MBL transition in quasiperiodic systems

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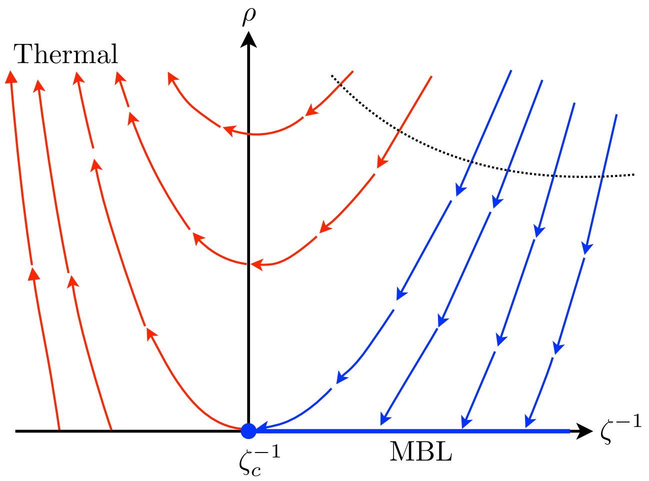
MBL symposium 2021 (“Dead or alive”)



H. Singh, B. Ware, RV & S. Gopalakrishnan, PRB ‘21

Collaborators

H. Singh
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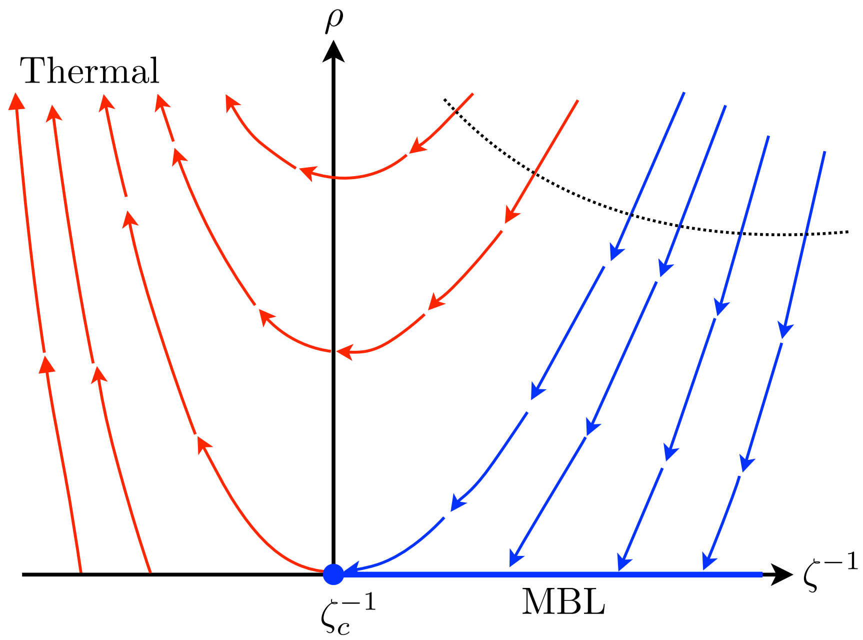
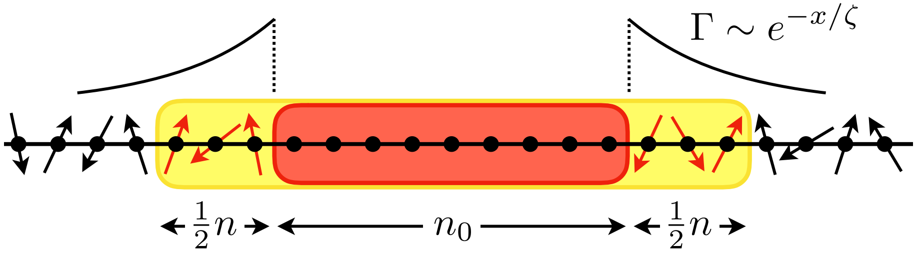
(Penn State)

Singh, Ware, RV & Gopalakrishnan, PRB '21

Random MBLT: where are we at?

