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For Quantum Theory, A Jump

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Leverett Professor of Physics Gerald Gabrielse and his team recently advanced one of the major theories in phsyics by measuring the magnetic moment (G-factor) of an electron to a precision an order of magnitude higher than previous measurements, confirming that an electron has no internal structure and is, indeed, a fundamental particle.

“To make such a big step in accuracy is something I feel privileged to be a part of. We’ve poked and prodded at our most basic reality and it’s amazing at this incredible precision,” Gabrielse said.

The findings contribute to one of the most basic theories in physics, Quantum Electrodynamics (QED), which determines how light and charged particles interact.

The new measure of the G-factor can be plugged into a power series to calculate the binding energy of atoms, revealing that the binding energy is actually a millionth of a percent weaker than previously thought.

The breakthrough that allowed for this new precision include a new technique to cool an electron until it reached its quantum-mechanical ground state, according to physics graduate student David A. Hanneke, who co-authored the paper. The researchers then carefully controlled the planar and axial motions of the electron through a combination of electric and magnetic forces to measure precisely the frequency responses of the electron.

Another new technique was also employed when the researchers used a cylindrical trap for the electrons, as opposed to a hyperbolic shaped one.

Hanneke said that there will likely be further advances, perhaps by using the same techniques to measure the positron—the electron’s anti-matter counterpart.

“I expect in the not-too-distant future that we’ll have an even better measurement.”

Upon reading the paper, Professor Emeritus of the School of Natural Sciences at the Institute of Advanced Study Freeman J. Dyson, one of the inventors of QED, sent Gabrielse a letter of congratulations.

“He finds it amazing that this many years after they so carelessly scribbled this tune [QED], we find nature dancing to it at this parts per trillion level,” Gabrielse said. “We don’t get to decide what’s true. We get to decide what’s there.”

The recent paper is a result of two decades of research and experimentation, as well as the theoretical contribution of Toichiro Konoshita of Cornell University, whose work calculating the third coefficient of the anomalous magnetic moment began in 1980.

“Physicists in the entire world form a community and collaborate on topics of common interest,” Konoshita wrote in an e-mail.

In total, seven Harvard graduate students and 10 to 15 undergraduates worked on the project in one capacity or another, according to Gabrielse. He said that the chance to work on cutting-edge research has attracted many physics students to Harvard.

One of the paper’s co-authors agreed. “I entered the group a curious student and I left a capable scientist,” said Brian C. Odom of the University of Chicago. “Sometimes advisers give their students projects which are a waste of time, or they don’t give them enough guidance, but Jerry gives the right projects and the right level of guidance to turn the students into scientists.”

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