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Metal-insulator transitions in weakly disordered flatbands

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Metal-insulator transition in infinitesimally weakly disordered flatbands

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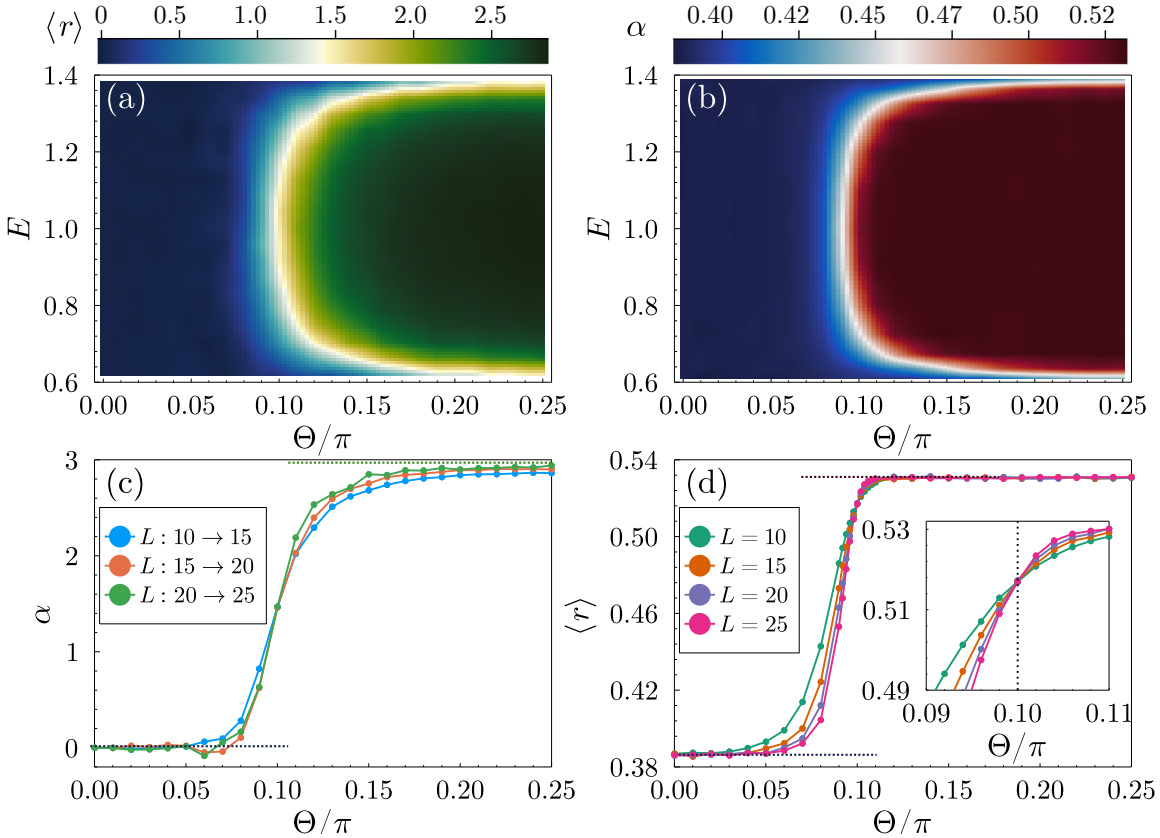
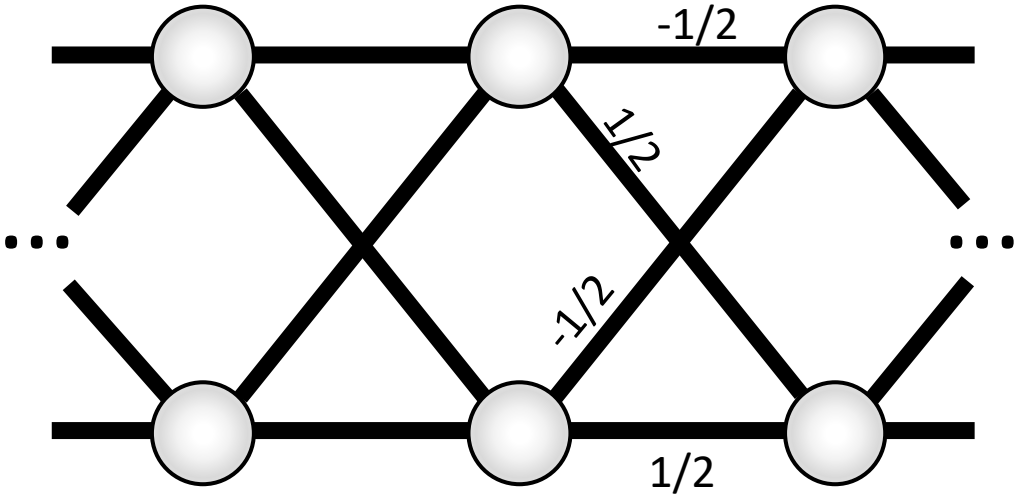