- MBL "transition" observed in ED likely has nothing to do with the "real" transition
    - Harris/CCFS/CLO bounds, some observables indicate large Wc
    - big chunk of the observed MBL phase is actually thermal
- Avalanche instability as a believable instability driving the transition
- Leads to an appealing (?) "KT-like" picture of the transition



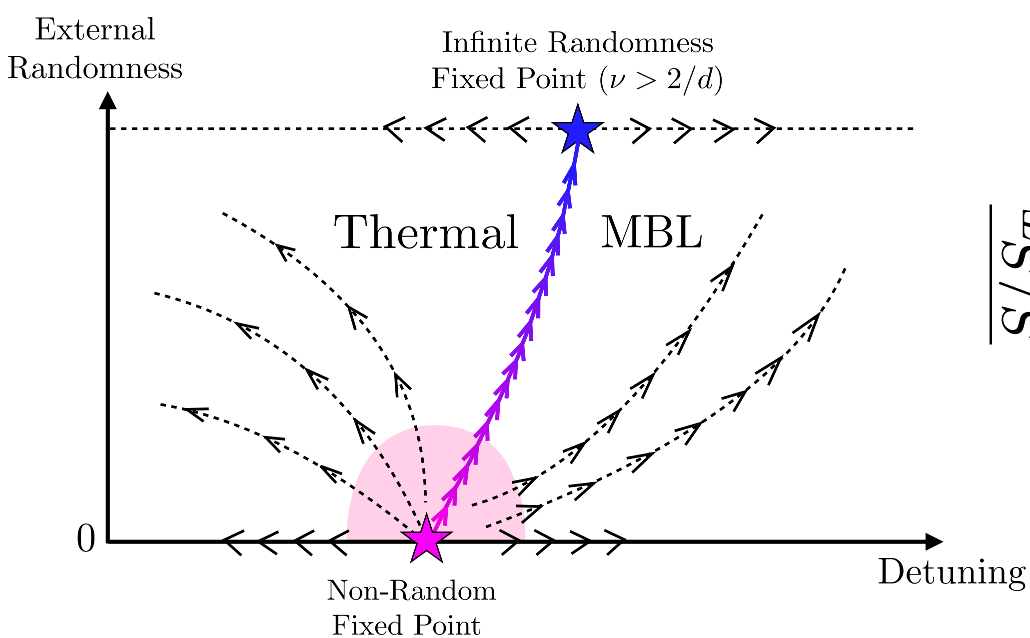


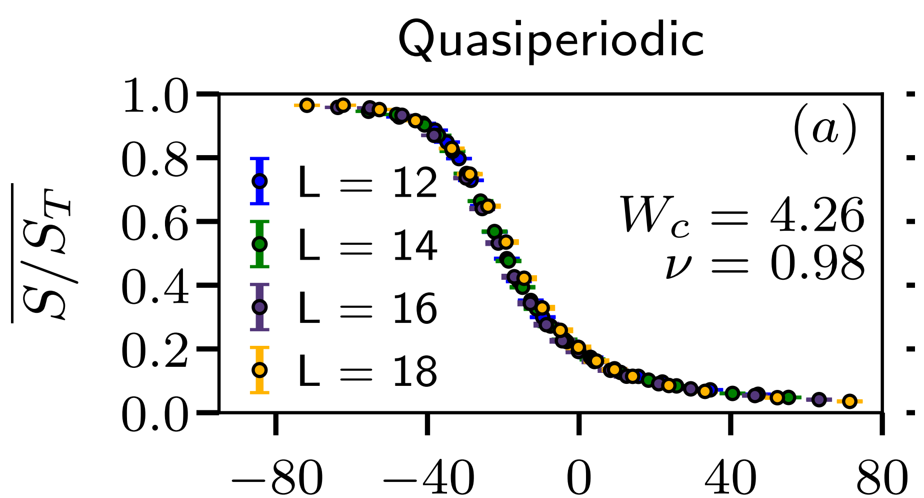
Huveneers & De Roeck, PRB '17
Thiery, Huveneers, Muller & De Roeck, PRL '18
A. Goremykina, RV & M. Serbyn, PRL '19
P. Dumitrescu, A. Goremykina, S. Parameswaran, M. Serbyn & RV, PRB '19
Morningstar & Huse, PRB '19
Morningstar, Huse & Imbrie, PRB '20

Quasiperiodic MBLT

- Obvious motivation from cold atom experiments
- Different phenomenology? No rare regions? No avalanches? Small sample-to-sample fluctuations…
- More accessible to ED numerics? Simple-minded QP RGs give $\nu = 1$

