Molecules in Optical Cavities: Precision Spectroscopy and Strong Light-Matter Interactions

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In this talk, I will discuss my lab's efforts to harness optical enhancement cavities both as a platform to explore molecular physics under strong light-matter interactions and as tools for precision spectroscopy.

Polaritons are hybrid light-matter states with unusual properties that arise from strong interactions between a molecular ensemble and the confined electromagnetic field of an optical cavity. Cavity-coupled molecules appear to demonstrate energetics, reactivity, and photophysics dramatically distinct from their free-space counterparts, but the mechanisms and scope of these phenomena remain uncertain. I will discuss our new experimental platforms to investigate molecular dynamics under strong coupling. In one thrust, we are engineering polariton formation in cold gas-phase molecules, where attaining sufficiently strong light-matter interactions is a challenge and had not been previously reported. We are harnessing this infrastructure as a testbed to study fundamental polariton photophysics and chemistry. We are also searching for signatures of cavity-altered dynamics in benchmark condensed-phase systems using ultrafast transient absorption spectroscopy with the goal of better understanding exactly how and when reactive trajectories may be influenced by strong light-matter interactions.

I will also discuss our efforts in cavity-enhanced spectroscopy of complex molecular systems. Cavity-coupled frequency comb lasers enable simultaneously high-resolution, high-sensitivity, broadband, and rapid-acquisition spectroscopic measurements. We are using cavity-enhanced frequency comb spectroscopy to reveal the structure and behavior of astrochemically-relevant molecules and clusters. We are also extending these techniques towards the study of atmospherically-relevent aerosols.