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Coherences and collisions of ultracold RbCs molecules.

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The formation of ultracold heteronuclear molecules possessing long-range dipole-dipole interactions opens up many exciting areas of research spanning quantum computation, quantum simulation and fundamental studies of quantum matter. Long-lived, trapped samples of molecules with full quantum control of the molecular internal state are crucial to many of these applications. Here we report the results of investigations into the rotational coherence and collisional stability of ultracold RbCs molecules prepared initially in the rovibrational ground state. Using coherent microwave control of the internal state of the molecule, we study the AC Stark effect due to the trapping light in low-lying rotational levels. Our measurements reveal a rich energy structure with many avoided crossings between hyperfine states. Understanding this structure allows us to enhance the rotational coherence through a judicious choice of internal state and intensity. Understanding the trap potential also allows us to study the lifetimes of the molecules for various rotational and hyperfine states. We observe rapid loss that is insensitive to the internal state and compare our findings with the 'sticky collision' hypothesis that pairs of molecules form long-lived collision complexes. We demonstrate that the loss of molecules is best described by second-order rate equations, and that the rate differs from the limit of 'universal loss' for s-wave collisions. We show that dipolar effects lead to significantly faster loss for an incoherent mixture of rotational states. As an outlook, we will briefly describe our plans for imaging and addressing of single molecules in ordered arrays as a basis for quantum simulation.