Quantum optics of ultracold molecular fields

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We apply concepts of quantum optical coherence to characterize the coherent generation of a molecular field created from a quantum-degenerate atomic sample, and discuss the impact of the quantum statistics of the atoms on that field. For atoms initially in a BEC the resulting molecular field is to a good approximation coherent. This is in sharp contrast to the case of atoms in a normal Fermi gas, where we can made use of an analogy with the Tavis-Cummings model to show that the statistics of the resulting molecular field is similar to that of a single-mode chaotic light field. The BCS case interpolates between the two extremes, with an 'incoherent' contribution from unpaired atoms superposed to a 'coherent' contribution from atomic Cooper pairs. These statistics provide therefore a distinct signature of the initial atomic state and suggest the use of single molecule counting as a diagnostic tool for atomic states. We also comment on the temporal fluctuations characteristic of the formation of molecular dimers from ultracold fermionic atoms.