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Bose and Fermi Polarons in Atom —Ion Hybrid Systems

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Charged quasiparticles dressed by the low excitations of an electron gas constitute one of the fundamental pillars for understanding quantum many-body effects in some materials. Quantum simulation of quasiparticles arising from atom-ion hybrid systems may shed light on solid-state uncharted regimes. Here, we will discuss ionic polarons created as a result of charged dopants interacting with a Bose-Einstein condensate [1,2] and a polarized Fermi gas [3]. Here, we show that even in a comparatively simple setup consisting of charged impurities in a weakly interacting bosonic medium and an ideal Fermi gas with tunable atom-ion scattering length, the competition of length scales gives rise to a highly correlated mesoscopic state in the bosonic case; in contrast, a molecular state appears in the Fermi case. We unravel their vastly different polaronic properties compared to neutral quantum impurities using quantum Monte Carlo simulations. Contrary to the case of neutral impurities, ionic polarons can bind many excitations, forming a nontrivial interplay between few and many-body physics, radically changing the ground-state properties of the polaron.

[1] Astrakharchik, G.E., LAPA, Schmidt, R. et al. Ionic polaron in a Bose-Einstein condensate. Commun Phys 4, 94 (2021).

[2]. Astrakharchik, G.E., LAPA., Jachymski, K. et al. Many-body bound states and induced interactions of charged impurities in a bosonic bath. Nat Commun 14, 1647 (2023).

[3] R.Pessoa, S. A Vitiello, LAPA. Fermi polaron in atom-ion hybrid systems. ArXiv:2401.05324 (2024).

Title

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