Advancing the study of antimatter

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"Right now, most physicists would predict that hydrogen and antihydrogen have the same properties," Gerald Gabrielse tells *Physorg.com*, "What's irresistible is that we of the opportunity to – potentially – look for tiny differences."

Gabrielse, a professor at Harvard University, is the leader of the ATRAP Collaboration. The ATRAP Collaboration consists of an international team that includes others from Harvard, as well as the Forschungszentrum Jülich and the Johannes Gutenberg-Universität in Germany, and York University in Toronto.

ATRAP works with very cold atoms, and has been working on studies in antimatter. Recently, the ATRAP Collaboration showed that it is possible to create antihydrogen so that it can be trapped within a certain magnetic field. Their work is published in *Physical Review Letters*: "Antihydrogen Production within a Penning-Ioffe Trap."

Antimatter is extremely rare; almost nothing in the universe is made of antimatter. Besides, when antimatter comes in contact with regular matter, it annihilates, leaving nothing but an energy release. But antimatter offers an interesting study for many physicists. "Our most basic theories predict that antimatter should behave like matter," Gabrielse explains. He and his colleagues believe that they may have found a way to trap antihydrogen so that it can be precisely studied. "This is exciting, because many said that it wasn't possible to produce antimatter in the environment that we did."

"We have to take it one step at a time," Gabrielse continues. "Right now, we've just shown that it's possible to create antihydrogen in this region where the magnetic field is at the minimum."

He explains the process of creating antihydrogen in the ATRAP technique: First, antiprotons are slowed by lowering their temperatures to close to four degrees above absolute zero. Positrons are also cooled down. "Next, we get the positrons and the antiprotons to interact – we get them to collide," Gabrielse says. "If we do it at a low enough energy, there is a probability that they will get attached and form an antihydrogen atom."

The problem is that, without charge, the antihydrogen doesn't trap very well. The ATRAP Collaboration overcame this problem by "creating a trap within a trap," Gabrielse explains. A Penning trap, which is designed for the antiprotons and positrons, is located inside an Ioffe trap with four current-carrying poles. This creates a region where the magnetic field is at a minimum. "Antiydrogen atoms that are cold enough and in the right quantum state will preferentially stay in the place where the magnetic field is lowest," Gabrielse explains. The Ioffe trap is designed to keep the antihydrogen, once it's formed, in place.

Gabrielse points out that they don't know if they have any trapped antihydrogen yet. "Our first step was to show that we could produce it under these conditions. Some said it couldn't be done, but we did it. We are working on making colder antihydrogen atoms that are better able to 'stick' inside the trap."

Once this is done, it should be possible to study the properties of antihydrogen and compare them to the properties of hydrogen. "If we discover they have different properties," Gabrielse says, "it will have huge implications at a fundamental level. If we find that they are the same, that reality does conform to theory, it's still a winning situation."

Even though there are no immediately obvious applications for antihydrogen, Gabrielse believes that this technique may move beyond the study of fundamentals in time: “When nuclear magnetic resonance was discovered, Ed Purcell thought it would only be good for studying fundamentals, but now MRIs are used all the time. Norman Ramsey had no idea that his maser would be incorporated into today’s GPS technology.”

“Our trap designs are now being used by others to analyze pharmaceuticals and our magnet designs are now being used to make MRI magnets that can be located closer to elevators and other sources of changing magnetic fields,” Gabrielse continues.

“These discoveries often lead to new inventions and techniques that become part of everyday life and our culture. It’s the way science works.”

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