Mixing dimensions in systems of ultracold atoms in optical traps

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Ultracold quantum atoms (UCAs) have become a topic of great interest over the last years since the experimental realization of the first Bose-Einstein Condensate [1]. Nowadays, UCAs lie among the most promising platforms for quantum information and computation due to the excellent degree of control that we have to manipulate and control them. One way to do so consists in tuning the interparticle interactions with the help of Feshbach resonances by application of external magnetic fields [2].

Moreover, quantum gases are routinely confined in optical traps of different shape and geometry (optical lattices, tweezers, dipolar traps, etc.). Changing the trapping potential enables an alternative way to manipulate the atomic sample through the so-called inelastic confinement-induced resonances (ICIRs). They were first observed in a groundbreaking experiment in Innsbruck [3]. The origin of the ICIRs lies on the coupling between the center-of-mass (CM) and the relative-motion (rm) coordinates due to the nonlinearities in the trapping potential. Consequently, they are absent in perfectly harmonic traps.

More recently, ICIRs have been observed in a 3D optical trap, demonstrating the existence of this phenomenon in more general situations. In this line, the theoretical model that reproduce the resonances has been validated in quasi-1D and refined in 3D confinements [4]. Knowing the position of the ICIRs is important due to their influence on quantum gases: sometimes, one must try to avoid them due to the losses that they cause in the atomic sample, while in other situations experimentalists make use of them to create coherent molecules [5]. The experimental developments over the last years have also enabled experiments where two interacting atomic clouds are confined in optical traps of different dimension [6]. The natural question is whether or not the dimension confinement affect the resonances.

In this communication, we try to sed light to the last question examining the ICIRs in mixed-dimensional optical traps with full CI *ab initio* simulations. For this purpose, we calculate the energy spectrum of a system of two ^{7}Li atoms confined in several settings (quasi-1Dquasi-1D), (quasi-1D–quasi-2D), (quasi-1D–3D), (quasi-2D–3D), (quasi-2D–quasi-2D) and (3D-3D) traps by solving the corresponding six-dimensional Schrdinger equation for several values of the s-wave scattering length a_0 (see for example Fig. 1). ICIRs manifest as avoided crossings in the spectrum due to the interaction between the least-bound (molecular) state and the first-trap state. Moreover, we increase the anisotropy between the longitudinal and transversal directions for the sake of breaking the degeneracy and, therefore, split the resonances in two branches. We have observed that the position of the ICIR's is strongly influenced by the trap dimensionality. The study for systems with heteronuclear species, which is experimentally more interesting [6], is currently under study.

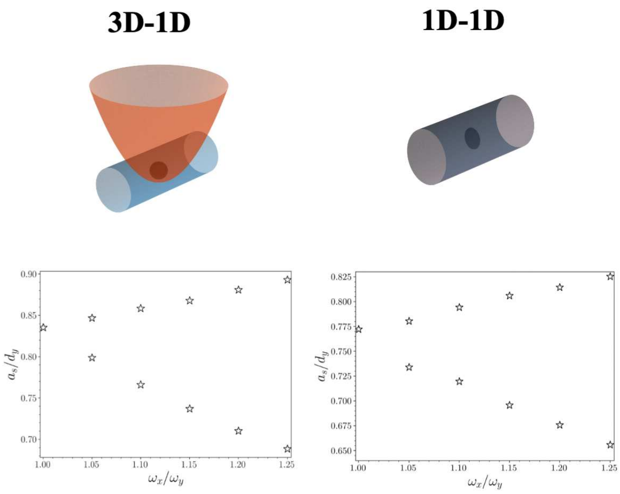

Fig. 1. Inelastic Confinement-Induced Resonances produced by two atoms of ^{7}Li in quasi-1D optical traps (right) and in mixed 3D–quasi-1D confinement (left) as a function of the anisotropy between the longitudinal (X) and transverse directions (Y, Z). Upper branch corresponds to the atomic level $(n_x, n_y, n_z) = (0, 2, 0)$ and the lower to $(n_x, n_y, n_z) = (2, 0, 0)$.

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