Many-body localization of bosons in optical lattices

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This contribution is based mainly on [1]. Many-body localization for a system of bosons trapped in a one dimensional lattice is discussed. Two models that may be realized for cold atoms in optical lattices are considered. The first one is Bose–Hubbard model with a random on–site potential

$$H = -J\sum_{\langle i,j\rangle}\hat{a}_i^\dagger\hat{a}_j + \frac{U}{2}\sum_i \hat{n}_i(\hat{n}_i-1) + \sum_i \mu_i\hat{n}_i \tag{1}$$

where $a_i^\dagger$ and a_i are operators creating and annihilating boson at site i of the lattice, J and U are respectively tunneling amplitude and interaction strength and μ_i is a random on–site potential distributed uniformly in interval $[-W,W]$. The model (1) is compared with random interactions model [2-3]

$$H = -J\sum_{\langle i,j\rangle}\hat{a}_i^\dagger\hat{a}_j + \frac{1}{2}\sum_i U_i\hat{n}_i(\hat{n}_i-1) \tag{2}$$

where $U_i \in [0,U]$ is random interaction strength. While the origin and character of the disorder in both systems is different they show interesting similar properties. In particular, many-body localization appears for a sufficiently large disorder strengths W and U as verified by a time evolution of initial density wave states as well as using statistical properties of energy levels for small system sizes. Starting with different initial states, we observe that the localization properties are energy-dependent which reveals an inverted many-body localization edge in both systems – that finding is also verified by statistical analysis of energy spectrum – see Fig. 1. Moreover, we consider computationally challenging regime of transition between many body localized and extended phases where we observe a characteristic algebraic decay of density correlations which may be attributed to subdiffusion (and Griffiths-like regions) in the studied systems. Ergodicity breaking in the disordered Bose-Hubbard models is compared with the slowing-down of the time evolution of the clean system at large interactions.

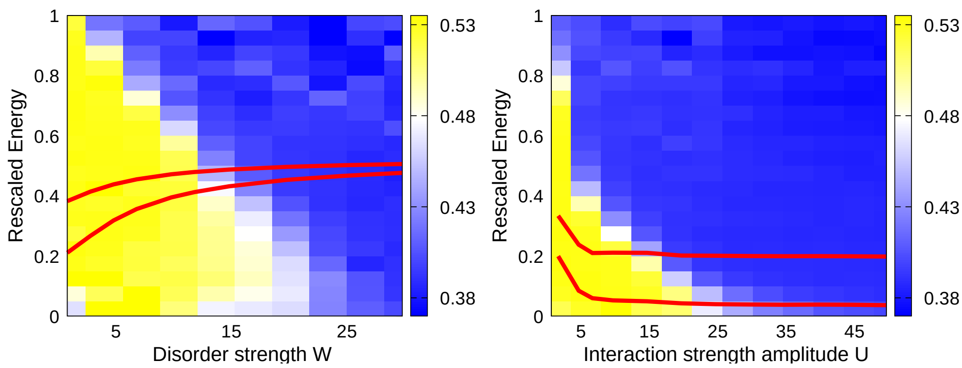

Fig. 1: The mean gap ratio $\bar{r}$ in the plane of disorder strength (W or U depending on the model) and the relative position in the spectrum of the system ε with $N = 12$ bosons on $L = 8$ sites. Left panel – random chemical potential for $U = 1$; right panel – the random interactions case. Yellow color corresponds to $\bar{r} \approx 0.53$ and to the ergodic regime, whereas the blue color denotes $\bar{r}$ characteristic for localized states. Red curves indicate energies of the density wave states $|2121...\rangle$ and $|3030...\rangle$ which are studied in the context of their localization properties. Observe that both systems are characterized by an inverted mobility edge – a feature characteristic for bosonic systems.

References

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