move around within the entire lump of material. The result is a positively charged lump of quarks known as a quark nugget.

For relatively small agglomerations, quark nuggets surrounded by an atmosphere of electrons behave chemically much like atoms with nuclei having an equivalent positive charge. Such nuggets differ from ordinary nuclei in the extra mass they carry. Thus, for a given nuclear charge, strange matter has an extraordinarily large mass. In mass-spectrometry experiments, which measure the charge-to-mass ratio of atomic nuclei, strange matter would appear as unusually heavy isotopes of conventional substances. Searches for such exotic isotopes have so far turned up no evidence for strange matter.

In larger lumps of strange matter, any electrons present would actually burrow into the material, where they would be free to move about in the same way electrons move in a metal. "It would be an ultradense metal," Jaffe says. "If you had a lump of strange matter the size of the Earth, it would look and behave like a giant metallic ball."

One place to look for strange matter is in stars that have undergone a supernova explosion and collapsed into a small, dense ball. Astrophysicists generally believe these collapsed cores end up as neutron stars – which consist largely of closely packed neutrons – or as black holes. But the gravitational pressure at the center of such a collapsed star may be large enough to drive neutron matter into strange matter.

"It's thought that if you subject ordinary matter to high enough pressure, those little bags of nucleons would overlap and the system would make a transition to a quark gas," Jaffe says. "You push on them so hard that the quarks all collapse into one big bag."

This quark gas initially consists of "up" and "down" quarks in highly energetic states. One by one, a fraction of these turn into strange quarks. Once a small lump of strange matter forms at a neutron star's center, it grows rapidly by absorbing neutrons. "The strange matter is very stable and actually eats its way to the star's crust," Jaffe says. One seed of strange matter converts an active neutron star into a "strange" star.

Detecting strange stars turns out to be tricky. Their behavior differs little from that of neutron stars. In the Dec. 26 PHYSICAL REVIEW LETTERS, Jes Madsen of the University of Aarhus in Denmark argues that observations of rapidly spinning neutron stars, or pulsars, may help. The assumption that pulsars showing glitches (sudden variations in their rate of spin) must be neutron stars rather than strange stars puts severe constraints on the likelihood of the existence of strange stars and on the number of quark nuggets in the interstellar medium, Madsen says.

"But that's really just a hypothesis," Alcock says. "The bottom line is that we've not found a convincing way of distinguishing strange stars from neutron stars."

Researchers are also looking for evidence of strange matter on Earth. Small amounts could have survived from the early days of the universe or may have been produced in collisions between neutron stars. Such material may have been incorporated in the Earth during the planet's formative years, or it may still be arriving as a gentle rain of cosmic quark nuggets.

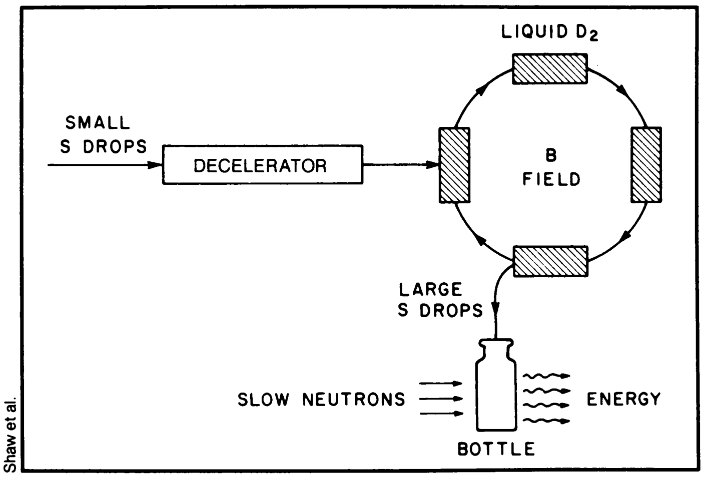
By whatever mechanism strange matter may come to Earth, the Earth is in no danger of being swallowed up and transformed. The positively charged quark nuggets repel the nuclei of ordinary matter, discouraging any such interaction.

A group of scientists in West Germany and Israel recently looked for quark nuggets by bombarding small meteorite samples with beams of lead and uranium ions. The idea was that if these heavy ions happened to encounter a particularly heavy nucleus, they would be deflected through a large angle, perhaps even bounced back.

The researchers found no such evidence for the presence of strange matter. Their results, reported in the Feb. 2 NATURE, indicate the abundance of quark nuggets in the mass range tested must be exceedingly small – if such nuggets exist at all.

A somewhat more sophisticated approach would send in heavy ions at just the right energy so they would interact with any strange matter in the target material. The lump of strange matter would absorb the incoming nucleus, eventually getting rid of its excess energy by releasing a distinctive burst of X-rays and gamma rays.

"This signature would be totally unconventional," says Jaffe. However, because of the technical difficulties involved, no one has yet attempted this particular experiment.



In this schematic diagram of a proposed apparatus for rapidly growing small drops of strange matter (S-drops) into larger drops, the S-drops are first circulated through liquid deuterium (D_2) in a magnetic field (B), then stored in a "bottle." When stored S-drops capture slow neutrons, they release energy.

