Nonlinear Luttinger Liquid

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For many years, Luttinger liquid theory has served as a useful paradigm for describing one-dimensional (1D) quantum fluids in the low-energy limit. This theory is based on a linearization of the dispersion relation of the constituent particles. However, beyond the low-energy limit, the nonlinearity of the dispersion relation becomes essential. Newly developed methods are capable of tackling this nonlinearity, thus extending conventional Luttinger liquid theory. This new nonlinear Luttinger liquid theory combines the phenomenology developed in the context of the single-impurity problem in a conventional Luttinger liquid with perturbative Fermi liquid theory. The new theory made it possible to uncover and fully characterize the threshold singularities of various dynamic correlation functions, including the widely used energy- and momentum-resolved dynamic structure factor and spectral function. It can be applied to a wide variety of 1D quantum fluids, from spin liquids to electrons in quantum wires and cold atoms confined by 1D traps. Moreover, nonlinear Luttinger liquid theory shows how dispersion nonlinearity leads to finite lifetimes of excitations in one dimension. The theory has been successfully applied to explain the results of several experiments with quantum wires and has motivated a number of new experiments. The crossover between the low-temperature regime of a generic nonlinear Luttinger liquid and the high-temperature regime described by the KPZ equation remains an open and conceptually important question.