Orthogonality Catastrophe in Quantum Sticking

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(Dated: February 15, 2012)

Abstract

Atom-surface collisions are one of the most powerful diagnostic tools in surface science. As a result of progress in cryogenics, cold atom-surface collisions have given surface scientists new opportunities to investigate the subtle and exotic quantum interference and quantum many-body effects. A thorough understanding of cold atom-surface collisions will benefit new technologies, including atomic clocks, matter-wave interferometers, atom chips and other quantum information processing devices. In cold atom-surface collisions, how the probability that an atom will stick to a surface at low energies is a central question under debate. A prediction based on quantum perturbation theory from 1930s has seemingly passed the experimental tests. We reexamine this prediction by including many-body effects non-perturbatively. Using mean field variational ansatz, we find new threshold laws of quantum sticking for both neutral and charged atoms colliding with surfaces for a certain class of interactions that commonly occur. We find for surfaces above a critical temperature, the sticking probability abruptly vanishes. This "superreflective" transition is a result of Anderson's orthogonality catastrophe. We provide a numerical example to demonstrate that the new threshold laws and the phase transitions are experimental accessible. The new discoveries have applications to atomic "micro-traps" where ultra-cold atoms are confined above the surface of an atom chip.

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