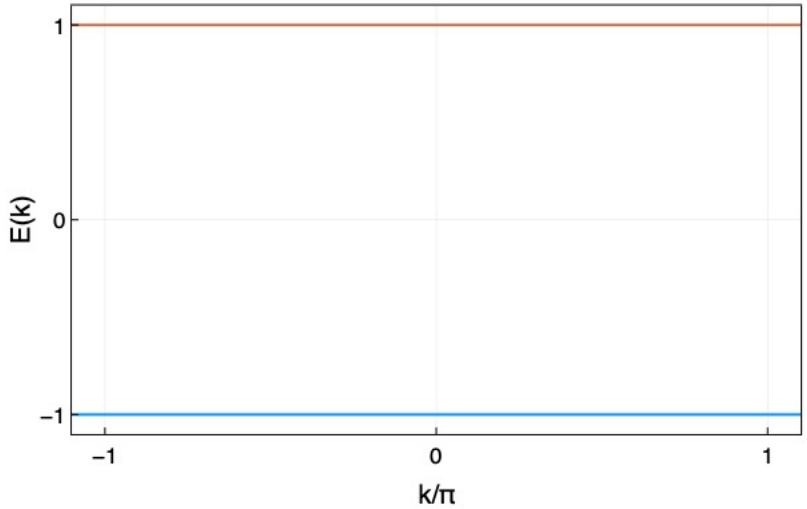
Introduction

All-bands-flat(ABF) lattices

- Infinite effective mass
- Macroscopic degeneracy
- Compact localized states(CLS)
- Highly sensitive to perturbations: disorder, interactions

