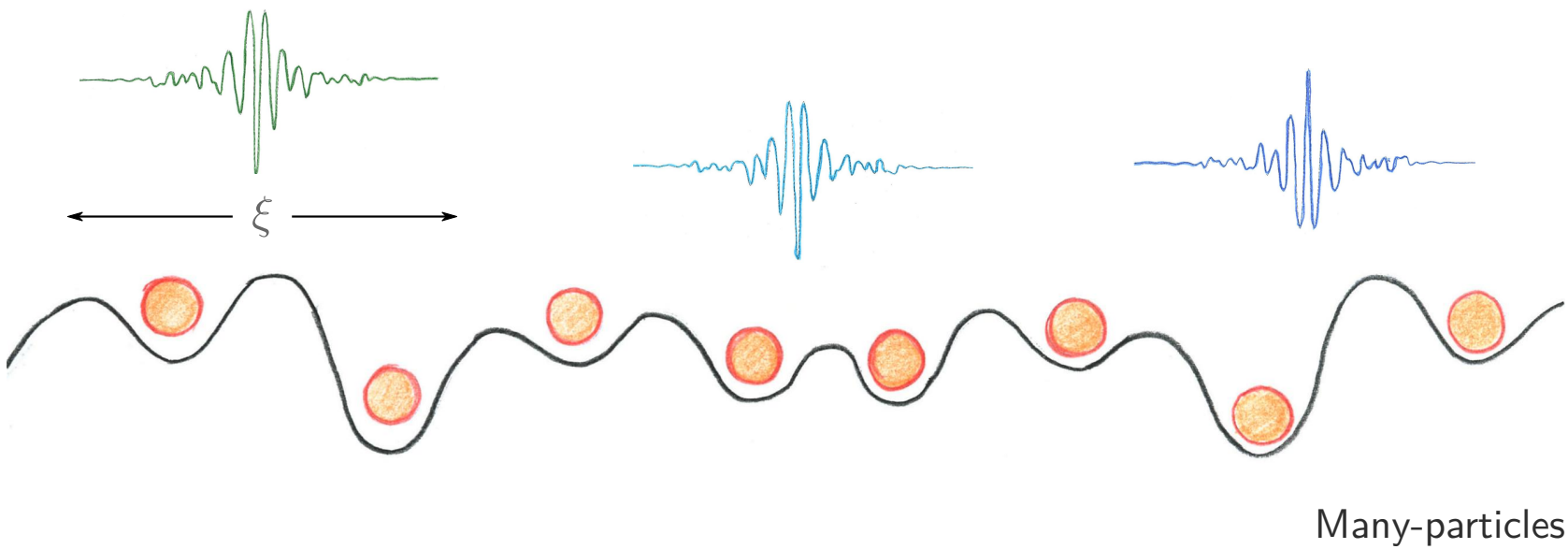
Ergodic side of the many-body de-localization - localization transition

