Physicists propose new method of measuring the weak interaction

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A particular class of hydrogen atoms may prove ideal for the study of one of the four fundamental forces of physics, according to research performed at the U.S. Department of Energy's Argonne National Laboratory.

Argonne physicists Roy Holt and Bob Dunford proposed a method by which parity violations in hydrogen atoms could be observed and precisely measured in hydrogen atoms excited to a certain long-lived — or metastable — state. Parity indicates the symmetry of behavior in the interaction of a particular physical entity with that of its mirror image. Essentially, a parity experiment determines whether an atom knows the difference between right and left, according to Dunford.

At its first excited level, hydrogen can exist in one of two states of opposite parity, designated 2s(1/2) and 2p(1/2). A parity violation arises when an isolated atom exists in a combination of these states, because electromagnetic force theory dictates that states of opposite parity cannot mix. Because the 2s(1/2) and 2p(1/2) states have very similar energy levels, they are particularly sensitive to interactions which could cause a parity-violating atomic blend.

The detection of parity violations indicate the effect of the weak force, which along with the electromagnetic force, the strong force and gravity cause the physical interactions between all bodies in the universe. As its name implies, the weak force is almost impossible to detect directly in atoms, so scientists must rely on the observation of secondary effects in order to determine its intensity. Because physical bodies affected solely by electromagnetic, strong or gravitational forces conserve parity, parity violations correspond directly to the influence of the weak force. "If you want to see the weak interaction affecting an atom, you have to look at parity violation because that's the only way to tell the weak interaction from the electromagnetic force," Holt said. "If it wasn't for that, it'd be hopeless to measure the weak force."

While previous experiments into the effects of the weak force achieved precise measurements using heavier elements, especially cesium, the complexity of their atomic structures makes further advances difficult.

"In order to make progress in our research we need precision measurements of the weak force," Dunford said. "But in larger atoms, the interactions for which we need these kinds of measurements are being hidden by the run-of-the-mill complications with making calculations in a complex atomic structure."

Measuring the parity violations in hydrogen, which has only a single proton and electron, removes many of the obstacles, according to Holt. "In hydrogen, you have to solve only a two-body problem, so the basic principles become much simpler," he said.

However, earlier attempts to use hydrogen for research on the weak force failed because the effects were too small to be measured. Indeed, scientists preferred experimenting with the heavier atoms because the intensity of the force increases dramatically with the number of protons in an atom's nucleus.

In order to observe the weak interaction in hydrogen, Dunford and Holt suggested the use of an ultraviolet free electron laser to produce a slow, intense beam that would contain a sufficient quantity of excited hydrogen in the metastable 2s(1/2) state. "A couple years ago, you couldn't make enough of this excited hydrogen in order to be able to accurately measure the weak interaction. What you really need is a prolific source of slow metastable atoms," Holt said.

The weak, electromagnetic, and strong forces compose the building blocks of what physicists have termed the Standard Model, a simple, comprehensive theory that describes nearly all known forms of matter and their behaviors. However, the Standard Model fails to incorporate some parts of physics, most notably gravity, so physicists have been trying for decades to formulate a new theory that could find a single cause for at least the first three, and hopefully all four, fundamental forces. While work in physics beyond the Standard Model typically requires enormously expensive equipment and manpower, Holt and Dunford's research provides another avenue for investigating the physics at the core of our universe. "It's not the first method that people would typically think of," Holt said, "but this is a way of doing tabletop experiments to test the Standard Model."

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