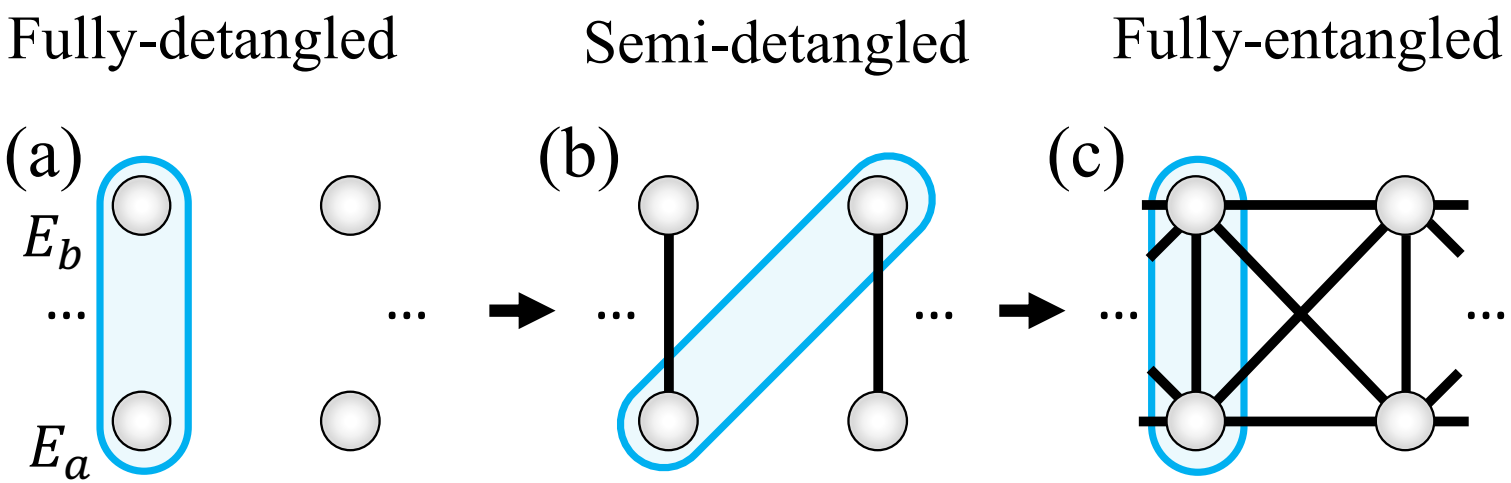


d = 1 ABF lattice



Band structure

Construction of ABF lattice

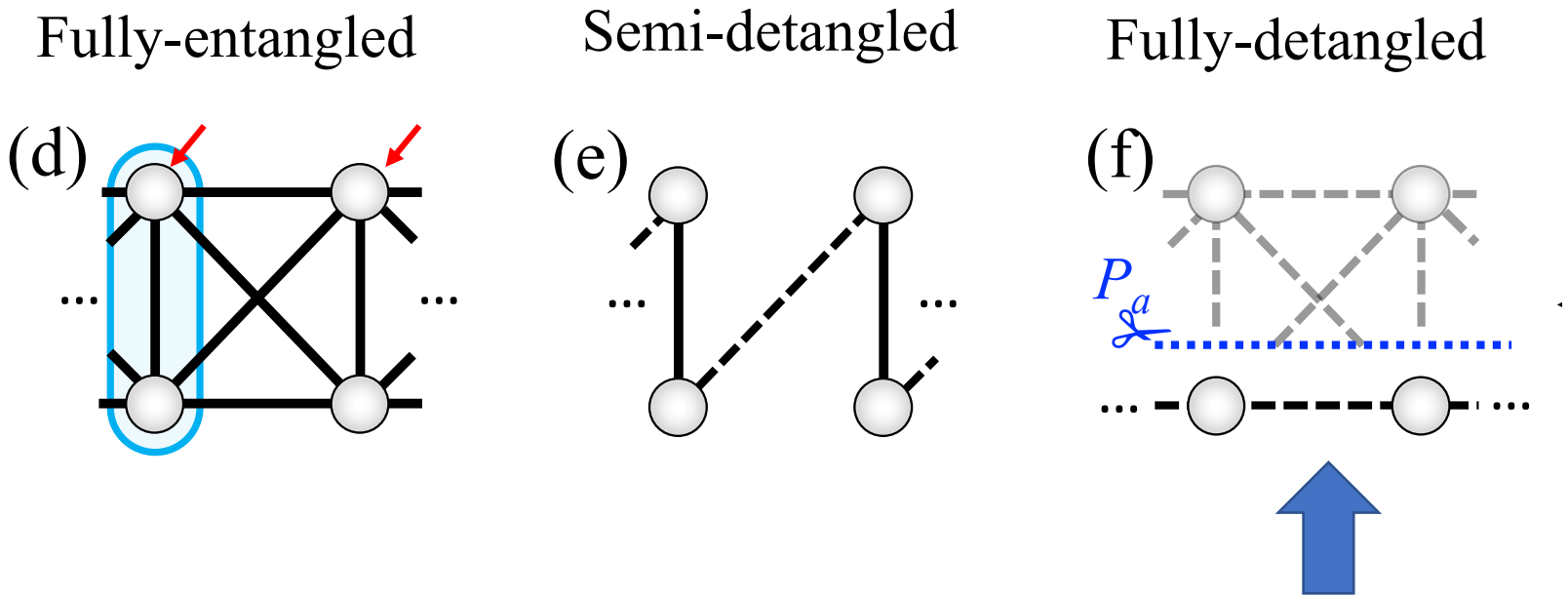


(a) Fully-detangled

$H_{FD} = \sum E_a |a_l\rangle\langle a_l| + E_b |b_l\rangle\langle b_l|$

(c) Fully-entangled $\boldsymbol{H_{FE}}$ $(\boldsymbol{\theta})$

Infinitesimal disorder & projected model



$$\widetilde{H}_{SF} = P_a\left[U^{\dagger}(H_{FE} + WD)U\right]P_a = W\left(\sum \varepsilon_l |l\rangle\langle l| + t_{l+1,l}|l+1\rangle\langle l| + h.c.\right)$$

W is an overall scaling factor of the hamiltonian.

What about other disorders?

