Quantum Super-Chemistry: Bose enhancement and matterwave phase matching

C. Chin, University of Chicago

Quantum mechanics allows for “spooky” interactions, ok, but does it also enable spooky reactions? In the quantum-degenerate regime, atoms and molecules occupy a single macroscopic quantum state and form coherent matter waves. In this limit, reactive scattering between quantum fields is theoretically described by nonlinear wave mixing, giving rise to a new paradigm of quantum many-body chemistry, also referred to as /quantum super-chemistry.

In this talk, I will describe our recent experiments with ultracold atoms and molecules coupled via a Feshbach resonance. When the sample is cooled below the superfluid transition temperature, we observe Bose-enhanced reaction dynamics, in qualitative agreement with quantum-field models. Using Bragg diffraction of both atoms and molecules, we further probe phase coherence in the reaction process and confirm the predicted matterwave phase doubling when atoms are paired into molecules, which is the matter-wave analogue of phase matching in nonlinear optics. Intriguingly, by employing entanglement witnesses, we also observe the emergence of non-classical correlations generated by the reaction dynamics.

Together, these experiments establish molecular Bose condensates as a powerful platform for uncovering new operating principles of chemical reactions in the quantum many-body chemistry.