Soumya Bera

IIT Bombay, Mumbai

arXiv:1610.03085



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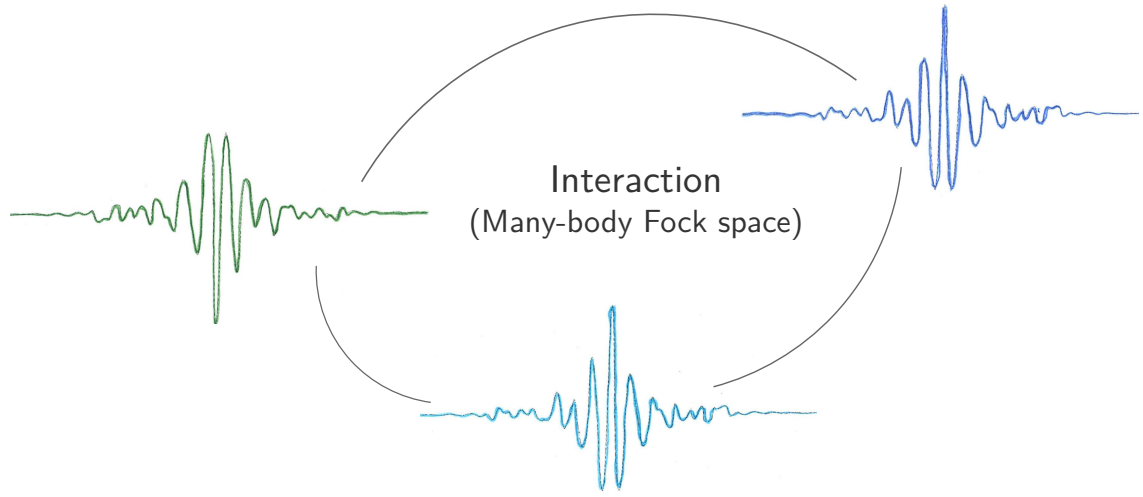
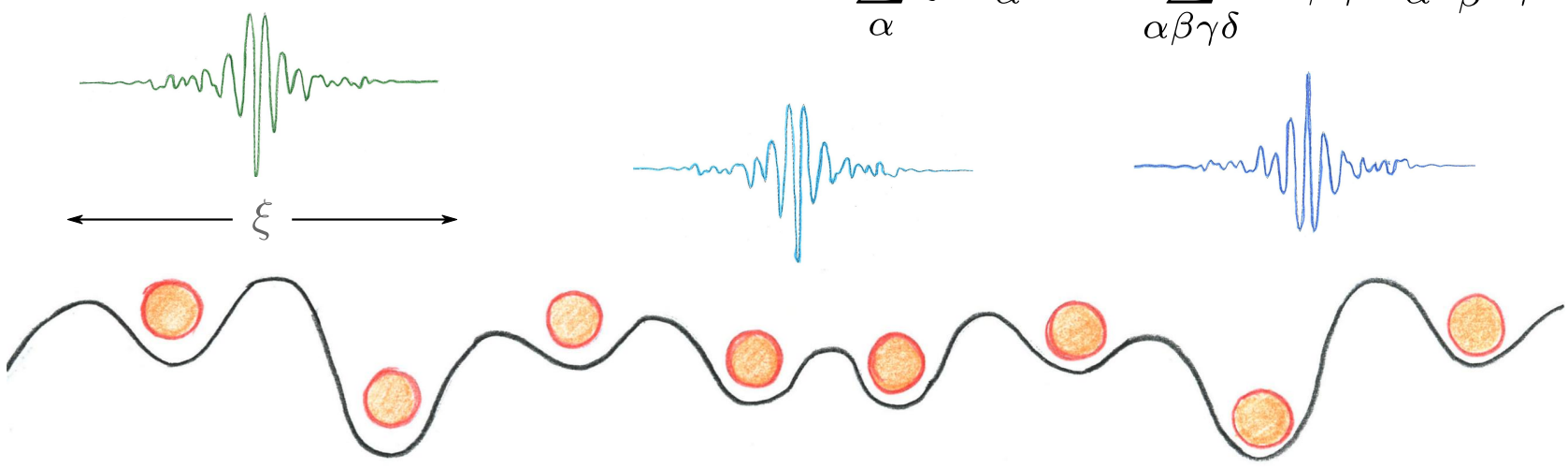
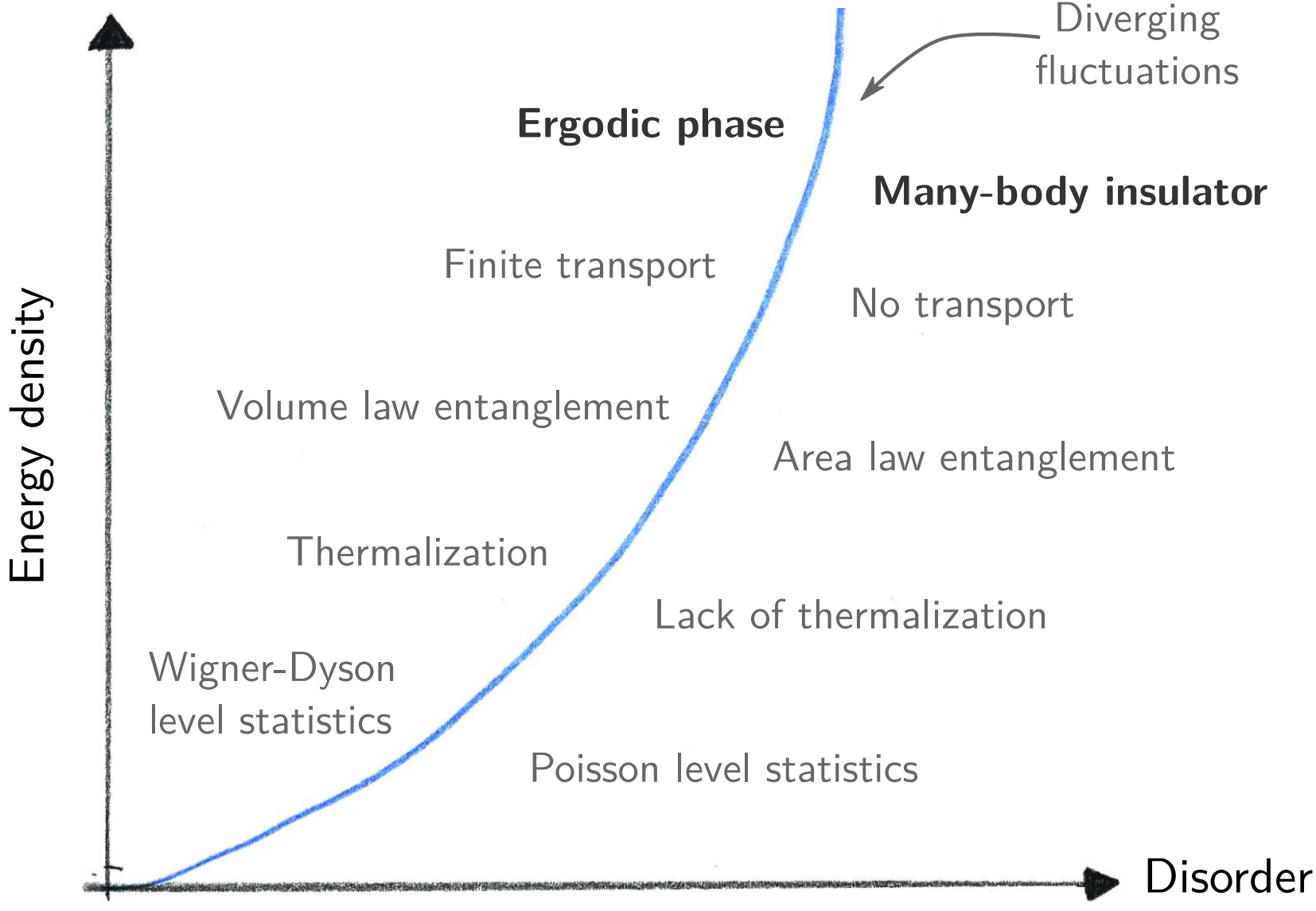