(Inifinitesimal)

✓ **Onsite disorder: metal-insulator transition in 3D**

Random potential ϵ

$$\epsilon \in \left[-\frac{W}{2}, \frac{W}{2}\right]$$

$$v \in \left[-\frac{V}{2}, \frac{V}{2}\right]$$

$$u \in \left[-\frac{U}{2}, \frac{U}{2}\right]$$

? Hopping disorder

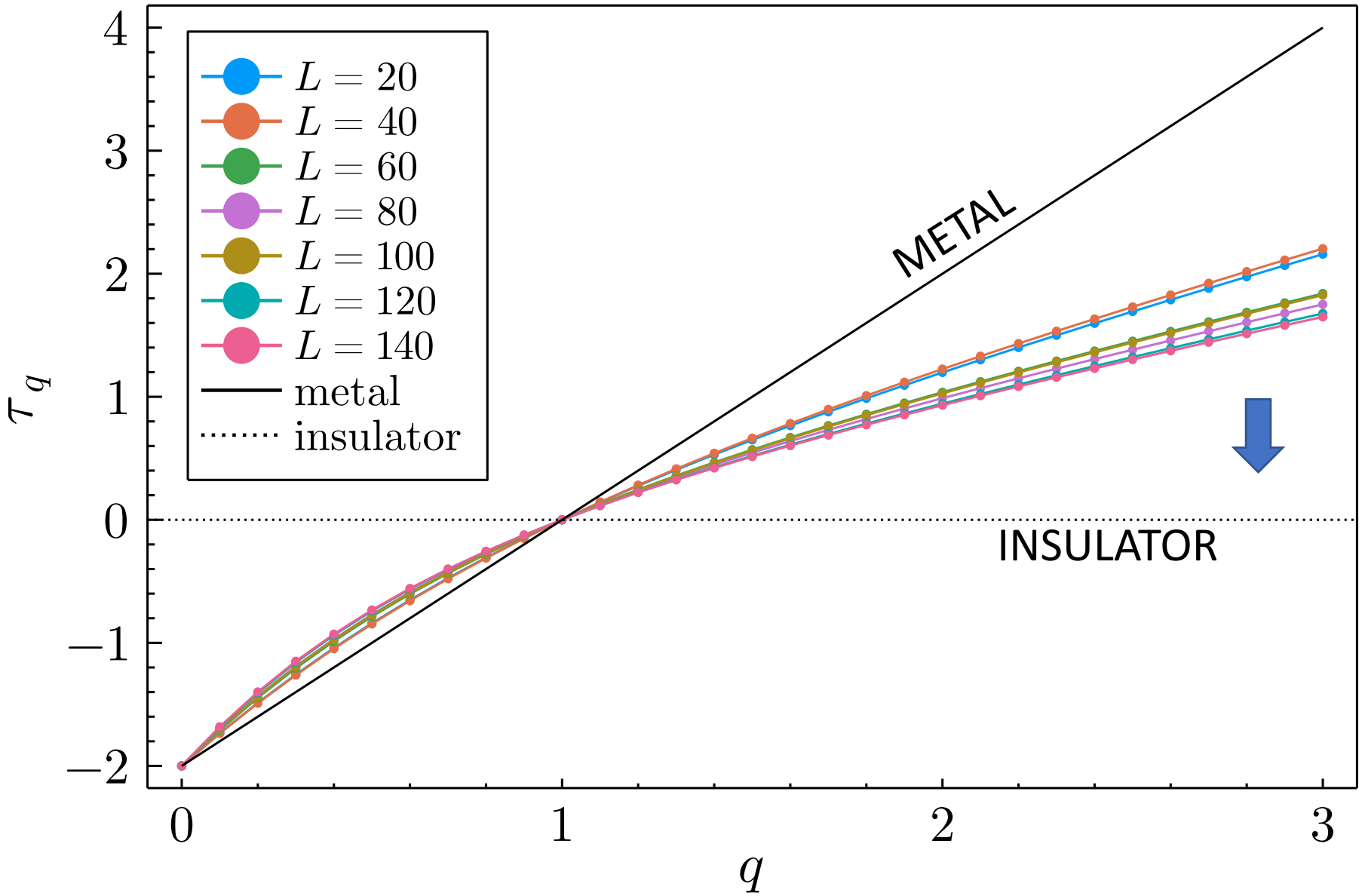
$$\tilde{t} = t + vt$$

? Phase disorder

$$\tilde{t} = te^{ui\phi} \approx t + iut\phi$$

Motivation: Can we get MIT in lower dimension?(d=2)

