Dynamical properties of Many-body localized phase

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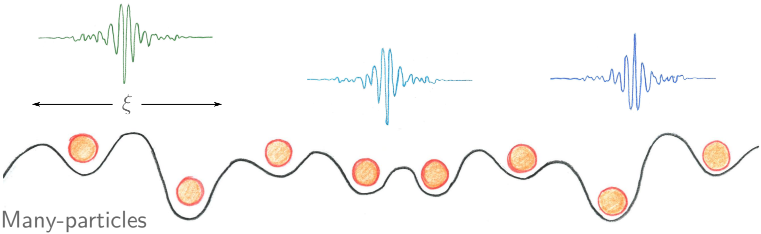
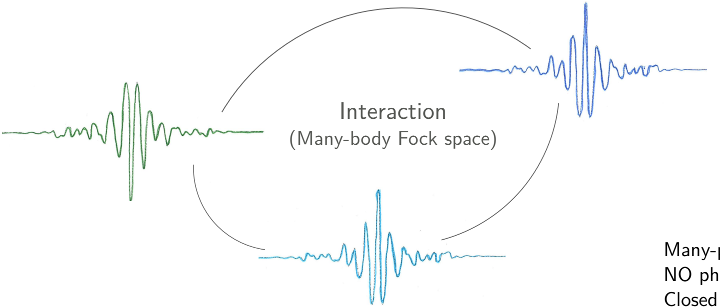
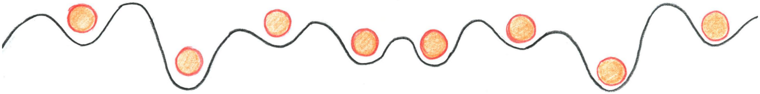
PRB 100, 104204 (2019)
(+ in preparation)



Fate of the Anderson insulator in the presence of electron-electron interaction



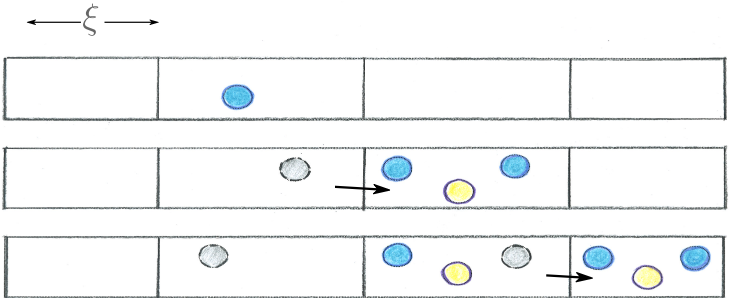
Many-particles
NO phonons
Closed q-system

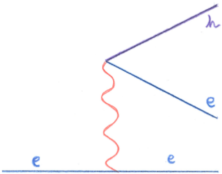


$$\mathcal{H} = \sum_{\alpha} \xi_\alpha c^\dagger_\alpha c_\alpha + \sum_{\alpha\beta\gamma\delta} V_{\alpha\beta\gamma\delta} c^\dagger_\alpha c^\dagger_\beta c_\gamma c_\delta$$

Basko, Aleiner, Altshuler Ann. Phys. 2006,
Gornyi, Polyakov, Mirlin PRL, 2005.

Ballistic strings leads to delocalization in Fock space

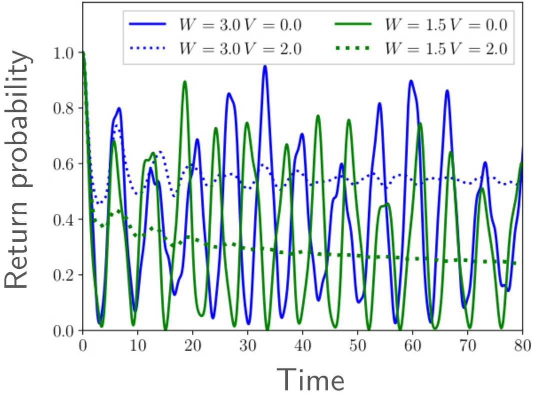




Primary inelastic process

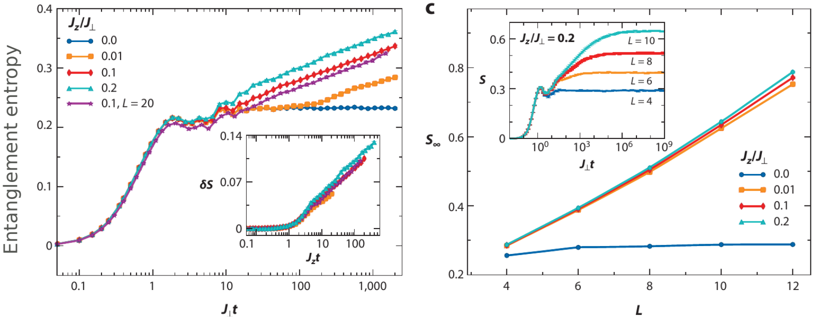
Basko, Aleiner, Altshuler Ann. Phys. 2006,
Gornyi, Polyakov, Mirlin PRL, 2005.