$$\mathcal{H} = \sum_{\alpha} \xi_{\alpha} c_{\alpha}^{\dagger} c_{\alpha} + \sum_{\alpha\beta\gamma\delta} V_{\alpha\beta\gamma\delta} c_{\alpha}^{\dagger} c_{\beta}^{\dagger} c_{\gamma} c_{\delta}$$



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

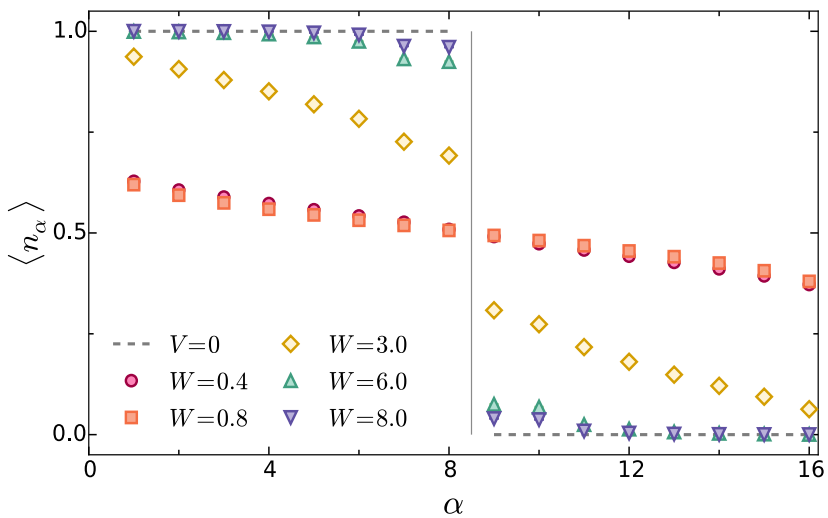
Presence of mobility edge in the many-body energy spectrum



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. ...

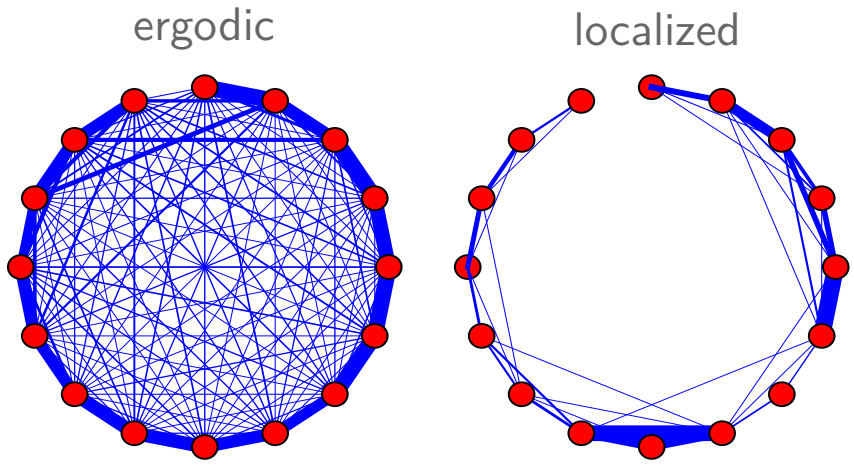
One-body density matrix and mutual information can distinguish extended and localized phases

$$\varrho_{ij} = \langle \Psi | c_i^\dagger c_j | \Psi \rangle$$



Phys. Rev. Lett. 115, 046603 (2015).