d = 2, pure onsite disorder



Multifractal analysis

$P_q = \sum |\psi_j|^{2q}$

$P_q \sim L^{-\tau_q}$

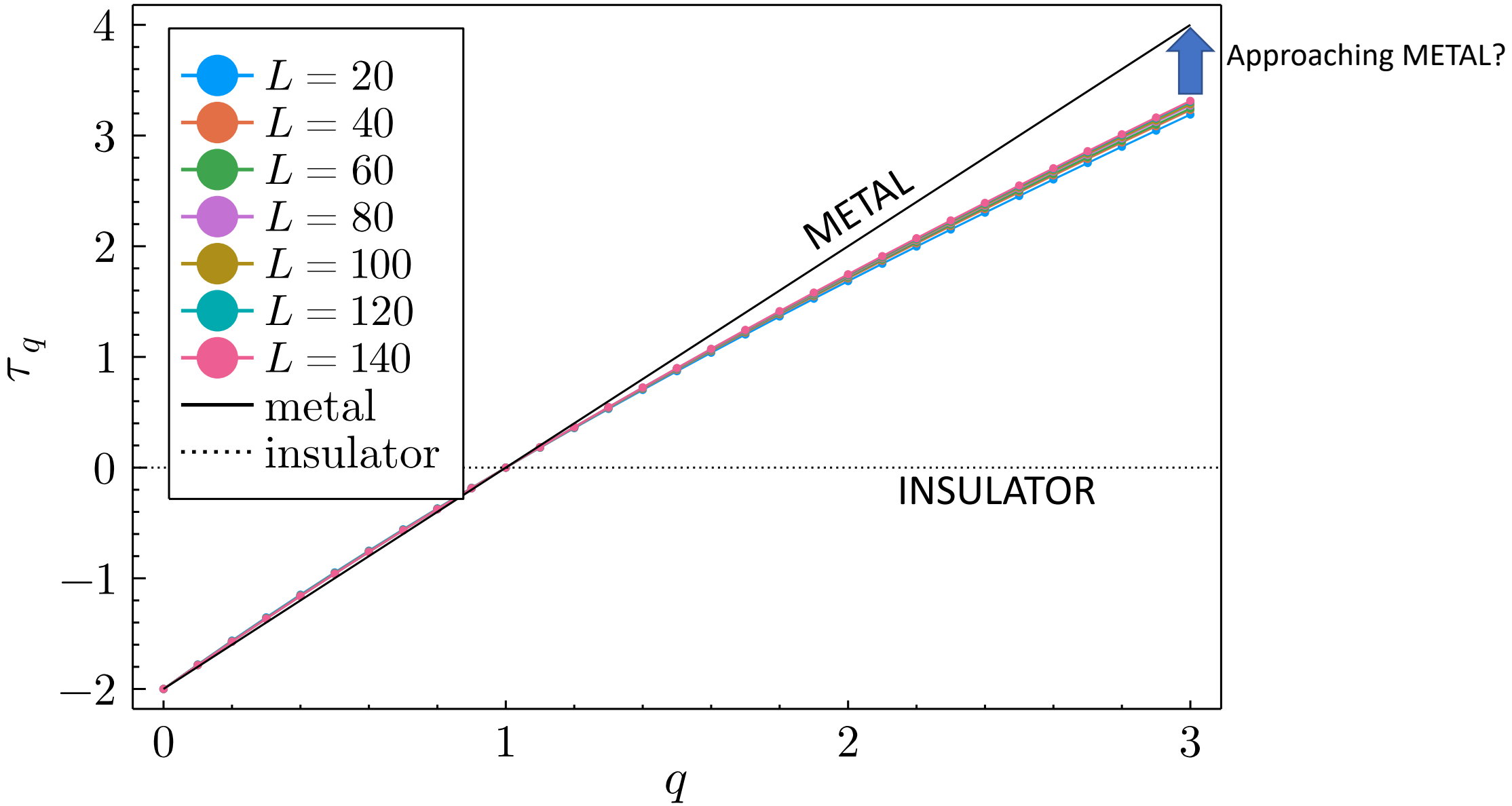
$\mu_q = |\psi_j|^{2q} / P_q$

$\tau_q = \alpha q - f(\alpha)$

