Precision Spectroscopy on the $2\ ^3S_1 \rightarrow 2\ ^1S_0$ transition in ^3He and ^4He

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Different determinations of the proton charge radius from high precision spectroscopy on electronic and muonic hydrogen, as well as from electron-proton scattering, show large discrepancies. This is known as the 'proton size puzzle'. Recent measurements in ^3He and ^4He, the second simplest atomic system after hydrogen, also show discrepancies.

The isotope shift between ^3He and ^4He on the highly forbidden $2\ ^3S_1 \rightarrow 2\ ^1S_0$ transition at 1557 nm provides a means to get a precise value of the nuclear size difference. To this end we have already measured this transition in ^4He with an accuracy of 0.2 kHz by performing spectroscopy on a Bose-Einstein condensate of metastable helium. This has been performed in an optical dipole trap at the magic wavelength for this transition which also allowed us to test polarizability calculations. In addition, with this approach we have been able to extract the triplet-singlet scattering length from the mean-field shift on the transition with an improved accuracy. Our next goal is to measure the transition in a degenerate Fermi gas of ^3He with a similar accuracy and compare our isotope shift results with those from the $2\ ^3S_1 \rightarrow 2\ ^3P$ transition at 1083 nm and from muonic helium, that are expected soon.