$$\mathrm{I}_{A,B} = \mathcal{S}(A) + \mathcal{S}(B) - \mathcal{S}(A \cup B)$$

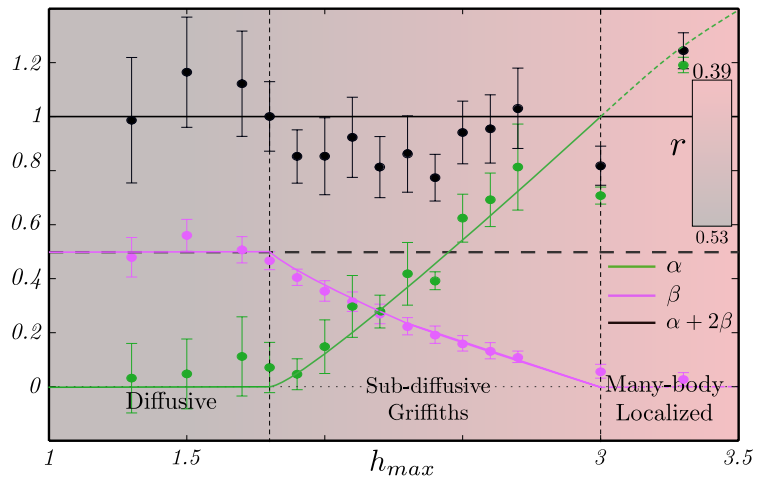


Phys. Rev. Lett. 118, 016804 (2017).

Is the dynamics (sub)-diffusive close to the transition?

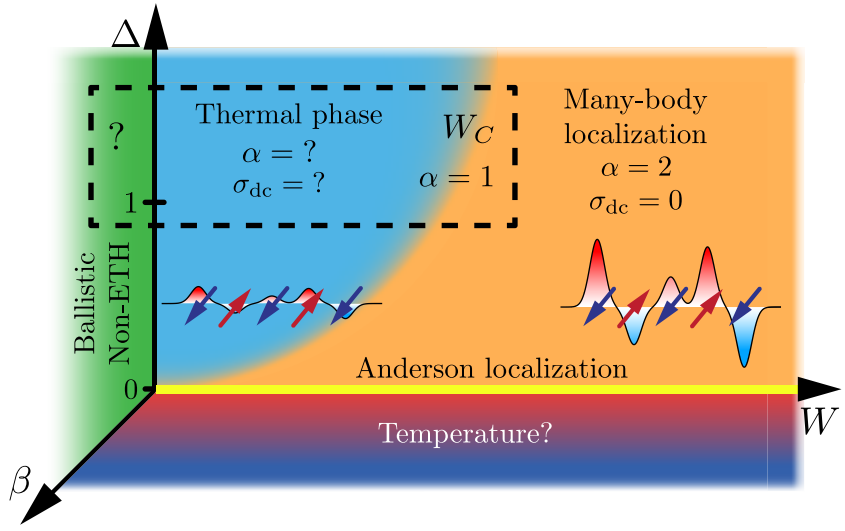
Observable: Return probability: $\mathcal{C}_{zz}(t) \sim t^{-\beta}$

$\sigma(\omega) \sim \omega^{\alpha}$



- Agarwal, Gopalakrishnan, Knap, Mueller, and Demler, PRL '15, PRB '16,
- Vosk, Huse, and Altman, PRX '15,
- Potter, Vasseur, and Parameswaran, PRX '15,
- Bar Lev, Cohen, and Reichman, PRL '15,
- Luitz, Laflorencie, and Alet, PRB '16,
- Khait, Gazit, Yao, and Auerbach, PRB '16,
- Znidaric, Scardicchio, and Varma, PRL '16.

Observable: $\sigma(\omega)$



Finite $\sigma_{\rm dc}$, $\alpha = 1$

- Steinigeweg, Herbrych, Pollmann, and Brenig arXiv: 1512:08519,
- Barisic, Kokalj, Balog, and Prelovsek, PRB '16.

1d lattice, spinless fermions and density-propagator

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

$\epsilon_i \in [-W, W]\,, \quad V/t = 1, \quad W_c/t \approx 3.5$ (Half-filling)

Density propagator:

$$\Pi_\varepsilon(q,t) = \overline{\Phi_\varepsilon(q,t)/\Phi_\varepsilon(q,t{=}0^+)}$$

with,

$$\Phi_\varepsilon(i,t) = \left[\langle\hat{n}_i(t)\hat{n}_0\rangle_\varepsilon - \langle\hat{n}_i\rangle_\varepsilon\langle\hat{n}_0\rangle_\varepsilon\right]\Theta(t)\,;\ \langle\hat{\mathcal{O}}\rangle_\varepsilon = \mathrm{Tr}\hat{\mathcal{O}}\hat{\rho}(\varepsilon)$$

