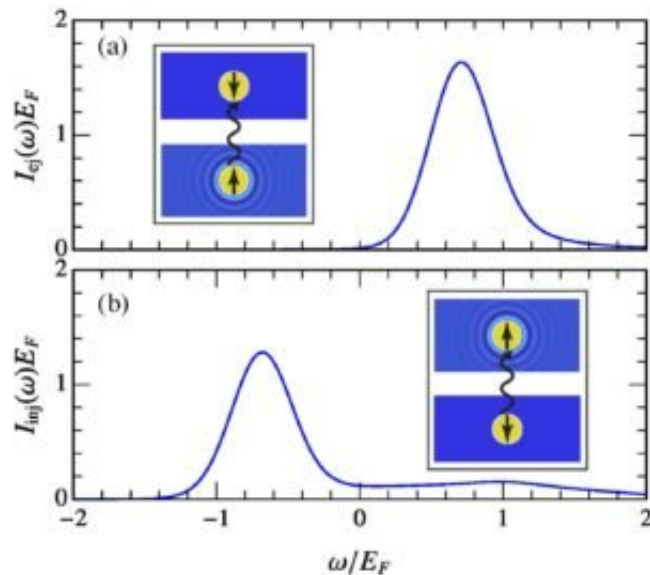


Temperature evolution of impurities in a quantum gas

October 14 2020



'Push' and 'pull': Impurity ejection (a) and injection (b) spectra in a quantum-gas experiment. An RF field drives a transition between the interacting (\uparrow) and noninteracting (\downarrow) impurity spin states. Credit: ARC Centre of Excellence in Future Low-Energy Electronics Technologies

A new, Monash-led theoretical study advances our understanding of its role in thermodynamics in the quantum impurity problem.

Quantum [impurity](#) theory studies the behavior of deliberately introduced atoms (ie, 'impurities') that behave as particularly 'clean' quasiparticles within a background atomic gas, allowing a controllable 'perfect test bed'

study of quantum correlations.

The study extends quantum impurity theory, which is of significant interest to the quantum-matter research community, into a new dimension—the thermal effect.

"We have discovered a general relationship between two distinct experimental protocols, namely ejection and injection radio-frequency spectroscopy, where prior to our work no such relationship was known." explains lead author Dr. Weizhe Liu (Monash University School of Physics and Astronomy).

Quantum Impurity Theory

Quantum impurity theory studies the effects of introducing atoms of one element (ie, 'impurities') into an ultracold atomic gas of another element.

For example, a small number of potassium atoms can be introduced into a 'background' quantum gas of lithium atoms.

The introduced impurities (in this case, the potassium atoms) behave as a particularly 'clean' quasiparticle within the atomic gas.

Interactions between the introduced impurity atoms and the background [atomic gas](#) can be 'tuned' via an [external magnetic field](#), allowing investigation of quantum correlations.

In recent years there has been an explosion of studies on the subject of quantum impurities immersed in different background mediums, thanks to their controllable realization in ultracold atomic gases.

Modeling 'Push' And 'Pull' With Radio-Frequency

Pulses

"Our study is based on radio-frequency spectroscopy, modeling two different scenarios: ejection and injection," says Dr. Weizhe Liu, who is a Research Fellow with FLEET, FLEET working in the group of A/Prof Meera Parish and Dr. Jesper Levinsen.

The team modeled the effect of radio-frequency pulses that would force impurity [atoms](#) from one [spin state](#) into another, unoccupied spin state.

- Under the 'ejection' scenario, radio-frequency pulses act on impurities in a spin state that strongly interact with the background medium, 'pushing' those impurities into a non-interacting spin state.
- The inverse 'injection' scenario 'pulls' impurities from a non-interacting state into an interacting state.

These two spectroscopies are commonly used separately, to study distinctive aspects of the quantum impurity problem.

Instead, the new Monash study shows that the ejection and injection protocols probe the same information.

"We found that the two scenarios—ejection and injection—are related to each other by an exponential function of the free-energy difference between the interacting and noninteracting impurity states," says Dr. Liu.

More information: Weizhe Edward Liu et al, Theory of radio-frequency spectroscopy of impurities in quantum gases, *Physical Review A* (2020). [DOI: 10.1103/PhysRevA.102.023304](https://doi.org/10.1103/PhysRevA.102.023304)

Provided by ARC Centre of Excellence in Future Low-Energy
Electronics Technologies

Citation: Temperature evolution of impurities in a quantum gas (2020, October 14) retrieved 24
April 2024 from

<https://phys.org/news/2020-10-temperature-evolution-impurities-quantum-gas.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.