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Probing non local order parameters in highly correlated Bose insulators

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Ground states of integer spin chains are known since the late 80's to sustain highly non local order described by infinite string operators of the spins. Such states defy the usual Landau theory description and can be considered simple prototypes of topological order. Recently we showed that spinless Bose insulators with nearest neighbor or longer range repulsion in one dimension can exhibit similar string order in terms of the boson density [1]. The tunability of cold atomic systems would allow much more flexibility in probing the non local order than spin systems do. For example the bosons can be tuned across a quantum phase transition between the exotic insulator, which we term Haldane insulator, and the usual Mott insulator. Investigating how the transition responds to external perturbations lends direct access to properties of the string order parameter. I will demonstrate this with several new results obtained from a field theoretic description of the phases and confirmed by numerical calculations using DMRG. Particularly revealing of the unusual character of the string order is the prediction that any external perturbation, which breaks the lattice inversion symmetry, would eliminate the distinction between the Haldane and Mott phases and allow a fully gapped adiabatic connection between them. This is remarkable given that neither phase involves spontaneous breaking of lattice inversion symmetry. We also predict that inter-chain tunneling destroys the direct phase transition between the two insulators by establishing an intermediate superfluid phase. Finally I will discuss how the new phases and phase transitions may be realized and probed in actual experiments with ultra cold atoms or polar molecules.

[1] E. G. Dalla Torre, E. Berg and E. Altman, Phys. Rev. Lett. 97, 260401 (2006)