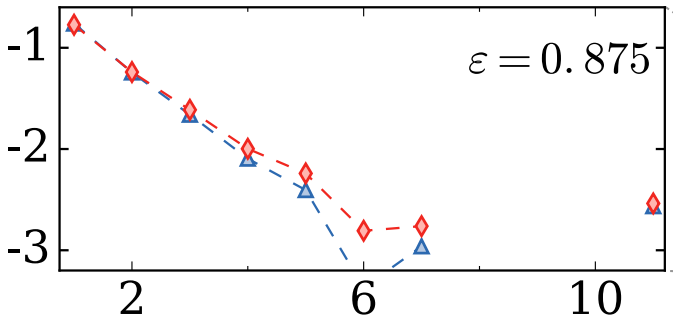
Density operator:

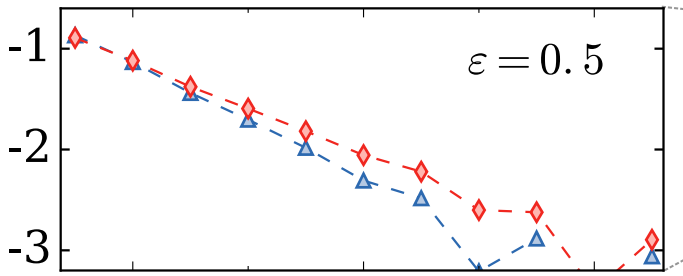
$$\hat{\rho}(\varepsilon) = \mathcal{N}^{-1}\int_{\varepsilon-\Delta\varepsilon/2}^{\varepsilon+\Delta\varepsilon/2} d\varepsilon' \sum_\gamma^{\mathcal{N}} |\gamma\rangle\delta(\varepsilon_\gamma - \varepsilon')\langle\gamma|$$

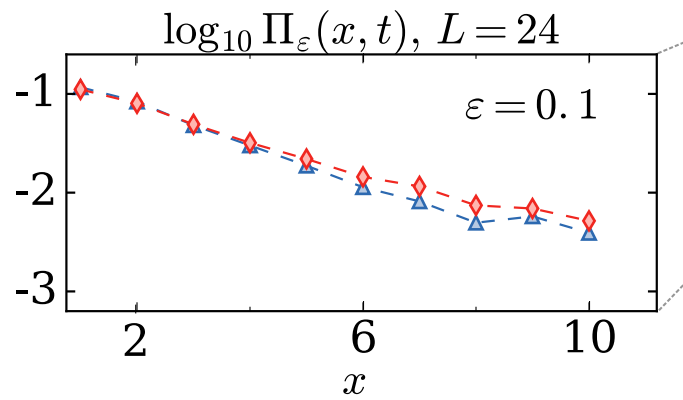
$\varepsilon_\gamma = \frac{E_\gamma - E_{\min}}{E_{\max} - E_{\min}}$ $\mathcal{N}$: Normalization

$\Delta\varepsilon = 0.1$

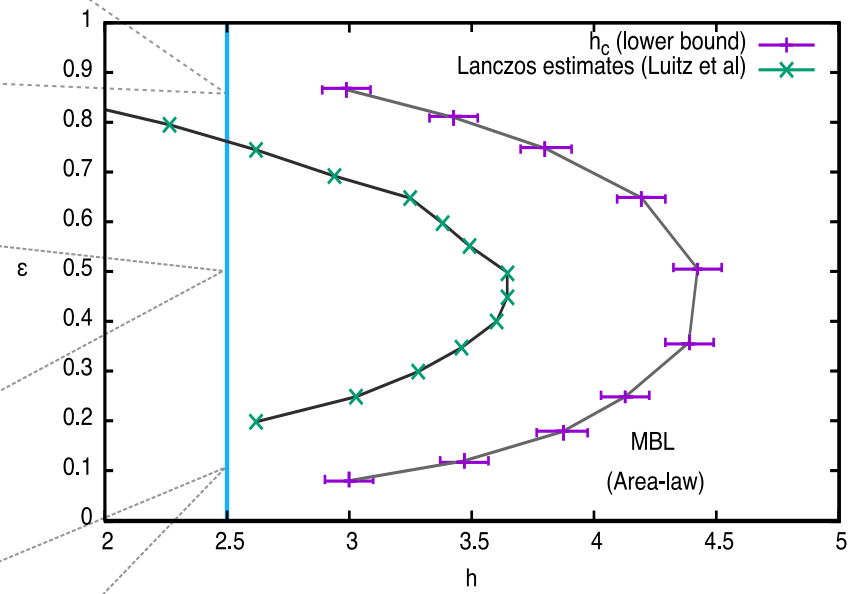
Interacting propagator shows exponential decay in real space at intermediate disorder strength