Another way to study strange matter is to make it at particle accelerators. Gordon L. Shaw of the University of California, Irvine, and his colleagues suggest a novel scheme for generating small drops of strange matter by smashing together heavy ions traveling at high speeds. The resulting small drops of strange matter, though somewhat unstable, could last long enough to grow larger and more stable by absorbing neutrons. Eventually, they would become stable enough to be isolated, slowed down and stored. Because the addition of neutrons releases a great deal of energy, the growth of stable strange matter to even larger sizes shows promise as a potential energy source, Shaw says.

One problem with making the scheme work is ensuring that the hot, low-density quark-gluon plasma created in the collision of high-speed heavy ions (SN: 10/8/88, p.229) cools in the right way to produce high-density, low-temperature drops of strange matter. No one has yet proposed a detailed mechanism for accomplishing this feat — akin to extracting an ice cube from boiling water.

"Despite these reservations, the proposal does not seem to be an expensive addition to experiments that are already in progress," Alcock comments in the Feb. 2 NATURE. "As the payoff in physics would be so large if strange matter were detected, the ideas should be further explored. And the engineering ideas raise long-term prospects for energy generation."

Does strange matter exist? No one knows yet.

"The issue is far from settled," Alcock says. "Even though the experiments may be somewhat farfetched, if things work out, the possible consequences for our understanding of fundamental physics are very great."

In particular, theorists are struggling to understand how matter is put together. "We have this elegant theory of quantum chromodynamics, which is supposed to describe the binding of the fundamental constituents of all matter, but we don't know how to make it work," Jaffe says. "We can't even do something as basic as building protons out of quarks. Understanding the very special role of strange quarks is becoming the focus of the whole puzzle."

Physicists are also considering the possibility that strange matter, rather than being absolutely stable, is actually quasistable, meaning that strange matter, once created, would decay into other forms in seconds or less. A group of researchers is now planning to test the idea by putting a detector — a type of mass spectrometer — a short distance downstream from a heavy-ion collision experiment. The instrument would be close enough to the production zone to capture strange matter, even if it decayed within microseconds.

A positive result, says Jaffe, "would give us not only a lot of insight into quantum chromodynamics but also a tool for understanding heavy-ion reactions." Collisions between heavy ions usually produce complicated patterns that are hard to interpret.

The quest for strange matter is fraught with difficulty and frustration. "Not finding strange matter in a given experiment is interesting but doesn't really prove anything," Alcock says. "Finding one piece of strange matter, under any circumstances, would tell you something fundamental about physics." □

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"discrimination." But the economic bottom line is that without such screening, those of us who are healthy (and in particular, who are sufficiently "discriminating" to keep away from high-risk situations) will end up paying out-of-sight premiums for the high-risk life style of homosexuals and drug users.

John Bryant
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Why did your author so studiously avoid the ultimate outrage of genetic screening: the potential for denial of life to an unborn human because he or she had the misfortune to be diagnosed in their mother's womb as having, for instance, the wrong color eyes?

Alfred R. Beronio
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'Fluoride is not the answer'

As a longtime researcher of the biologic effects of fluoride, I feel compelled to comment on your recent article touting a "new" fluoride treatment for osteoporosis ("Fluoride-Calcium Combo Builds Better Bones," SN: 1/21/89, p.36).

This long-held delusion that fluoride will be a safe, effective and marketable treatment for osteoporosis is what concerns me. There have been many attempts to achieve this golden result but all have failed: Fluoride is simply too toxic and its benefits are too little. Its toxicity at these high doses is not limited to gastric irritation but also shows up as pain and stiffness of joints and ligamentous structures. The slightly denser bone that eventually develops in the spine after several years of fluoride medication is disordered and lacks tensile strength. As the article indicates, the researchers reported that the treatment failed to decrease the incidence of hip fractures, which are the major debilitating effect of osteoporosis.

Wax-encapsulated tablets are not new. The fact that high-dose fluoride can result in a slight increase in bone density as measured by X-ray also is not new. The fact that it doesn't decrease the risk of hip fracture is well established. The treatment is not available to the public. In a recent special report published by POSTGRADUATE MEDICINE, Louis V. Avioli, Shoenberg Professor of Medicine at Washington University School of Medicine, St. Louis, pointed out that research already exists to show that the fracture rate of a fluoride-treated group of patients actually increased in relation to that of the control group during the first year, osteoarticular side effects occurred in 47 percent of the fluoride-treated patients, hip fractures were not prevented, and fluoride was simply not worth further exploration as a therapy for postmenopausal osteoporosis.

The major defect of postmenopausal osteoporosis results from the lack of estrogen *and* progesterone. I have treated this condition for more than six years in over 100 patients with balanced estrogen-progesterone hormone supplementation and have demonstrated 15 to 50 percent increase in bone density as measured by dual photon bone mineral density tests. Clinically, the nontraumatic fracture rate fell to zero. Clearly, fluoride is not the answer; proper nutrition and hormone supplementation is.

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