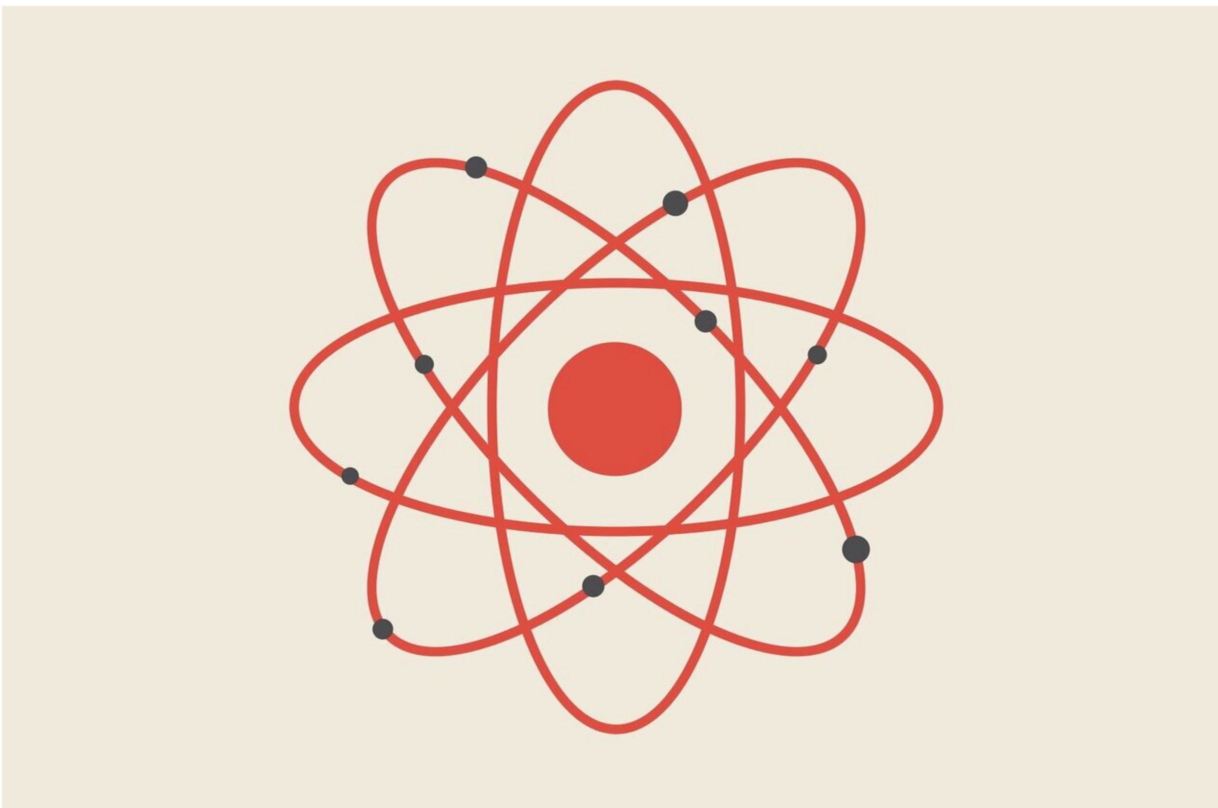
Improved modelling of nuclear structure in francium aids searches for new physics

August 5 2020



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Thanks to researchers from The University of Queensland, we now know with much greater certainty the nuclear magnetic moments of francium atoms.

Dr. Ben Roberts, a postdoctoral research fellow in UQ's School of Mathematics and Physics, said that the nuclear magnetic moment is a fundamental property of atoms, and knowing its value precisely is important when testing fundamental physics theories.

"But because francium is radioactive, the standard techniques for determining nuclear magnetic moments can't easily be applied," Dr. Roberts said.

"Using new methods, we were able to calculate moments with uncertainties four times smaller than the previous best values.

"Take francium-211, for example: its nuclear magnetic moment was previously determined to be in the range 3.92 to 4.08 (in the natural unit for expressing these moments).

"Our calculations now show it's between 3.90 and 3.94."

This may not seem like a huge difference, but Dr. Jacinda Ginges, an ARC Future Fellow at UQ and Associate Investigator at the ARC Centre of Excellence for Engineered Quantum Systems (EQUS), said that when you're talking about atomic physics, small differences can have a huge effect, so narrowing the range of possible values is a big deal.

"Our current understanding of the fundamental particles that make up the Universe and their interactions relies on the standard model of particle physics, but we also know this model is incomplete, there are some things it can't explain," Dr. Ginges said.

"We need precise values for nuclear magnetic moments to be able to test the validity of our atomic models, which in turn are really important for testing the standard model of particle physics.

"By combining precision experiments in atoms with high-precision atomic theory, we get a powerful way to search for new physics."

The improvement in precision was the result of very precise calculations of the hyperfine structure of francium—the tiny differences in atomic energy levels caused by its nuclear magnetic moment—and more accurate models of nuclear effects.

"Previous determinations assumed that the nucleus of a francium atom was like a ball with uniform magnetisation, but in our calculation we assumed a more realistic model that allowed the magnetisation to vary within the nucleus," Dr. Roberts said.

"The effect of non-uniform magnetisation (known as the Bohr–Weisskopf effect) is especially large in francium, so by accurately taking this into account we were able to determine its nuclear magnetic moments much more precisely."

"Our results can now be used to benchmark atomic theory, which will help interpret experiments currently underway at Canada's national nuclear and particle physics facility, TRIUMF," Dr. Ginges said.

"They also show how important it is to accurately model nuclear effects, and will have implications for past and future precision experiments with heavy atoms."

The results are published in *Physical Review Letters*.

More information: Nuclear Magnetic Moments of Francium-207–213 from Precision Hyperfine Comparisons, *Physical Review Letters* (2020). journals.aps.org/prl/abstract/ … ysRevLett.125.063002

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Provided by Australian Research Council