

Lifetimes of ultralong-range Strontium Rydberg molecules in a dense BEC

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Synopsis The lifetimes and decay channels of ultralong-range strontium Rydberg molecules that contain tens to hundreds of ground-state atoms within the electron orbit are examined by monitoring the time evolution of the Rydberg population using field ionization.

Ultralong-range Rydberg molecules excited in a BEC can be used to explore collective phenomena in quantum degenerate gases such as the creation of polarons[1]. Their use as a probe, however, requires that their lifetimes be sufficient to allow interactions to produce measurable effects. Here we examine the lifetimes of strontium Rydberg molecules in a BEC and the reactions responsible for their destruction.

⁸⁴Sr atoms cooled in a magneto-optical trap are loaded into an optical dipole trap where they are subject to evaporative cooling to create a BEC with a peak density of $\sim 4 \times 10^{14} \text{ cm}^{-3}$. Two-photon excitation is used to create Rydberg molecules with values of principal quantum number n in the range $49 \leq n \leq 72$. A typical excitation spectrum is included in Fig. 1, expressed as a function of detuning from the atomic line. The sharp peak at zero detuning results from excitation of thermal non-condensed atoms present in the trap, the broad feature extending to the red results from molecular excitation, the larger the detuning the larger the number of atoms present in the molecule. The evolution of the Rydberg population is monitored by field ionization. Analysis of the data indicates that the destruction of Rydberg molecules results from the same processes as identified in earlier studies with rubidium[2], namely associative ionization, leading to formation of Sr_2^+ molecules, and L -changing reactions.

Figure 1 shows the time evolution of the total Rydberg population. The initial rapid decrease in the Rydberg population results from associative ionization. The slower rate of loss

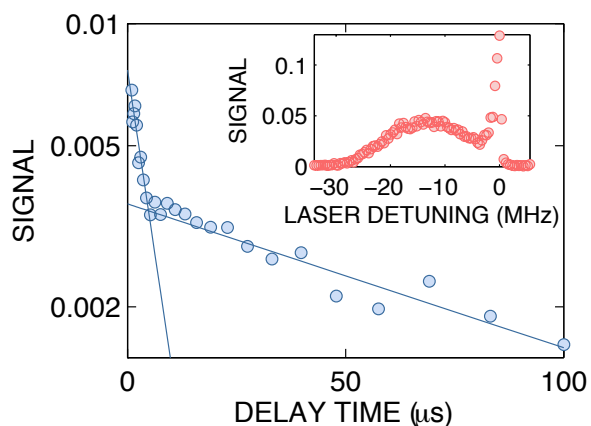


Figure 1. Time evolution of the Rydberg population following excitation of $n=60$ Rydberg molecules at a detuning of -21.6 MHz in a BEC. The inset shows the $n=60$ excitation spectrum.

seen at later times results from the decay of L -changed Rydberg atoms. The measured molecular lifetimes, $\sim 3\text{-}10 \mu\text{s}$, limit the timescales over which studies involving Rydberg molecules in cold, dense gases can be undertaken, and reduce the coherence time in such measurements.

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References

- [1] F. Camargo et al. to be published
- [2] M. Schlagmüller et al. 2016 *Phys. Rev. X* **6**, 031020