PENNED-IN POSITRONS

Captured positrons create the first antimatter plasma on Earth

By FAYE FLAM

Though rare on Earth, plasmas are actually the most common form of matter in the universe. Inside a star, heat and overcrowding wrench electrons from their orderly positions around atoms, creating a sea of negatively charged electrons floating among positively charged nuclei. This stuff of stars is a plasma. Scientists have learned to make a variety of plasmas in the laboratory, including ones consisting of many varieties of atomic nuclei with electrons, and even ones with just electrons. Now a team of physicists reports creating for the first time a plasma made out of the electron's antimatter equivalent — the positron.

Physicists define a plasma as a fluid or gas of charged particles. Positrons, the antimatter equivalent of electrons, are the exact opposite of an electron in charge and in all other properties except mass, which is the same. In a matter world, antimatter has the disadvantage of vanishing when it touches its matter equivalent, annihilating both itself and the bit of ordinary matter, and leaving behind pure energy in the form of gamma rays. Therefore, storing up and holding on to positrons takes some special equipment and ingenuity.

To contend with this problem, Clifford M. Surko, now at the University of California, San Diego, and Marvin Leventhal and Albert Passner of AT&T Bell Laboratories in Murray Hill, N.J., designed a clever trap to collect and hold the elusive particles. In the Feb. 20 PHYSICAL REVIEW LETTERS, they suggest their new plasma will prove useful as a source of particle "bullets" for accelerators and as a tool to develop better fusion energy reactors, among other applications. Surko and Leventhal are now using the positron plasma to learn more about antimatter and about the exotic state of matter — or, in this case, antimatter — known as plasma.

Surko, Leventhal and Passner started by capturing energetic positrons thrown off from decaying radioactive sodium. They snared the fast-moving particles in a trap made from electric and magnetic fields. To keep the positrons from bouncing right out of the trap, the researchers slowed them down with nitrogen gas inside the trap — enough to cool the positrons without annihilating them. Adjusting the electric and magnetic fields and the nitrogen density enabled the researchers to gather some 300,000 positrons in a space about the size of an egg — a collection dense enough to qualify as a plasma.

But the first trapped positrons were quick-escape artists, slipping through the electromagnetic cage in about 1 second. In comparison, electrons confined in the trap remain for about 100 seconds. The positrons weren't leaking out the trap's edges but instead disappeared from the middle.

This odd behavior led the scientists to a serendipitous discovery. They found that before disappearing, the positrons stuck briefly to molecules of oil that accidentally got into the trap from other parts of the machinery — a mysterious phenomenon, since physicists expect molecules to repel positrons. A closer look revealed that large molecules, such as those in the oil, attracted positrons, while smaller molecules repelled them. Positrons bound to the oil molecules for about 1 nanosecond, after which the positron and one of the oil's electrons disappeared into pure energy.

Physicists are intrigued by the gamma rays that appear when positrons in a plasma encounter electrons. All gamma rays created in this way have the same frequency, but other aspects of the rays depend on the environment of their creation. Astrophysicists plan to compare the gamma rays created in the laboratory plasma with ones from positron annihilations in space, hoping to learn more about distant plasmas.

While the positron plasma itself has brought some surprises, Surko, Leventhal and Passner say they anticipate using it to create another type that promises even more interest — a mixture of electrons and positrons with a life expectancy of a few minutes. This will be the first laboratory-produced plasma in which all particles have the same mass. In contrast, more commonplace plasmas have positive charges on the heavy particles and negative charges on the lighter electrons. Leventhal, who studies astrophysical plasmas, speculates that very hot electron-positron plasmas may lurk in the vicinity of black holes, and perhaps around the postulated black hole in the center of our galaxy.

On a smaller scale, the trapped, concentrated positrons could make a good beam to aim at other particles in accelerators, the researchers suggest. They also propose that in experiments requiring positive ions, positrons may be used to ionize molecules by annihilating the molecules' electrons.

One of the positron plasma's more practical applications may emerge in diagnosing problems with fusion energy reactors. One reason our homes aren't lit by fusion power is that particles — possibly electrons — leak out of the experimental chambers where the energy-releasing fusion reactions take place. The particles escape from these chambers, known as a tokamaks, more than 100 times faster than present theory predicts they should, stealing critical energy away from the reactor.

Surko, Leventhal and Passner want to add some positrons to a reaction chamber. The positrons should escape just like ordinary matter, except that they will leave a trail. An escaping positron would give itself away because as it slipped out, it would hit an electron in the wall of the reaction chamber and annihilate itself and the electron, leaving behind gamma rays with a telltale frequency. Learning how positrons, and therefore other particles, escape from the fusion chamber might enable scientists to design a better way to contain them, Surko says.

Isolating a positron plasma also represents an important step toward creating antihydrogen — an antimatter atom with a negatively charged nucleus and a surrounding positron. Scientists may need a very concentrated source of positrons to get antihydrogen to form, Surko notes. The idea of anti-atoms and antimolecules has captured the public's imagination. Some envision harnessing the energy given off when matter and antimatter annihilate, using it to propel far-traveling spacecraft. Others are curious to see if gravity affects antimatter differently, since some theories predict antimatter will fall more slowly, or may even fall *up*.

Though antimatter spacecraft remain in the realm of science fiction, the containment of an antimatter plasma promises to advance both knowledge and technology. "We couldn't have conceived of doing these things 10 years ago," Surko says. "What we are learning will have an impact on the way we think about the physical world." □