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Laser spectroscopy of muonic deuterium

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The deuteron is too small, too

The radius of the proton has remained a point of debate ever since the spectroscopy of muonic hydrogen indicated a large discrepancy from the previously accepted value. Pohl *et al.* add an important clue for solving this so-called proton radius puzzle. They determined the charge radius of the deuteron, a nucleus consisting of a proton and a neutron, from the transition frequencies in muonic deuterium. Mirroring the proton radius puzzle, the radius of the deuteron was several standard deviations smaller than the value inferred from previous spectroscopic measurements of electronic deuterium. This independent discrepancy points to experimental or theoretical error or even to physics beyond the standard model.

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Abstract

The deuteron is the simplest compound nucleus, composed of one proton and one neutron. Deuteron properties such as the root-mean-square charge radius r_d and the polarizability serve as important benchmarks for understanding the nuclear forces and structure. Muonic deuterium μd is the exotic atom formed by a deuteron and a negative muon μ^-. We measured three 2S-2P transitions in μd and obtain $r_d = 2.12562(78)$ fm, which is 2.7 times more accurate but 7.5σ smaller than the CODATA-2010 value $r_d = 2.1424(21)$ fm. The μd value is also 3.5σ smaller than the r_d value from electronic deuterium spectroscopy. The smaller r_d, when combined with the electronic isotope shift, yields a "small" proton radius r_p, similar to the one from muonic hydrogen, amplifying the proton radius puzzle.

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