Dephasing washes out mesoscopic fluctuations, still MBL is robust.



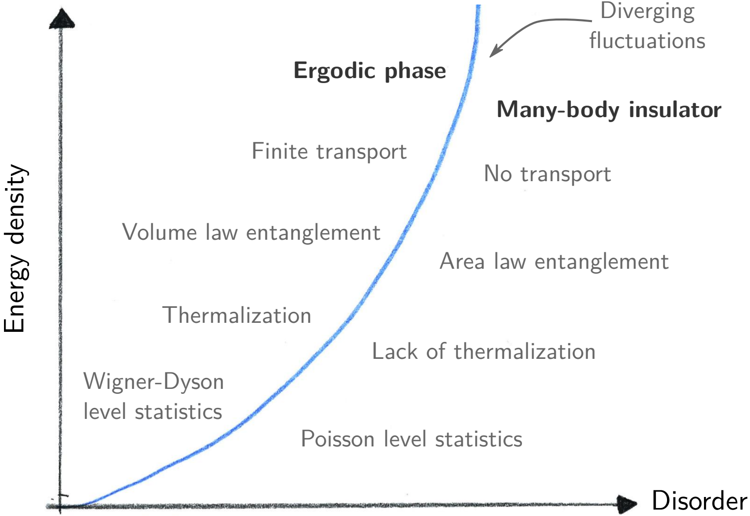
Weiner et. al., PRB '19

Logarithmic growth of entanglement due to interaction induced dephasing



Bardarson, Pollmann, Moore, PRL, '12.
+ many others.

Presence of mobility edge in the many-body energy spectrum



Basko et al, Ann. Phys. '06, Gornyi et al., PRL '05, Oganesyan, Huse PRB 2007, Bauer et al, JSM 2013, Kjaell et al.,PRL 2014, Vosk, Altman, PRL 2013, Serbyn, Papic, Abanin PRL 2013, Huse, Nandkishore PRB 2014, Luitz et al., PRB '15, Bera et al., PRL 2015. ...

Localized phase shows slow propagation of charge

$$H = t\sum_{i=1}^{L}\left[-\frac{1}{2}(c_i^\dagger c_{i+1} + \mathrm{h.c.}) + \epsilon_i\left(n_i - \frac{1}{2}\right) + V\left(n_i - \frac{1}{2}\right)\left(n_{i+1} - \frac{1}{2}\right)\right]$$

$\epsilon_i \to \cos(2\pi\sigma i + \phi)$

$$G^{(2)}(d) = \langle n_i n_{i+d}\rangle - \langle n_{i+d}\rangle\langle n_i\rangle$$

$$\Delta x(t) = \sqrt{G^{(2)}(d,t)d^2} \propto t^{1/2}$$ (diffusion)

Weiner et. al., PRB '19.
Rispoli et. al., Nature '19

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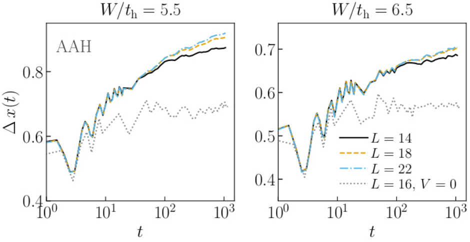

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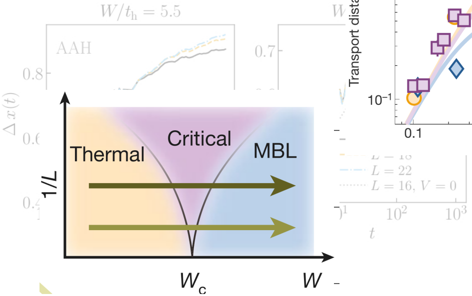
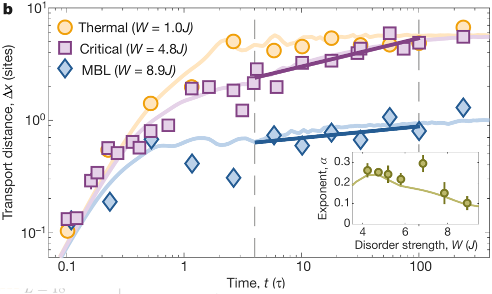




