Precision spectroscopy of the 2S-4P transition in atomic hydrogen

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Precision measurements of atomic hydrogen (H) have long been successfully used to extract fundamental constants and to test bound-state quantum electrodynamics. Both the Rydberg constant R_∞ and the proton root mean square charge radius r_p are determined to a large degree by H spectroscopy, requiring the measurement of at least two transition frequencies. With the very precisely measured 1S-2S transition frequency [1] serving as a corner stone, the current limitation of this extraction is the measurement precision of other H transition frequencies. Moreover, r_p extracted from the H spectroscopy world data disagrees by 4 standard deviations with the much more precise value extracted from spectroscopy of muonic hydrogen (μp) [2].

Using a cryogenic beam of H atoms optically excited to the initial 2S state, we measured the 2S-4P transition in H with a relative uncertainty of 4 parts in 10^{12} [3]. We motivate an asymmetric fit function, which eliminates line shifts from quantum interference of neighboring atomic resonances. Combining our result with the 1S-2S transition frequency yields the values of the Rydberg constant $R_\infty = 10973731.568076(96)\,\mathrm{m}^{-1}$ and $r_p = 0.8335(95)\,\mathrm{fm}$. Our r_p value is 3.3 combined standard deviations smaller than the previous H world data, but in good agreement with the μp value.

[1] C. G. Parthey *et al.*, Physical Review Letters **107** (2011) 203001.
[2] A. Antognini *et al.*, Science **339** (2013) 417.
[3] A. Beyer, L. Maisenbacher, A. Matveev *et al.*, Science **358** (2017) 79.