Quench Dynamics of Trapped Few-Body Systems

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Few-body physics underlies a large number of fields. It is critical to nuclear, atomic and molecular physics and plays an important role in fields such as nanocircuitry or superfluid turbulence. Another such field is dilute ultracold gases, these systems are of particular note because they are excellent experimental test beds of quantum theory, they can be reliably constructed, [1], controlled, [2], and measured, [3, 4].

To truly understand few-body systems we need to understand their behaviour away from equilibrium and completely describing non-equilibrium dynamics has historically proven challenging. We consider a spherically symmetric harmonic trap occupied by two or three particles interacting via a contact interaction parametrised by the s-wave scattering length, a_{s}. We then consider a quench in a_{s} and analytically or semi-analytically calculate observables of the system as functions of time after the quench.

Specifically we calculate the Ramsey signal (the wavefunction overlap of the pre- and post-quench states) and the particle separation. For the two-body case this is done for a general quench, from any initial a_{s} to any final a_{s}. For the three-body case these calculations are done for quenches between the non-interacting, $a_{\mathrm{s}} = 0$, and unitary, $a_{\mathrm{s}} \to \infty$, regimes. In both cases any initial state can be considered.

We find the Ramsey signal is well defined in both the two- and three-body cases as is the particle separation in the non-interacting to unitary quench. However in the unitary to non-interacting quench we find that the particle separation is divergent in both the two- and three-body cases. Using physical arguments we are able to institute a cut-off and the predicted amplitudes of oscillation are significantly larger than in the non-interacting to unitary quench. Nonetheless the presence of this divergence demonstrates a shortcoming in standard theoretical tools used to model quantum gases.

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