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Quantum Optics of Ultracold Molecular Dimers

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A remarkable outcome of the availability of ultracold, quantum degenerate atomic samples is the coherent formation of molecular dimers by means of Feshbach resonances and by two-photon Raman photoassociation. These processes are formally closely related to the optical three-wave mixing mechanisms of second-harmonic generation and sum-frequency generation, with however the important difference that the atoms and molecules involved can be either bosonic or fermionic. The talk will discuss the dependence of the quantum statistics of the molecular field on the initial state of the atomic source, considering the cases of an atomic Bose condensate, a quantum-degenerate gas of atomic fermions, and a BCS-type superfluid Fermi gas. For short enough times, BEC atomic states are found to give rise to an essentially coherent molecular field, while a normal Fermi gas results in a a molecular field with 'chaotic' molecule statistics, analogous to the photon statistics of a classical light source. The BCS situation is intermediate between the two. We also discuss the impact of quantum fluctuations on the early stages of molecule formation by means of the so-called "passage time statistics" familiar from studies of superradiance. In collaboration with D. Meiser and H. Uys, University of Arizona, and C. P. Search, Stevens Institute of Technology