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Ultralong-range Molecules in Strontium Rydberg Gases[1]

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Alkaline-earth metal atoms are attracting increased attention for studies of ultracold Rydberg gases because of new opportunities created by strong core transitions accessible with visible light and the presence of excited triplet states. We have created and characterized ultralong-range Sr_2 molecules formed from one ground-state $5s^2\ {}^1S_0$ atom and one atom in a 5sns ${}^3S_1$ Rydberg state. Molecules are formed in a trapped ultracold atomic gas using two-photon excitation, near resonance with the 5s5p ${}^3P_1$ intermediate state. Spectra for both a thermal gas and a Bose-Einstein condensate have been studied, and highly structured vibrational spectra are obtained for molecular dimers, trimers, and tetramers. Measured lifetimes of Rydberg atoms and molecules in dense gases of ground state atoms show that, in marked contrast to earlier measurements involving rubidium Rydberg molecules, the lifetimes of the low-lying molecular vibrational states are very similar to those of the parent Rydberg atoms. This reflects the fact that in strontium there is no p-wave resonance for electron scattering in this energy regime, unlike the situation in rubidium. The absence of a resonance offers advantages for experiments involving strontium Rydberg atoms as impurities in quantum gases and for testing theories of molecular formation and decay.

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