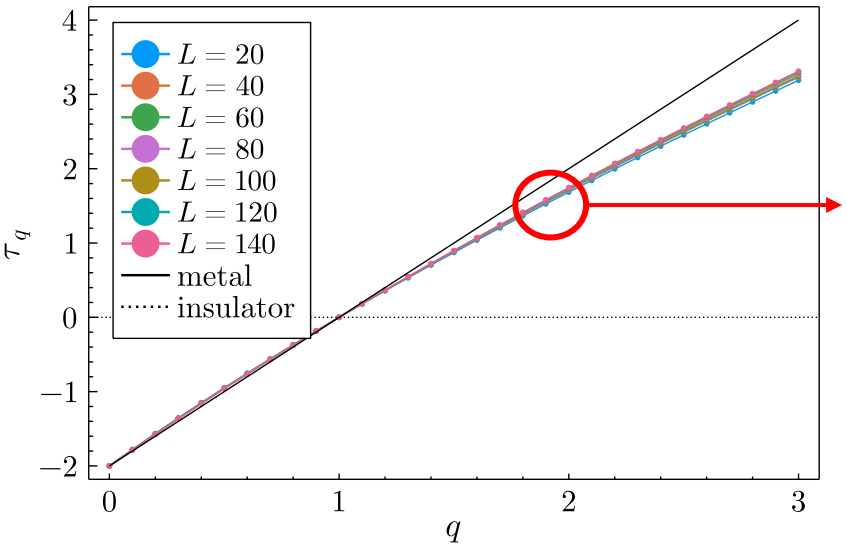
$\alpha(q) = \sum \mu_{qj} \ln |\psi_j|^2 / \ln \epsilon$

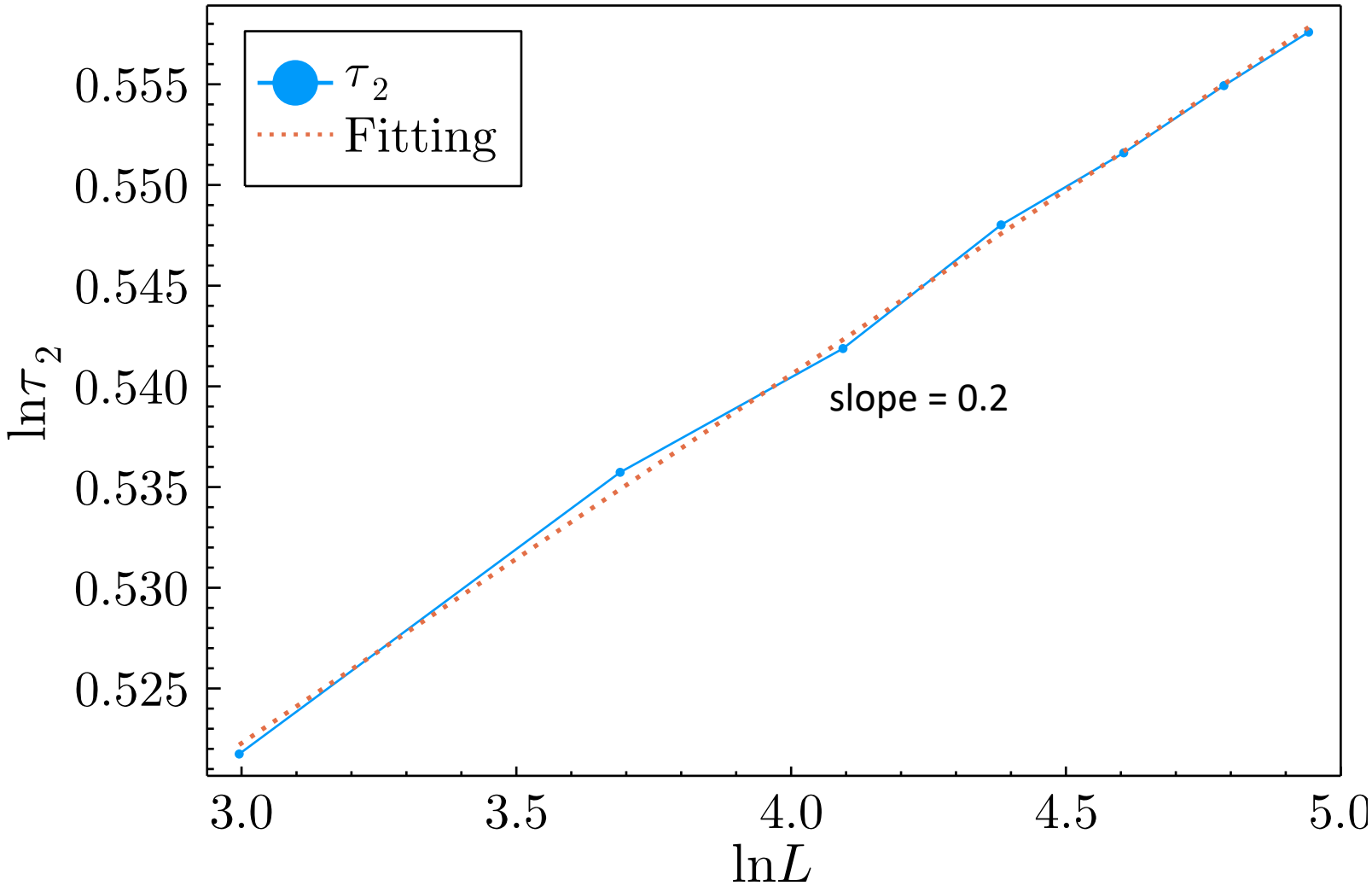
$f(q) = \sum \mu_{qj} \ln \mu_q / \ln \epsilon$