^{87}Rb atoms (12 lattice sites)

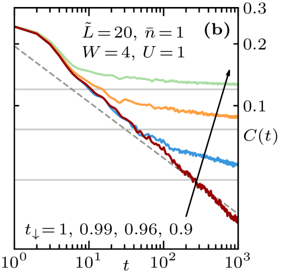
Weiner et. al., PRB '19.
Rispoli et. al., Nature '19

Presence of symmetries give rise to new features in MBL

(or even can destroy MBL)

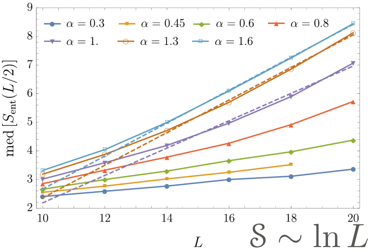
SU(2) symmetric Hubbard model

$$\mathcal{H}_0 = -\sum_{i,\sigma} t_\sigma c_{i\sigma}^\dagger c_{i+1\sigma} + \mathrm{h.c.} + \epsilon_i (n_{i\uparrow} + n_{i\downarrow})$$ + Hubbard U



Spin dynamics subdiffusive, charge localized

Sroda et. al., PRB '19.



SU(2) implies anomalous thermalization

Protopopov et. al., PRB '17, '18, arXiv: 1902.09236.

Particle hole symmetric model and Dyson singularity, quasi-localized states

Random XX chain:

$$\mathcal{H} = \sum_i J_i(\sigma_i^x \sigma_{i+1}^x + \sigma_i^y \sigma_{i+1}^y)$$

Real hopping, time reversal symmetric model: $\mathcal{T}^2 = 1$

Particle-hole symmetry: $\mathcal{C}^2 = 1$, where: $\mathcal{C} = \mathcal{T}\tau_z$

sub-lattice symmetry
acts on even-odd subspace

Operation wise: $\mathcal{C}\mathcal{H}\mathcal{C}^{-1} = -\mathcal{H}$, where: $\mathcal{C} = \prod_i \sigma_i^x$

Dyson '53, Evers, Mirlin RMP, 08.

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Vosk, Altman, PRL '13,
Huang, Moore, PRB '14,
Detomasi et. al., PRB '16.

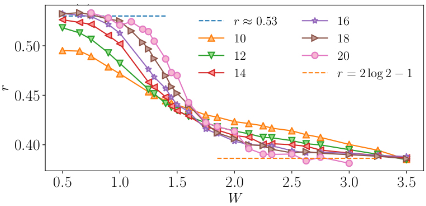
Consequences:

Diverging density of states: $\varrho \sim 1/E \log^3 E$ as $E \to 0$

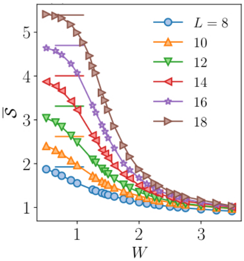
Zero energy states are quasi-localized : $\xi_L(E=0) \sim \sqrt{L}$

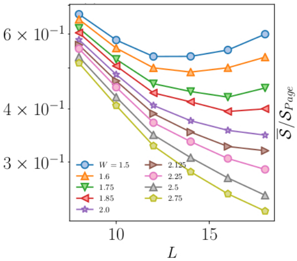
At higher energy density-- 'Quantum Critical Glass' $\mathcal{S} \sim \log\log(t)$

Sub-thermal bipartite entanglement instead of Area law



Poisson statisics with usual caveat of slow flow !

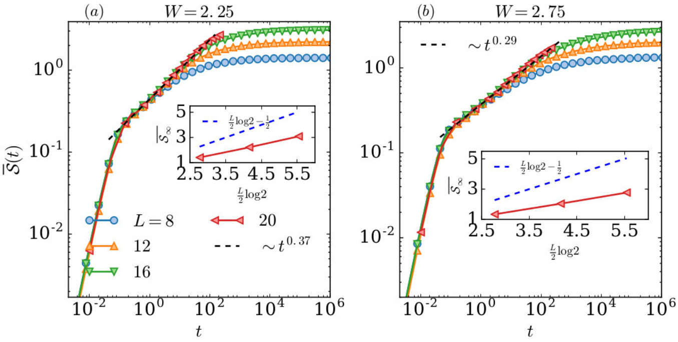




Eigenstate entanglement does not show area law.

