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Universal induced interaction between heavy polarons in superfluids —Effective field theory approach to polaron physics—

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The force between particles is one of the most elementary concepts from condensed-matter physics to high-energy physics. Not only the fundamental interaction mediated by gauge bosons but also the induced interaction between quasiparticles plays an essential role in modern physics.
Recently, impurities in superfluids, called polarons, have been attracting much attention in ultracold atom physics. In particular, thanks to the high experimental controllability of ultracold atoms, induced interactions between two polarons of ultracold atoms are an appealing topic with the potential to be confirmed experimentally.

In this work, we investigate the long-range behavior of the induced interaction between two spinless heavy impurities in a superfluid. With the help of an effective field theory, we show that the induced interaction universally exhibits power-law behaviors at both zero and finite temperatures and that the magnitude of the potential depends on the medium properties only through the speed of sound [1]. Our formulation provides a new approach to polaron physics using effective field theory and is valid regardless of the interaction strength between the medium particles. We apply our results to the fermionic superfluid showing the BCS-BEC crossover and evaluate the magnitude of the obtained potential using experimental data of the sound velocity.

Our results, understood as a phonon-mediated Casimir force, provide new insights not only as polaron physics in ultracold atomic systems but also as induced forces in symmetry-breaking phases.

[1] K. Fujii, M. Hongo, and T. Enss, "Universal van der Waals force between heavy polarons in superfluids," arXiv:2206.01048 (2022).

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