MBL-Phase diagram

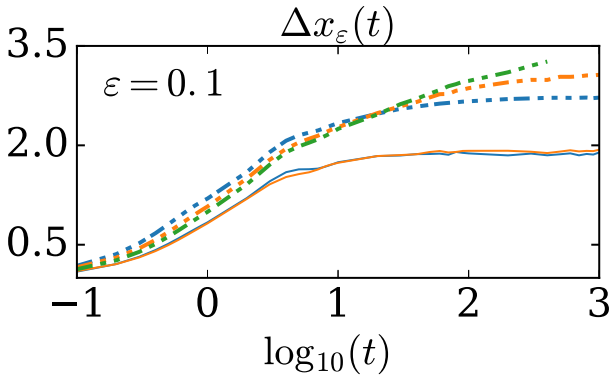


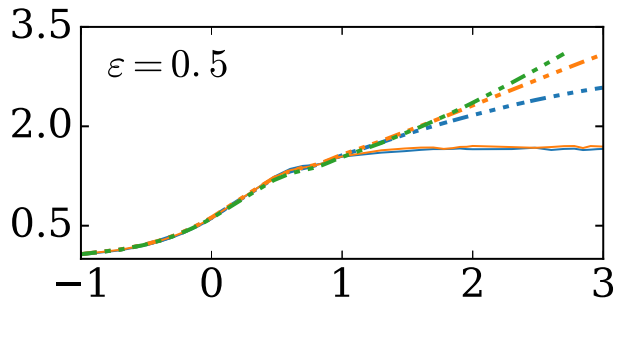
Luitz et. al., PRB '15.
Devakul, Singh, PRL, '16.

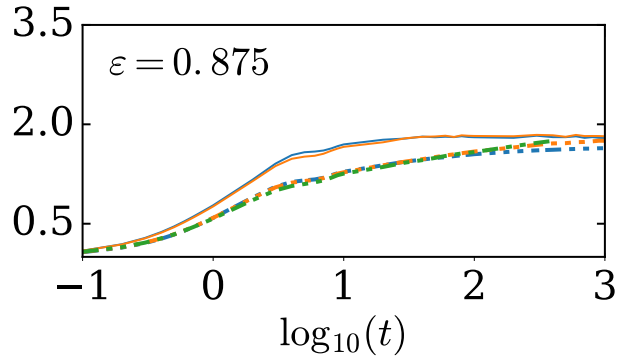
Slow wavepacket propagation leads to delocalization

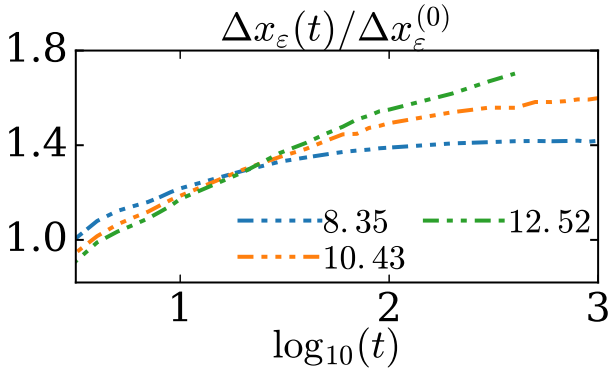
Second moment:

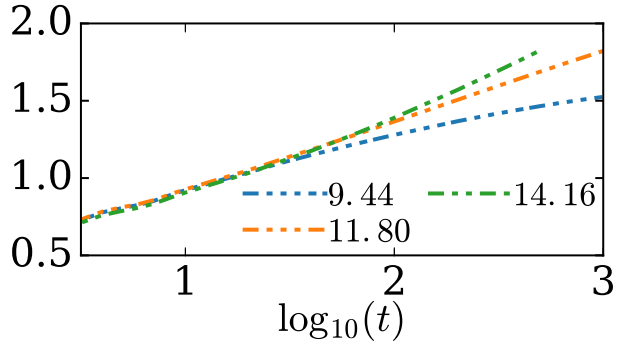
$$\Delta x_\varepsilon(t)^2 = \langle \hat{x}^2 \rangle_\varepsilon - \langle \hat{x} \rangle_\varepsilon^2, \qquad \langle x^n \rangle = \sum_{x=-L/2}^{L/2} x^n \Pi_\varepsilon(x,t)$$

