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Interplay between S-matrix resonance poles in an ultracold atom collider

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In quantum mechanics, collisions between two particles are captured by an energy-dependent scattering matrix describing the transfer from an initial entrance state to an outgoing final state. The scattering matrix can be analytically extended to a plane of non-physical complex energies where, remarkably, poles of this continued S-matrix will be intimately related to scattering resonances of the system. Upon changing the system's interaction potential, the poles will move and their ensuing flow has been investigated theoretically for numerous potential wells following the seminal work by Nussenzveig [1].
Here we report on the experimental observation of S-matrix pole flow and in particular the interplay that results from two poles coming close. Using a laser-based collider for ultracold atoms, we conduct scattering experiments in a parameter space spanned by energy and magnetic field. The magnetic field affects the position of a Feshbach resonance whose corresponding S-matrix pole is tuned into proximity of the pole for i) an anti-bound state [2] and ii) a shape resonance [3,4]. Our observations are in compelling agreement with the characteristic pole trajectories predicted by theory [5,6].

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