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 $R_\infty$ 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 ($\mu p$) [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 $R_\infty = 10973731.568076(96) \text{ m}^{-1}$ and $r_p = 0.8335(95) \text{ fm}$. Our $r_p$ value is 3.3 combined standard deviations smaller than the previous H world data, but in good agreement with the $\mu p$ value.