Quantum control of ion-atom collisions beyond the ultracold regime

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Tunable scattering resonances are crucial for controlling atomic and molecular systems [1]. However, their use has so far been limited to ultracold temperatures. These conditions remain hard to achieve for most hybrid trapped ion-atom systems—a prospective platform for quantum technologies and fundamental research [2]. We measure inelastic collision probabilities between a single Sr^+ ion and an Rb atom, and use them to calibrate a comprehensive theoretical model of ion-atom collisions [3]. Our theoretical results, compared with experimental observations, confirm that quantum interference effects persist to the multiple-partial-wave regime, leading to the pronounced state and mass dependence of the collision rates. Using our model, we go beyond interference and identify a rich spectrum of Feshbach resonances at moderate magnetic fields with the Rb atom in its lower ($f = 1$) hyperfine state, which persist at temperatures as high as 1 millikelvin. Future observation of these predicted resonances should allow precise control of the short-range dynamics in Sr^+ + Rb collisions under unprecedentedly warm conditions.

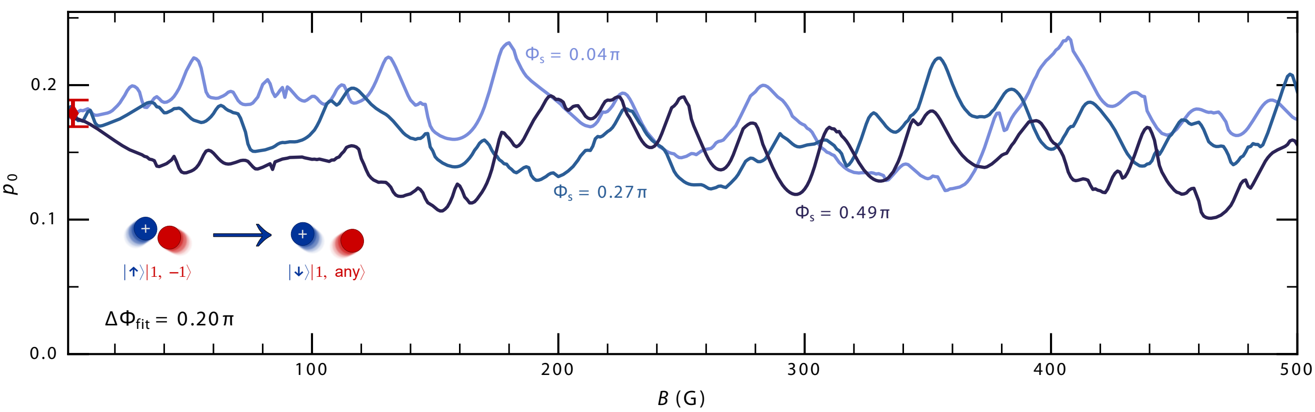

Figure 1: Probability of the spin-flip of the ion at $T = 0.5$ mK, calculated as a function of magnetic field for three different sets of singlet and triplet potential energy curves matching the measurements at $B = 2.97$ G. Φ_s and $\Delta\Phi$ denote the singlet semiclassical phase modulo π and the semiclassical singlet-triplet phase difference modulo π that we use to describe the interaction potentials.

References

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