R Vasseur et. al., PRB '16.
Bera et. al., in preparation.

PH symmetric MBL shows power law entanglement growth and slow charge dynamics



Bera et. al., in preparation.

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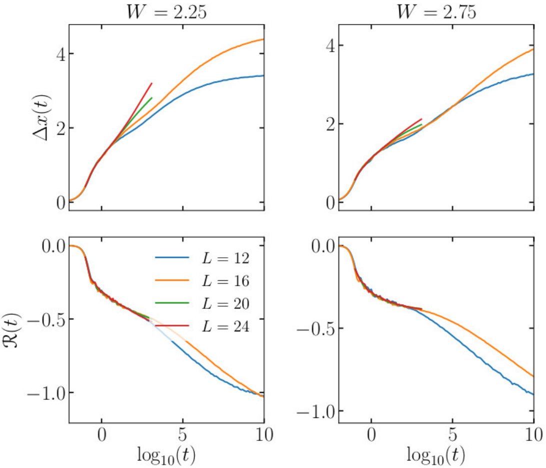


Bera et. al., in preparation.

PH symmetry gives rise to hopping dynamics in the two particle sub-space

Anderson basis Hamiltonian:

$$\mathcal{H} = \sum_l \epsilon_l f_l^\dagger f_l + \sum_{mnpq} \mathcal{B}_{mnpq} f_m^\dagger f_n f_p^\dagger f_q$$

Particle-hole symmetry implies:

$$\epsilon_{-k} = -\epsilon_k \qquad \varphi(i)_{-k} = (-1)^i \varphi_k(i)$$

$$|\varphi(i)_{\text{-}k}|^2 = |\varphi_k(i)|^2 \sim e^{-2\frac{|i-i_0|}{\xi}}$$

(same center of localization)

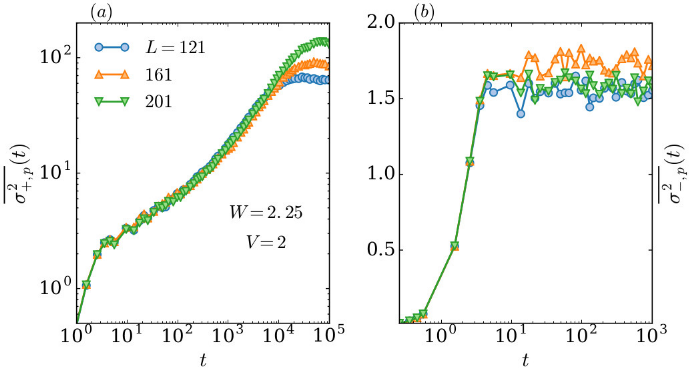
Consider only E=0 states, bound particles hopping:

$$f_k^\dagger f_{\text{-}k}^\dagger |0\rangle \rightarrow c_0^\dagger c_1^\dagger |0\rangle$$

$$\mathcal{H}^{\text{eff.}} = 2V \sum_{p,p'} \tilde{B}_{pp'} f_p^\dagger f_{p'} f_{\text{-}p}^\dagger f_{\text{-}p'}$$

(1st order apprxomiation)

PH symmetry gives rise to hopping dynamics in the two particle sub-space



Bera et. al., in preparation.

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Giuseppe de Tomasi
TU Munich

Felix Weiner
Uni Regensburg

Markus Heyl
MPIPKS, Dresden

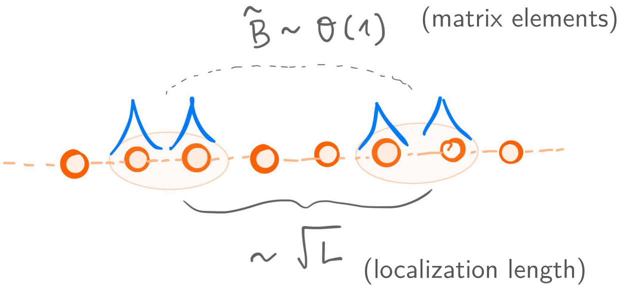
Ramanujan fellowship

Early carrer Award
DST, SERB

mpipks
Partner Group

IRCC IITB

Slow dynamics in particle-hole symmetric many-body localized phase caused by bound pairs



Thank you for your attention