Precision measurements using ultracold metastable helium

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The ultracold atomic sample created in the metastable helium (He*) BEC experiment is an ideal testbed for performing atomic physics experiments in a controlled environment on this, the simplest of multi-electron atoms. We have used this apparatus to determine for the first time the $2\,^3P_1 - 1\,^1S_0$ transition rate [1].

The experiment exploits the very long ($\sim$1 minute) confinement times obtained for atoms magneto-optically trapped in an apparatus used to create a Bose-Einstein condensate of metastable ($2\,^3S_1$) helium. The $2\,^3P_1 - 1\,^1S_0$ transition rate is measured directly from the decay rate of the cold atomic cloud following 1083 nm laser excitation from the $2\,^3S_1$ to the $2\,^3P_1$ state, and from accurate knowledge of the $2\,^3P_1$ population.

The decay rate measurement is performed in a relatively unperturbed environment by releasing the atoms momentarily from the trap. This is achieved by turning off the $2\,^3P_2 - 2\,^3S_1$ trapping laser (P2 light) and briefly irradiating the slowly expanding cloud with a laser tuned near the $2\,^3S_1 - 2\,^3P_1$ transition (P1 light). The presence of the P1 light continually replenishes the $2\,^3P_1$ population from the $2\,^3S_1$ state, thereby ensuring that the $2\,^3P_1 - 1\,^1S_0$ decay rate dominates the decay rate due to the otherwise much faster $2\,^3P_1 - 2\,^3S_1$ transition.

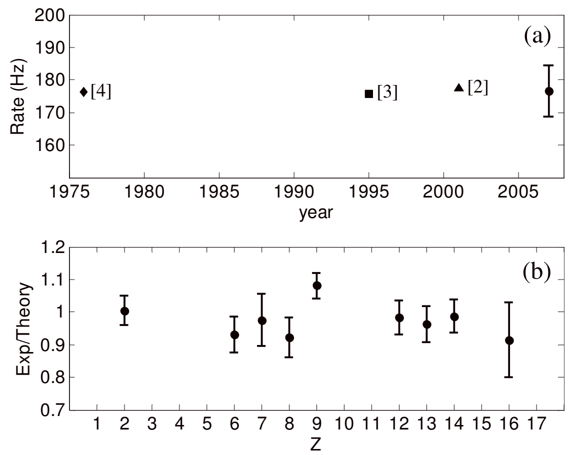

Figure 1:(a) Historical progress of theoretical determinations for the helium $2\,^3P_1 - 1\,^1S_0$ decay rate, together with the experimental value (and uncertainty) from the present work. (b) Ratio of the experimental to the most recent theoretical decay rates, along with experimental uncertainties, for the $2\,^3P_1 - 1\,^1S_0$ transition in the heliumlike isoelectronic sequence.

To determine the P1 population the trap light is extinguished momentarily, and a pulse of P1 light briefly saturates the ensemble following an interrogation pulse below saturation. The P1 population is then derived from the ratio of the fluorescence signals.

The value obtained for the decay rate is 177$\pm$8 s^{-1}, which agrees very well with theoretical predictions, the most recent value being 177.6 s^{-1} [2] (Figure 1a). This accuracy compares favorably with measurements for the same transition in heliumlike ions higher in the isoelectronic sequence (Figure 1b). The value for the helium decay rate is the only value for Z<6 and anchors the isoelectronic sequence for this transition.

A similar situation pertains to the $2\,^3P_2 - 1\,^1S_0$ transition for which there is no helium measurement, and for the $2\,^3S_1 - 1\,^1S_0$ transition where the only helium measurement has a very large uncertainty. The determination of these transition rates is the subject of future investigations in this laboratory.

References

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