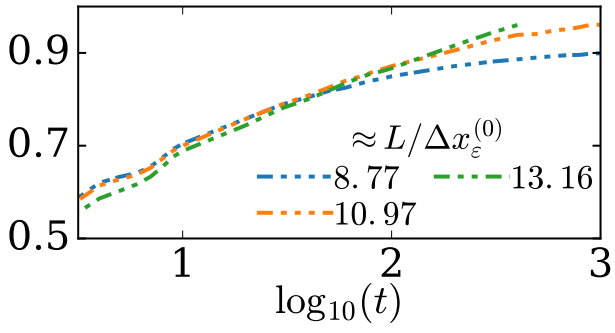








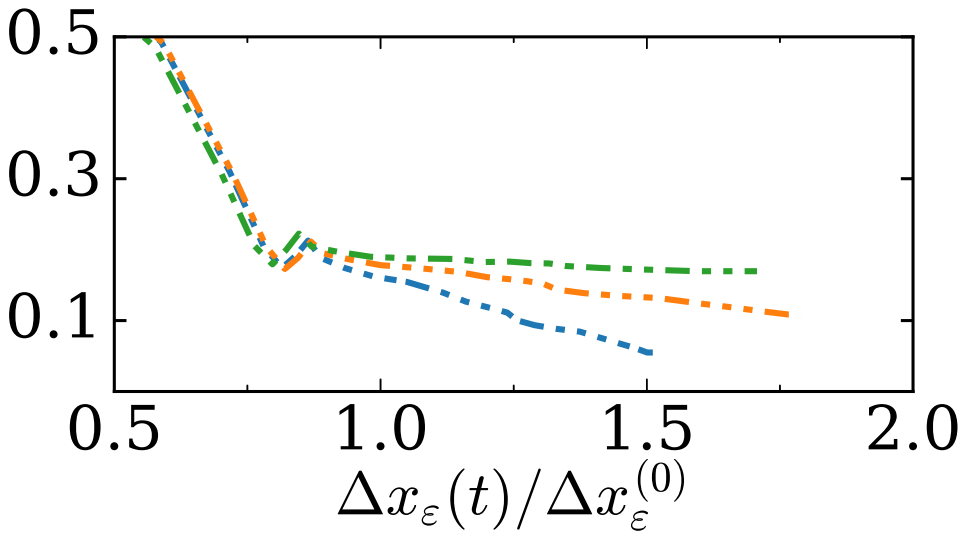




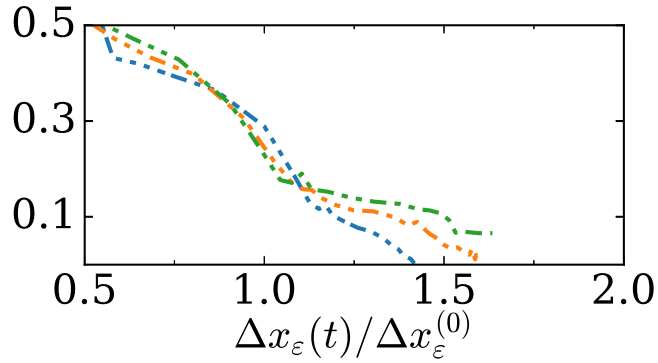
$L = \{16, 20, 24\}$

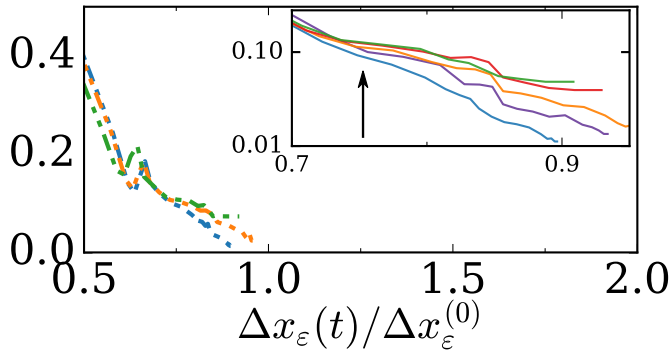
Evidence of transient sub-diffusive regime and finite size effects

$$\beta_\varepsilon(t) = \frac{d \log \Delta x_\varepsilon(t)}{d \log t}; \; \Delta x_\varepsilon(t) \sim t^{\beta_\varepsilon}$$



Middle of the band





arXiv:1610.03085

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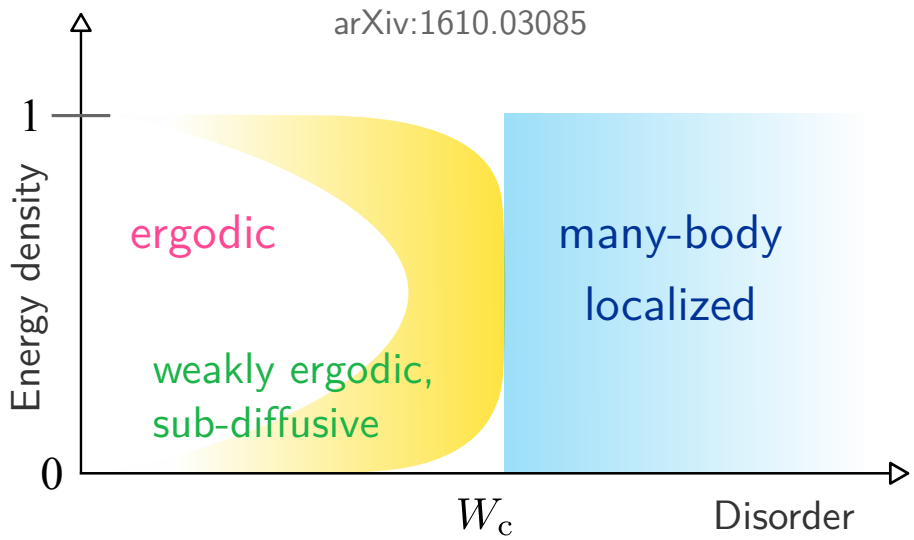
mpipks

erc European Research Council

QUANTMATT
(Jens H Bardarson)

