Experiment at CERN traps antimatter atoms

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In a paper published in *Nature*[1] November 17, scientists from the ALPHA collaboration at the European Organization for Nuclear Research (CERN), detailed the successful capture of 38 atoms of anti-hydrogen. The accomplishment opens new doors to the understanding of fundamental physics and the nature of the universe.

Among the largest mysteries in current understanding of physics is the absence of antimatter in the universe. Antimatter is the mirror image of everyday matter and is understood, according to particle physics, to have identical properties except for charge, which is opposite. Thus, while electrons have a negative charge, anti-electrons, commonly called positrons, have a positive charge, while all the other identifiers of the particles, such as mass, are the same.

Contact between a particle of matter and a particle of antimatter results in both particles being annihilated, with the combined mass converted into energy.

It should be noted that while physicists use the terms “matter” and “antimatter” for these mirror-image particles, both types of particles are matter in the philosophical sense of materialism, existing independently of our perception of them.

The mystery of antimatter revolves around the assumption that in the moments after the Big Bang, matter and anti-matter existed in equal parts. Had this state continued, the particles then in existence would have annihilated with each other, leaving nothing but light to fill the universe. However, an unknown phenomenon caused a slight imbalance in the balance of matter and antimatter, causing the universe to be dominated by matter, with antimatter existing only for moments before being annihilated. The cause of the imbalance at the beginning of the universe is what the researchers at ALPHA are investigating.

Antimatter was first hypothesized by Paul Dirac, in a paper published in 1928[2] Dirac's paper was a successful attempt to combine quantum mechanics and special relativity to more fully describe experiments that had occurred in the preceding decades that had left tantalizing hints about physical realities far outside the classical understanding of nature.

Dirac drew attention to a seeming mathematical anomaly that allowed for both positive and negative energy values for elementary particles. Since energy measures the quantity of matter's motion, the concept of negative energy posed serious conceptual problems.

With assistance from Robert Oppenheimer, Dirac resolved the notion of negative energies. In a 1931 paper[3], he suggested that an electron with negative energy is better described as one with positive energy but with a positive charge. Dirac also noted that if an “anti-electron” came into contact with an election, both would be annihilated. A year later, these predictions were confirmed by observations performed by Carl Anderson.

The effort to study antimatter focuses on one of most studied systems in quantum mechanics, the hydrogen atom. Comprised of a single proton and electron, hydrogen is also an extremely simple system, one whose properties are well known. The study of anti-hydrogen revolves around investigating whether the properties, outside of charge, are the same as those of hydrogen. The experimenters hope to find some subtle difference between hydrogen and anti-hydrogen that would help explain the imbalance after the Big Bang.

Producing and trapping of antimatter is a difficult and complicated process. The fact that antimatter annihilates all normal matter it touches means it cannot simply be stored in a container. Instead, streams of positrons and anti-protons are directed to a vacuum chamber where complex magnetic fields cause interaction between the two different particles to make anti-hydrogen. The magnetic fields also ensure that the generated antimatter refrains from contact with normal matter. The ALPHA experiment has demonstrated that this can be done for approximately a tenth of a second. While short by normal standards, a tenth of a second is an extremely long time in particle physics, ample time to perform studies on the anti-hydrogen.

Other research in this area is ongoing. In May, Fermilab, located near Chicago, announced that researchers in the D0 collaboration had discovered a very slight imbalance in the creation of muons and anti-muons. Muons are one of the two heavier cousins of the electron, with the same charge, but a much higher mass. Fermilab discovered a 1% difference in the creation of both particles, creating slightly more matter than antimatter. This breaks the symmetry that is expected by current theories of particle physics, and is a further step in understanding the abundance of matter in the universe.

Along with D0 and ALPHA, the LHCb collaboration is also researching antimatter. It is of the four main detectors of the Large Hadron Collider, located at CERN, and is tasked mainly with precise measurements that would indicate a violation of matter/antimatter symmetry in particle decays. Thus far, no major results have been published from the LHCb collaboration, but this is expected to be remedied after a full analysis is done on the data from 2010 and what will be collected in 2011.

Despite the difficulties in creating and containing antimatter, the physicists at CERN have proven to be equal to the challenge. Uncovering the structure of antimatter is a long-awaited study in fundamental physics. The ALPHA collaboration's results will only spur on more experiments to shed light on why an imbalance of matter and anti-matter exists.

[1] Trapped antihydrogen. [back]

[2] Paul A. M. Dirac. On the quantum theory of the electron. [back]

[3] Paul A. M. Dirac. Quantised Singularities in the Quantum Field. [back]