CERN physicists trap antihydrogen atoms for more than 16 minutes (w/ video)

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This is an artistic representation of the ALPHA neutral antimatter trap, suggesting the nature of the ALPHA apparatus as a container for antihydrogen. Credit: Chukman So, copyright © 2011 Wurtele Research Group. All rights reserved.

Trapping antihydrogen atoms at the European Organization for Nuclear Research (CERN) has become so routine that physicists are confident that they can soon begin experiments on this rare antimatter equivalent of the hydrogen atom, according to researchers at the University of California, Berkeley.

"We've trapped antihydrogen atoms for as long as 1,000 seconds, which is forever" in the world of high-energy particle physics, said Joel Fajans, UC Berkeley professor of physics, faculty scientist at Lawrence Berkeley National Laboratory and a member of the ALPHA (Antihydrogen Laser Physics Apparatus) experiment at CERN in Geneva, Switzerland.

The ALPHA team is hard at work building a new antihydrogen trap with "the hope that by 2012 we will have a new trap with laser access to allow spectroscopic experiments on the antiatoms," he said.

Fajans and the ALPHA team, which includes Jonathan Wurtele, UC Berkeley professor of physics, will publish their latest successes online on June 5 in advance of print publication in the journal Nature Physics. Fajans, Wurtele and their graduate students played major roles in designing the antimatter trap and other aspects of the experiment.

Their paper reports that in a series of measurements last year, the team trapped 112 antiatoms for times ranging from one-fifth of a second to 1,000 seconds, or 16 minutes and 40 seconds.

Since the experiment first successfully trapped antihydrogen atoms in 2009, the researchers have captured 309.

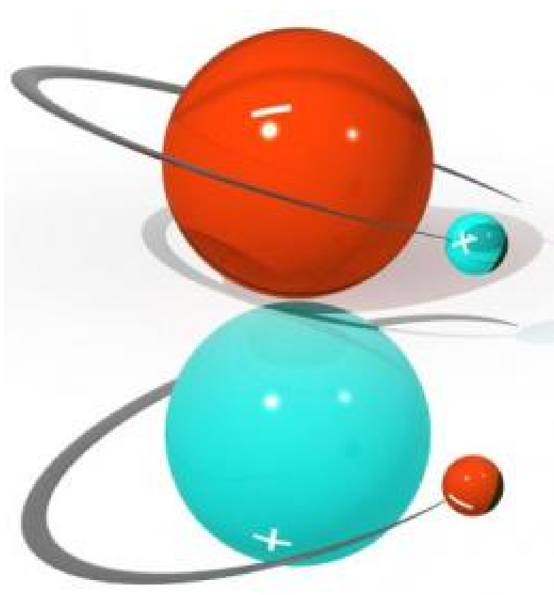
"We'd prefer being able to trap a thousand atoms for a thousand seconds, but we can still initiate laser and microwave experiments to explore the properties of antiatoms," Fajans said.

In November 2010, Fajans, Wurtele and the ALPHA team reported their first data on trapped antihydrogen: 38 antiatoms trapped for more than one-tenth of a second each. They succeeded in capturing an antiatom in only about one in 10 attempts, however.

Toward the end of last year's experiments, they were capturing an antiatom in nearly every attempt, and were able to keep the antiatoms in the trap as long as they wanted. Realistically, trapping for 10-30 minutes will be sufficient for most experiments, as long as the antiatoms are in their lowest energy state, or ground state.

"These antiatoms should be identical to normal matter hydrogen atoms, so we are pretty sure all of them are in the ground state after a second," Wurtele said.

"These were likely the first ground state antiatoms ever made," Fajans added.



In an antihydrogen atom (top), a positively charged antielectron, or positron, orbits a negatively charged antiproton: the mirror image of an ordinary hydrogen atom (bottom). Credit: Chukman So, copyright © 2011 Wurtele Research Group. All rights reserved.

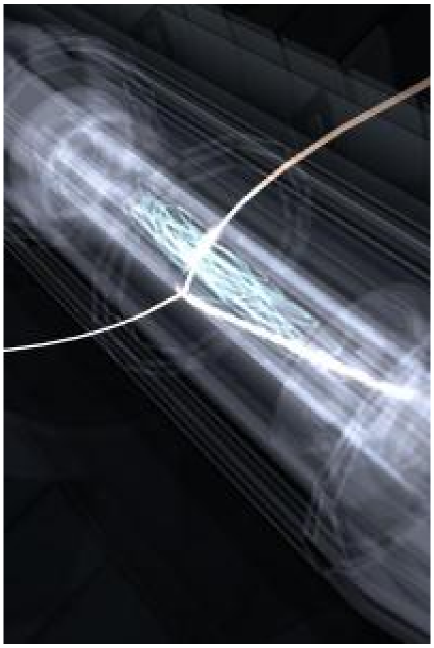
Antimatter is a puzzle because it should have been produced in equal amounts with normal matter during the Big Bang that created the universe 13.6 billion years ago. Today, however, there is no evidence of antimatter galaxies or clouds, and antimatter is seen rarely and for only short periods, for example during some types of radioactive decay before it annihilates in a collision with normal matter.

Hence the desire to measure the properties of antiatoms in order to determine whether their electromagnetic and gravitational interactions are identical to those of normal matter. One goal is to check whether antiatoms abide by CPT symmetry, as do normal atoms. CPT (charge-parity-time) symmetry means that a particle would behave the same way in a mirror universe if it had the opposite charge and moved backward in time.

"Any hint of CPT symmetry breaking would require a serious rethink of our understanding of nature," said Jeffrey Hangst of Aarhus University in Denmark, spokesperson for the ALPHA experiment. "But half of the universe has gone missing, so some kind of rethink is apparently on the agenda."

ALPHA captures antihydrogen by mixing antiprotons from CERN's Antiproton Decelerator with positrons – antielectrons – in a vacuum chamber, where they combine into antihydrogen atoms. The cold neutral antihydrogen is confined within a magnetic bottle, taking advantage of the tiny magnetic moments of the antiatoms. Trapped antiatoms are detected by turning off the magnetic field and allowing the particles to annihiliate with normal matter, which creates a flash of light.

Because the confinement depends on the antihydrogen's magnetic moment, if the spin of the antiatom flips, it is ejected from the magnetic bottle and annihilates with an atom of normal matter. This gives the experimenters an easy way to detect the interaction of light or microwaves with antihydrogen, because photons at the right frequency make the antiatom's spin flip up or down.



This is an artist's image of the ALPHA trap which captured and stored antihydrogen atoms. Credit: Chukman So

Though the team has trapped up to three antihydrogen atoms at once, the goal is to trap even more for long periods of time in order to achieve greater statistical precision in the measurements.

The ALPHA collaboration also will report in the *Nature Physics* paper that the team has measured the energy distribution of the trapped antihydrogen atoms.

"It may not sound exciting, but it's the first experiment done on trapped antihydrogen atoms," Wurtele said. "This summer, we're planning more experiments, with microwaves. Hopefully, we will measure microwave-induced changes of the atomic state of the antiatoms."

More information: "Confinement of antihydrogen for 1000 seconds," *Nature Physics*, www.nature.com/nphys/index.html

Provided by University of California - Berkeley