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RF spectra of lattice bosons: a probe of correlations, fluctuations, and quantum criticality

KADEN HAZZARD, Cornell University

We present a quantitative analysis of RF spectra of bosons in an optical lattice. We show that such spectra are an extremely powerful probe. Starting from an analysis of the 87Rb experiments of Campbell et al. [Science 313, p649 (2006)] we give a detailed description of what one learns from RF spectroscopy. In a system like 87Rb, where the clock shift is extremely small, the spectra give a histogram of the density and can be used to detect Mott shells. In a more strongly interacting system the spectra become more complicated – for example even a homogeneous superfluid sufficiently close to the superfluid-Mott phase transition will present a bimodal spectrum. We give a physical picture of this bimodality, and show how it is indicative of the correlations which develop in the gas as it approaches the phase transition. These two limiting behaviors correspond to those found in two prior theoretical approaches (based on single-particle spectra and sum rules), each of which emerges in some limit of our calculation. We derive the criterion for the crossover between them and provide a physical picture that is likely to generalize to other physical systems. Going beyond this zero-temperature calculation, we discuss finite temperatures, where thermal fluctuations also lead to a bimodal spectrum. Finally, we describe the universal structure of the RF spectra in the quantum critical regime, where both quantum and thermal fluctuations are important.