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Reply to "Comment on 'Measurement of the lifetimes of *S* and *D* states below $n=31$ using cold Rydberg gas'"

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In response to the preceding Comment, we present important experimental information on our *S*, *P*, and *D* Rydberg lifetime measurements for ^{85}Rb using a sample of cold Rydberg atoms. We analyze and discuss the implications of blackbody radiation transfer on our results. We also discuss the limitation of the theory compared with our results.

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Time domain spectroscopy is a powerful technique to test for the quality of computed wave functions, and it is used to optimize models of the electron distribution in complex atoms. Alkali-metal atoms have been used both theoretically and experimentally as prototypes for accurate measurements of Rydberg state lifetimes [1]. However, experimental conventional techniques to measure Rydberg lifetimes using thermal atoms have serious limitations from superradiance and collisional effects [2]. Cooling and trapping of neutral atoms is a technique which has been proposed as a powerful tool for high resolution spectroscopy. Conventional Doppler free techniques for thermal atoms have ultimate resolutions limited by velocity dependent effects, such as transient time and second order Doppler shift. These limitations and collisional shifts can be severely reduced if samples of cold trapped atoms are employed. Therefore, application of cold atom spectroscopy to Rydberg lifetime measurements should improve the experimental situation of this field.

In recent years, our group has used a sample of cold atoms to perform high precision measurements of Rydberg state lifetimes and compared the results with existing theory [3]. In the preceding Comment, the author pointed out two apparent flaws in our work [4]. The first flaw is about how the field ionization technique was used to detect the Rydberg population time evolution after laser excitation. The second flaw is the comparison of our experimental results with a simplified theory. In this Reply, we provide more information on the experimental procedure as well as on the comparison.

Blackbody transfer is an important depopulation mechanism of the target state to nearby states. Therefore, special care must be taken to use the field ionization technique to detect only the signal part that is due to the target state, avoiding in this way contribution from other states. The way we have described the use of this technique in our paper is inaccurate. One may get the impression that the Rydberg signal was acquired without any care. However, that was not the case. Therefore, some points of the experimental procedure (of all papers) must be clarified as follows. (i) The field values given in the papers are the maximum possible field in each experimental setup. (ii) The ionization field amplitude was adjusted for each target state in such a way that it was just large enough to ionize the target state and higher energy states, but not the lower energy states. (iii) We have stated that we detect the ions. In fact, we can detect either ions or electrons in our setup. But we have used only the electron signal due to its better state selection. (iv) The boxcar gate was set to acquire only the target state from the time-resolved electron signal. In Fig. 1, we show a typical time-resolved electron signal for the 31*D* target state at two different time delays between excitation and detection. The electron signal was normalized to simplify comparison. In Fig. 1, we show the time-resolved electron signal for the 31*D* state at 0.2 and 8 μs delay time between excitation and detection, and also the 0.1 μs boxcar gate (that was used in the experiments). At 8 μs delay time, we observe clearly the blackbody transfer to higher states. We also observe some broadening of the signal to the right of the 31*D* peak, which could be due to either adiabatic ionization of lower energy states or diabatic ionization of higher energy states. However, the contribution of such states to the acquired signal using the procedure described here remains to be determined. Nevertheless, our recent results on density dependence involving two-body collisions with Rydberg atoms, in which blackbody transfer plays an important role, indicate that this contribution to the acquired signal is negligible [5].

The comparison of our results with a simplified theory [2] was done because there are no published theoretical predictions at 300 K for the lifetime of the states we have measured. We were aware of the limitations of such a theory.

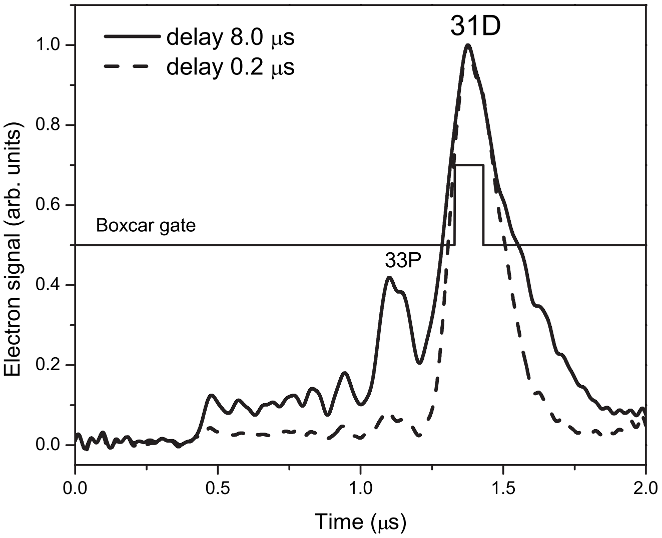

FIG. 1. Time-resolved electron signal for the 31*D* target state.

However, the comparison was done just to indicate that the experimental results were within the correct range. Our purpose was to stimulate theoretical work in this field. In fact, after the work by Oliveira *et al.* [3], Theodosoiu extended his previous work [6] up to $n=45$ at 300 K [7]. Unfortunately, he never published his results and we only have them as a private communication. Nevertheless, we can compare the simplified theory and the theory from Theodosoiu. The difference between them is about 7% for S state and 10% for D state. Since Theodosoiu's results were never published, we only had our comparison with the simplified theory to show that our experimental results have the expected qualitative behavior as a function of n. To summarize, we believe that the present information in this Reply resolves the points mentioned in the preceding Comment.

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