How big is a proton? No one knows exactly, and that's a problem

The experiments used modified hydrogen atoms to get at the size of the proton
Fritz Goro/The LIFE Picture Collection/Getty Images

By **Aviva Rutkin**

It's a subatomic mystery with big implications. Six years after physicists announced a bafflingly too small measurement of the size of the proton, we're still not sure what's going on. With the release of new data today, the mystery has, if anything, got deeper.

Protons are particles found inside the nucleus of atoms. For years, the proton's radius seemed pinned down at about 0.877 femtometres, or less than a quadrillionth of a metre.

But in 2010, Randolf Pohl at the Max Planck Institute of Quantum Optics in Garching, Germany, got a worryingly different answer using a new measurement technique.
Pohl's team altered the one proton, one electron composition of a hydrogen atom by switching the electron for a heavier particle called a muon. They then zapped this altered atom with a laser. Measuring the resulting change in its energy levels allowed them to calculate the size of its proton nucleus. To their surprise, it came out 4 per cent smaller than the traditional value measured via other means.

A 2013 measurement strengthened the finding, sending physicists searching for an explanation to the "proton radius puzzle". Pohl's experiment also applied the new technique to deuterium, an isotope of hydrogen that has one proton and one neutron – collectively known as a deuteron – at its nucleus. Accurately calculating the size of the deuteron took plenty of time, however.
Today, the team have published their measurements, revealing that like the proton, the deuteron comes up short: in this case by 0.8 per cent.

These new numbers show that the proton radius problem isn't going away, says Evangeline J. Downie at the George Washington University in Washington DC. "It tells us that there's still a puzzle," says Downie. "It's still very open, and the only thing that's going to allow us to solve it is new data."
Several more experiments, at Pohl's lab and others, are already under way. One will return to the same muon technique to measure the size of heavier atomic nuclei, like helium. Another plans to simultaneously measure the scattering of muons and electrons.

Pohl suspects the culprit may not be the proton itself, but an incorrect measurement of the Rydberg constant, a number that describes the wavelengths of light emitted by an excited atom. But this constant is well established through other precision experiments, so something drastic would have to have gone wrong.

Another explanation proposes new particles that cause unexpected interactions between the proton and the muon, without changing its relationship with the electron.

That could mean the puzzle is taking us beyond the standard model of particle physics. "If at some point in the future, somebody will discover something beyond the standard model, it would be like this," says Pohl, with first one small discrepancy, then another and another, slowly building to a more monumental shift.

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