# Fundamental Physics with atomic Hydrogen

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Discrepancies between theory and experiments have been fueling the development of physics. Today, Quantum Electrodynamics (QED) is the most accurate theory and served as a blueprint for all subsequent field theories. Physics beyond the Standard Model must exist as we know from observations of the cosmos. It is likely to be found where no one has looked before, i.e., at very large energies, high sensitivity, or high precision. To progress with the so-called precision frontier, high resolution spectroscopy of atomic hydrogen and hydrogen-like systems continues to play a decisive role because their simplicity. Testing QED means to verify the consistency of parameters that enter this theory. Values for these parameters are extracted from as many different measurements as possible.

The sharpest metrologically relevant line in atomic hydrogen is due to the 1S-2S transition. Since there is no 1P state, the 2S state can neither decay nor be excited with a single photon dipole transition, at least not in a field-free environment. Therefore the lifetime of the 2S state is very long leading to natural line width of only 1.3Hz. The 1S-2S transition frequency has been measured with almost 15 digits accuracy using an optical frequency comb and a cesium atomic clock as a reference [1].

However, the largest leverage for the determination of the parameters, the Rydberg constant and the proton charge radius, is currently due to the 1S-3S transition frequency that we are investigating in our lab [2]. With another experimental setup we are conducting a series of measurements between the metastable 2S and $n$P states [3]. To go further we are developing a method to trap atomic hydrogen in an optical dipole trap that operates at the magic wavelength. The proposed scheme avoids a cooling laser and will not be more complex than existing optical lattice clocks. Besides of improving the measured transition frequencies, trapped atomic hydrogen could eventually be the motivation to redefine the SI second in terms of the Rydberg constant. This would remove the last remaining object in the definitions of the SI which is otherwise based defined values of physical constants ($c$, $h$ and $e$).

[1] C.G. Parthey et al., Phys. Rev. Lett. 107, 203001 (2011).
[2] A. Grinin et al., Science 370, 1061 (2020).
[3] A. Beyer et al., Science 358, 79 (2017).