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Atoms and Molecules Illuminated from Within

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Molecules in the gas phase are unique quantum systems in that they exhibit many fundamental quantum mechanical effects and are yet complex enough to challenge the most rigorous theoretical treatments. Exploring these quantum systems in detail is challenging in large part because molecules in the gas phase are randomly oriented as molecules tumble and translate through space. I will describe a series of experiments that allows us to study electronic and fragmentation dynamics in the molecular frame, enabling observation of collective quantum phenomena in the gas phase. In particular, I will show how a resonant electron wave propagates through a molecular potential, interrogating the molecule as it emerges from one of the core molecular orbits, and how simultaneously measuring multiple particles allows for a complete determination of the continuum quantum states of an isolated molecule.