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Thermal Inclusions; Or, How a Central Spin can Destroy the Many-body Localized Phase

Many-body localized (MBL) systems lie outside the framework of statistical mechanics as they fail to equilibrate under their own quantum dynamics. Even basic features of MBL systems such as their stability to thermal inclusions and the nature of the dynamical transition to thermalizing behavior remain poorly understood. We study a simple model to address these questions: a two level system interacting with strength J with N >>1 localized bits subject to random fields. On increasing J, the system transitions from a MBL to a delocalized phase on the vanishing scale J_c(N) ~ 1/N up to logarithmic corrections. In the transition region, the single-site eigenstate entanglement entropies exhibit bi-modal distributions, so that localized bits are either "on" (strongly entangled) or "off" (weakly entangled) in eigenstates. The clusters of "on" bits vary significantly between eigenstates of the same sample, which provides evidence for a heterogenous discontinuous transition out of the localized phase in single-site observables. We obtain these results by perturbative mapping to bond percolation on the hypercube at small J and by numerical exact diagonalization of the full many-body system. Our results imply the MBL phase is unstable in systems with short-range interactions and quenched randomness in dimensions d that are high but finite.