d = 2, pure phase disorder

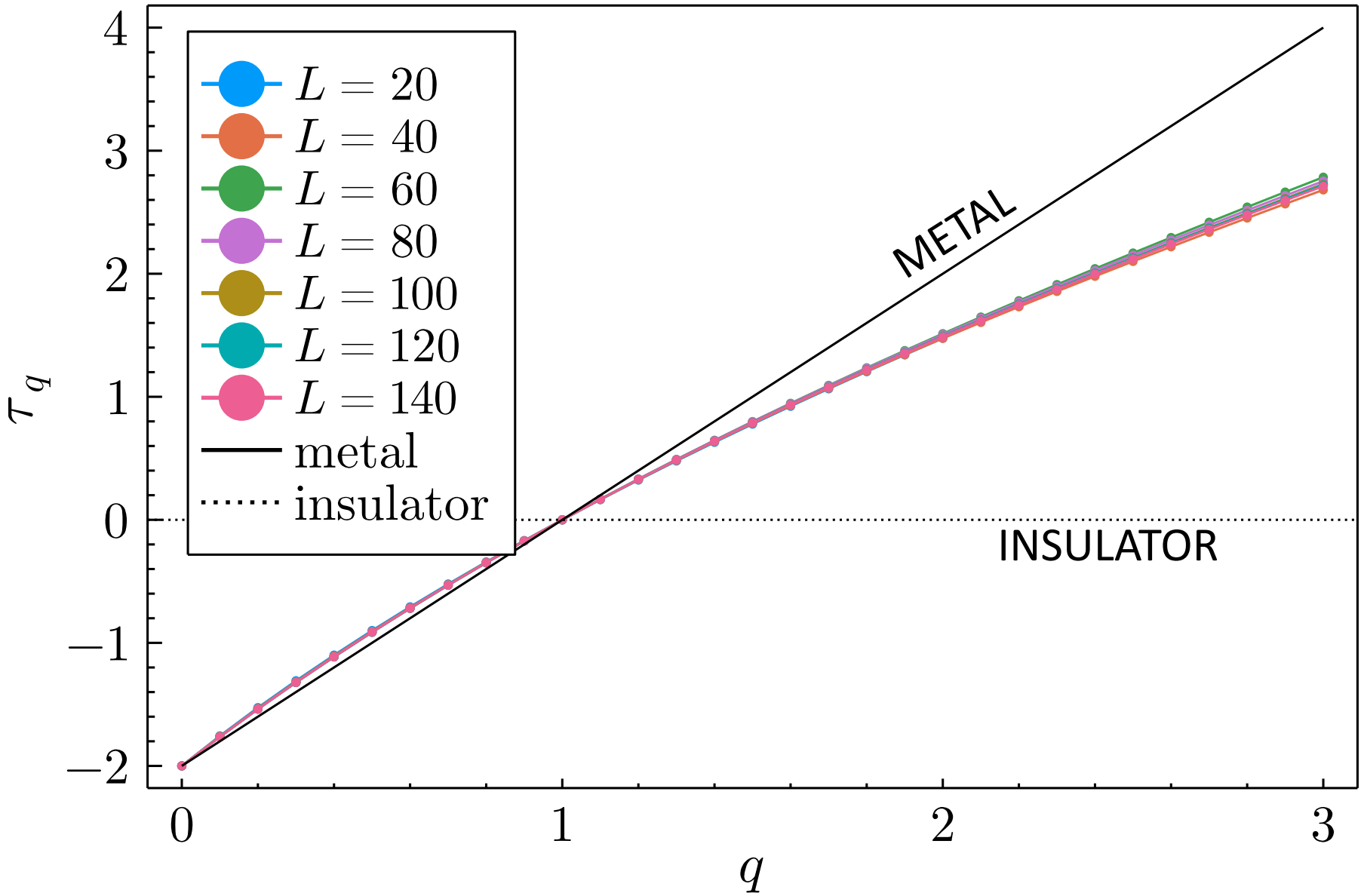


d = 2, pure phase disorder





d = 2, pure hopping disorder



Conclusion

- ABF lattices are systemically constructed and scale free(SF) hamiltonian is derived under weak disorder regime.
- In our presentation, we only focused on d=2 ABF. Three different disorder types are considered. Numerical