Cold collisions studied by high resolution spectroscopy, example Na

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In a molecular beam experiment starting with thermally populated molecular ground state levels we apply Franck-Condon pumping followed by a Raman process to access the last bound levels just below the dissociation limit 3s+3s of Na_2 [1]. Additionally, we observe shape and Feshbach resonances between the three hyperfine asymptotes belonging to the $X^1\Sigma_g^+$ and $a^3\Sigma_u^+$ states. In contrast to single color photoassociation, this method is able to select specific states of nuclear motion. It is sensitive to cold collision properties of two colliding atoms. The highly accurate determination of bound state energies enables us to derive precise values for ground state scattering lengths using an extrapolation procedure based on adiabatic potentials [2]. Choosing different vibrational levels of the $A^1\Sigma_u^+$ state as intermediate level for the Raman process, due to their different outer turning points, it is possible to examine the probability amplitude of the ground state scattering wave function as it depends on the internuclear separation. An example for the observed spectra using intermediate levels $v'_A = 139$ and $v'_A = 148$ is given in Fig. 1. The profiles of the resonances and the slope of the continuum background is significantly different for the processes.

The observed structures can be fully simulated by coupled channel calculations. For this purpose complete potentials for both $X^1\Sigma_g^+$ and $a^3\Sigma_u^+$ states were constructed from the data of the literature and our own measurements of levels close to the asympotes [3]. The calculated spectra are shown as dashed lines in the figure. Experimentally observed features with peaks going upwards are lines of the A-X system excited by a single photon process and are not related to the Raman process. Differences between observed intensities and calculated ones are due to saturation, which was not included in the calculations (panel b)). The overall agreement between experiment and theory is quite satisfactory.

Furthermore, an experiment for the manipulation of cold collisions properties with dynamic fields is presented. We investigate the influence of near resonant light fields on the energies of asymptotic vibrational levels at the A state asymptote. The progress of the experiment will be discussed.

[1] M. Elbs, H. Knöckel, T. Laue, Ch. Samuelis , and E. Tiemann, Phys. Rev. A **59**, 3665 (1999)
[2] A. Crubellier, O. Dulieu, F. Masnou-Seeuws, M. Elbs, H. Knöckel, and E. Tiemann, Eur. Phys. J. D **6**, 211 (1999)
[3] C. Samuelis, E. Tiesinga, T. Laue, M. Elbs, H. Knöckel, E. Tiemann, to be published

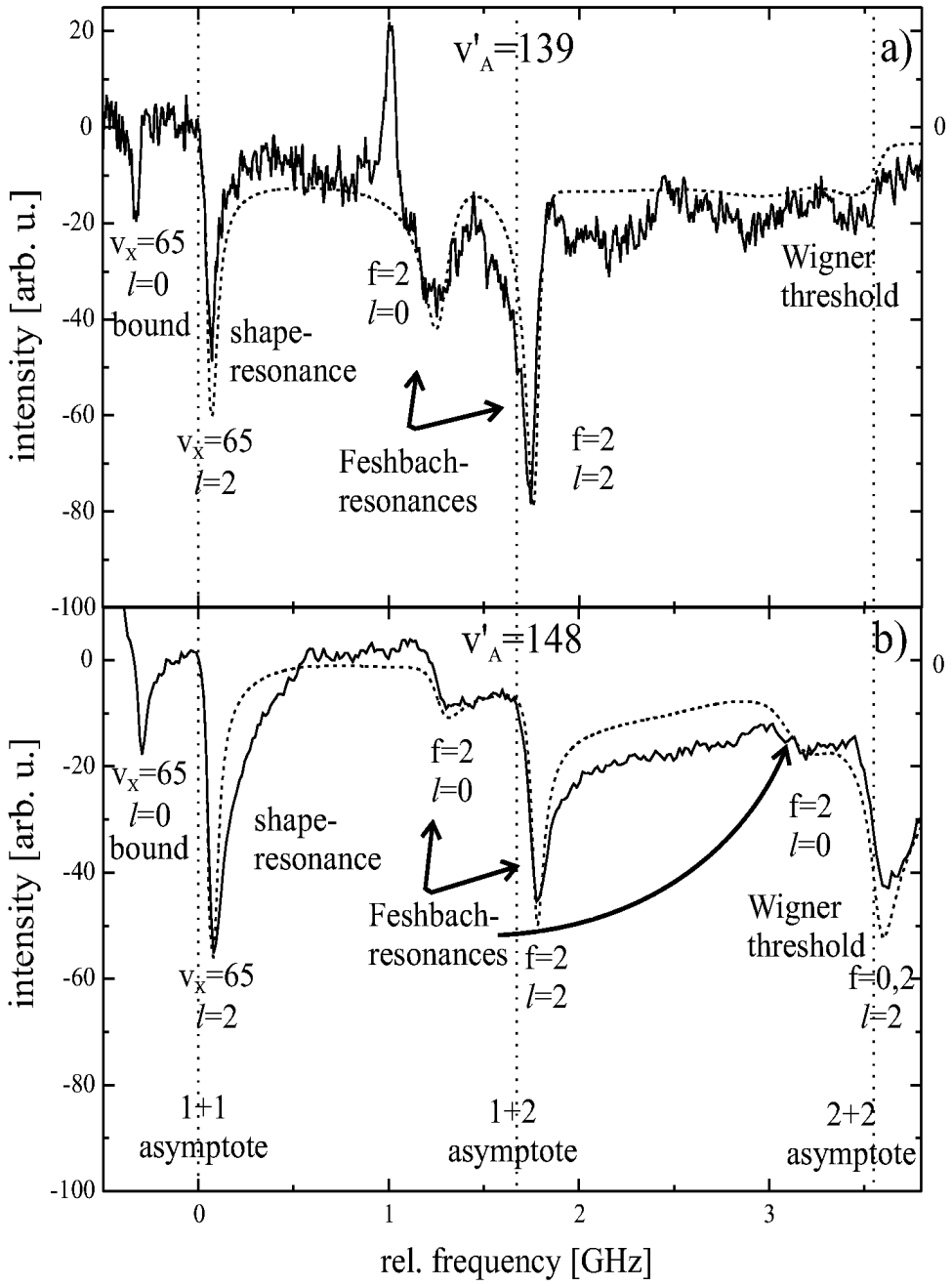

Figure 1: Variation of the observed line profiles with the upper level in the A state. The dashed spectra are simulated ones.