New dynamical phase diagram

- Non-Gaussian decay of the propagator.
- (Transient) Sub-diffusion dynamics close to the transition -- effects of finite size and time.
- Possible fractal Griffith phase.
- Possibility of a weakly ergodic sub-diffusive regime.



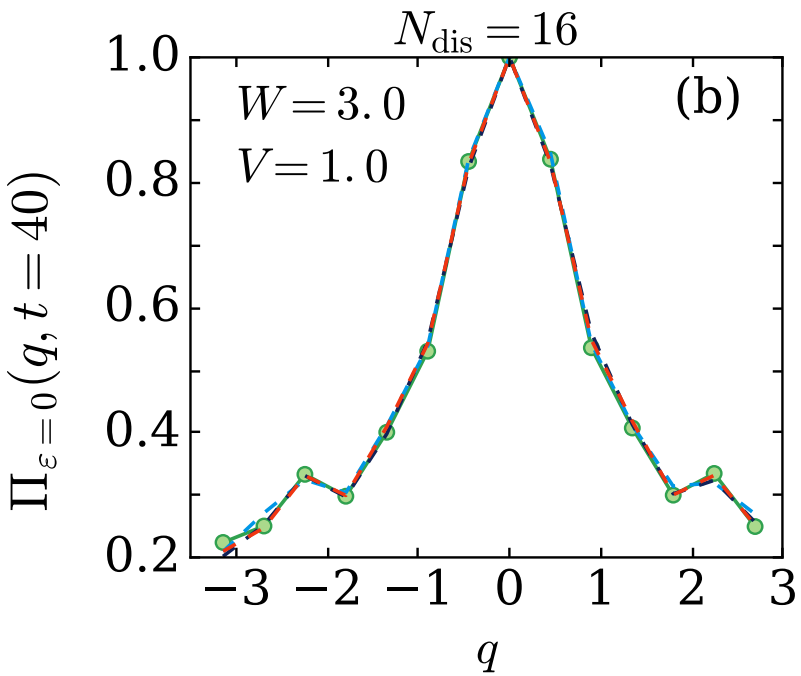
Thank you for your attention.

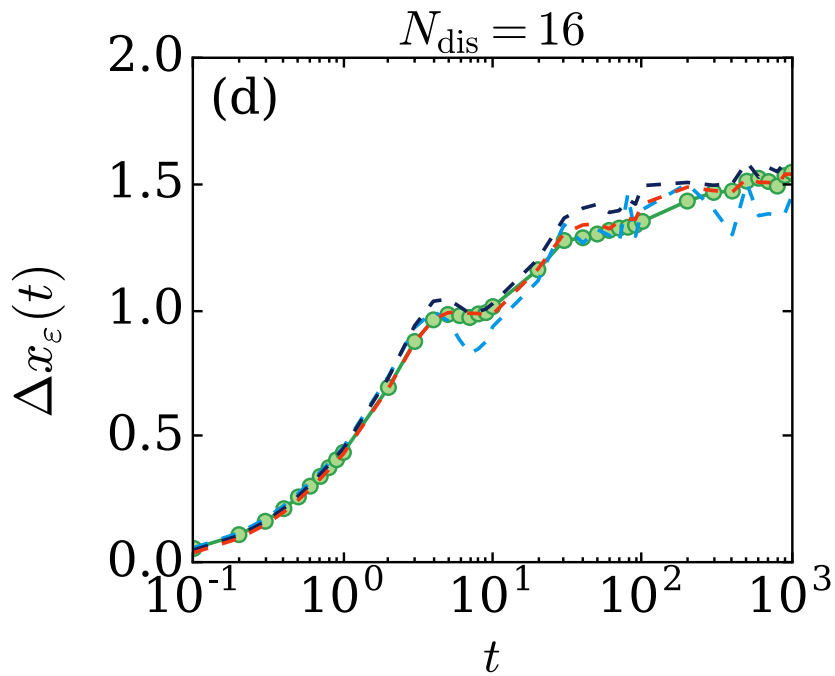
Numerical method

Time evolution : Chebyshev expansion techniques

Density matrix : Expanded in Chebyshev polynomials

Trace : Stochastically.





Weisse et al., RMP '06.

Tendency towards delocalization close to band edges