results might indicate that pure phase disorder might induce metal-insulator transition.
- To resolve this more clearly, careful analysis and simulations on larger system sizes need to be done.

Thanks for your attention

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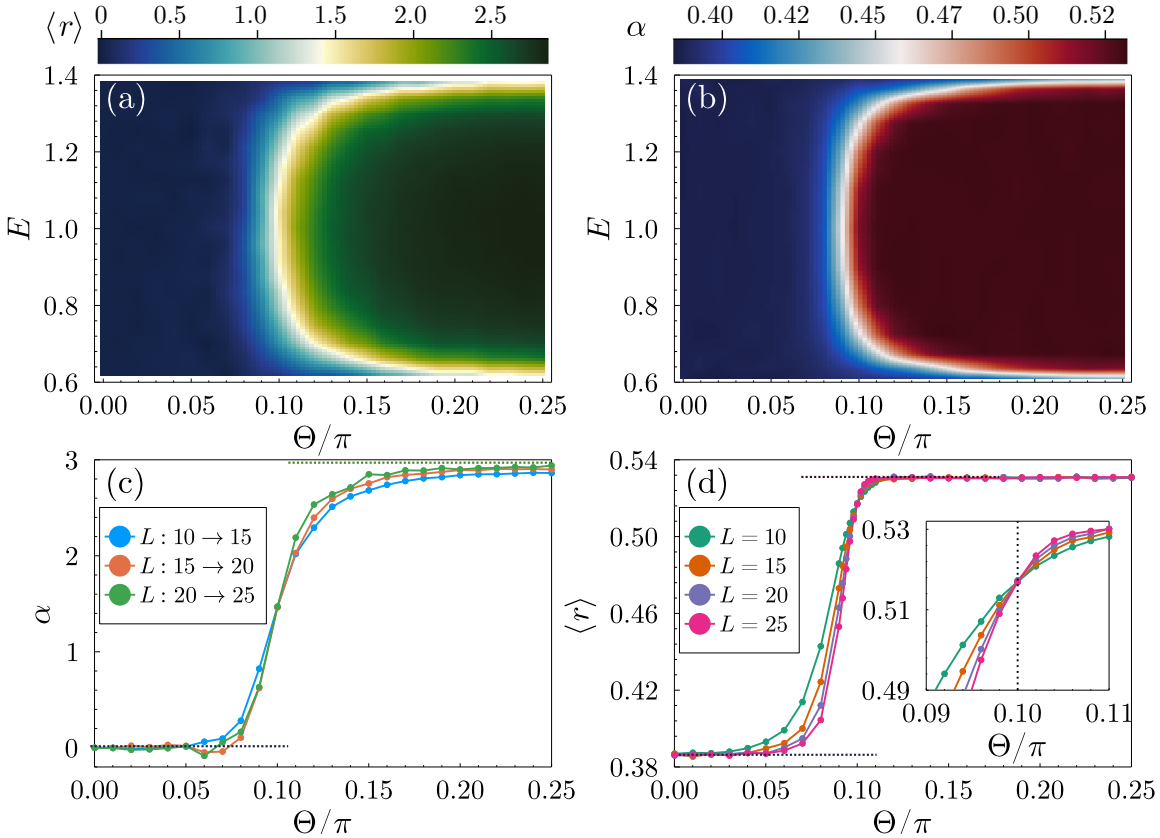
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