Synthetic superfluid chemistry with vortex-trapped quantum impurities

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Degenerate quantum gases represent exceptionally pure systems with which to study a plethora of quantum mechanical effects. Pioneering experiments having realised bosonic [1, 2] and fermionic [3] polarons, as well as the trapping of one matter-wave inside another [4]. Complementary to this, the ability to prepare condensates in box potentials facilitates a route to studying uniform quantum gases – a situation that offers an opportunity to study textbook superfluidity in a clean and precise way both close to and away from equilibrium.

We consider a bosonic two-component mass-imbalanced system where only the first component is condensed, while the second feels the superfluid as an effective potential [5]. We study how impurity atoms can be trapped and manipulated in individual and vortex pairs. Changing the number of atoms in the individual components causes distorted vortex profiles and a mass-dependent splitting of the impurities energy. Computing the excited states of the impurity reveals effects analogous to chemistry such as bonding and antibonding states as well as spectral level crossings. Our work provides a route to simulating synthetic chemical reactions with superfluid systems [6].

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