Agrawal, Gopalakrishnan & RV, Nat Comm '20





Iyer, Oganesyan, Refael & Huse, PRB '13
Khemani, Sheng & Huse, PRL '17

l-bits from ED

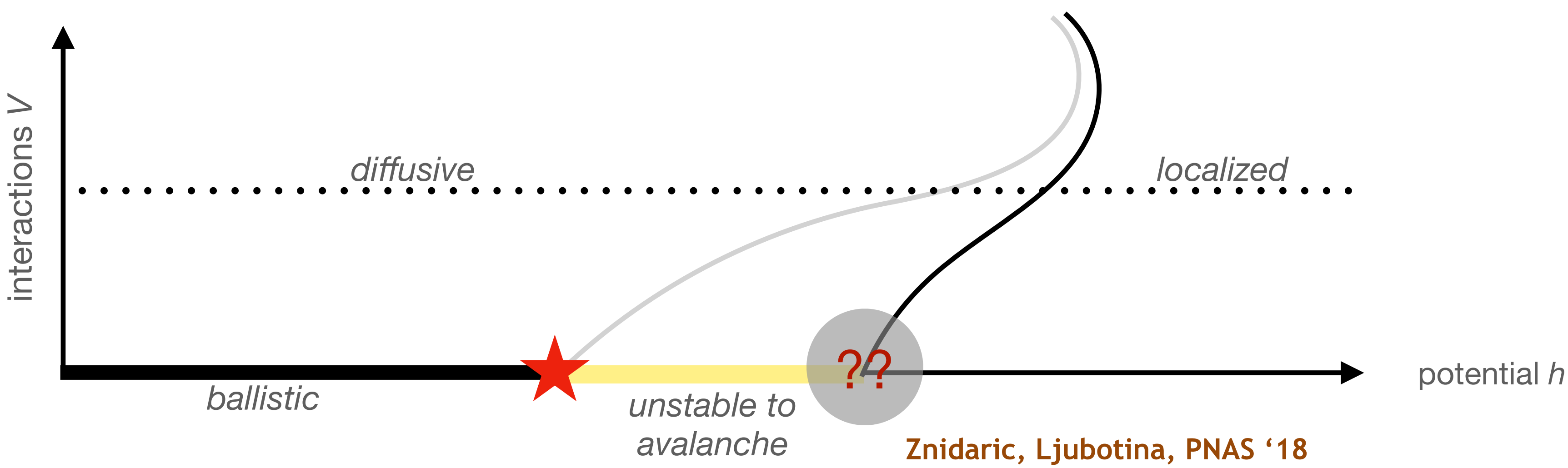
- Eigenstate perspective: self-generated configurational randomness (from initial state, or picking an eigenstate at random)
- Heisenberg perspective: focus on LIOMs/l-bits   Serbyn et al, Oganesyan et al '13, Imbrie '14
- Extract from time evolution: $$\bar{O} \equiv \lim_{T\to\infty} \frac{1}{T}\int_0^T dt\, O(t) = \sum_E \langle E|O|E\rangle |E\rangle\langle E|$$

Chandran, Kim, Vidal & Abanin PRB '15

Iyer, Oganesyan, Refael & Huse, PRB '13

$$H = \sum_{i=1}^{L-1} \sigma_i^x\sigma_{i+1}^x + \sigma_i^y\sigma_{i+1}^y + V\sigma_i^z\sigma_{i+1}^z + \sum_{i=1}^{L} h_i\sigma_i^z$$

$h_i = h\cos(2\pi/\varphi(i - L/2) + \phi)$



Znidaric, Ljubotina, PNAS '18

Free fermion weights

Expand in Majorana basis: $\bar{O} = \sum_{\boldsymbol{\alpha}} c_{\boldsymbol{\alpha}} w_1^{\alpha_1} w_2^{\alpha_2} \cdots w_{2L}^{\alpha_{2L}}$

(can clearly separate out interaction effects from nearby non-interacting transition)

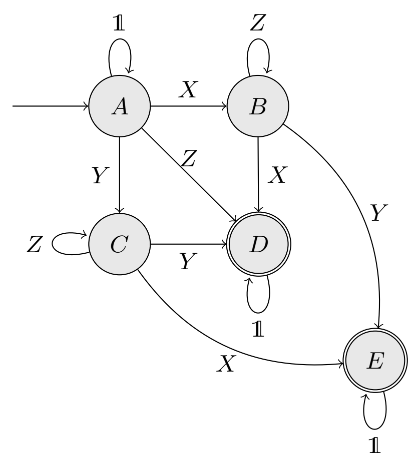
$$f_2 = \frac{1}{\mathcal{N}} \sum_{|\boldsymbol{\alpha}|=2} |c_{\boldsymbol{\alpha}}|^2, \qquad \mathcal{N} = \sum_{\boldsymbol{\alpha}} |c_\alpha|^2$$

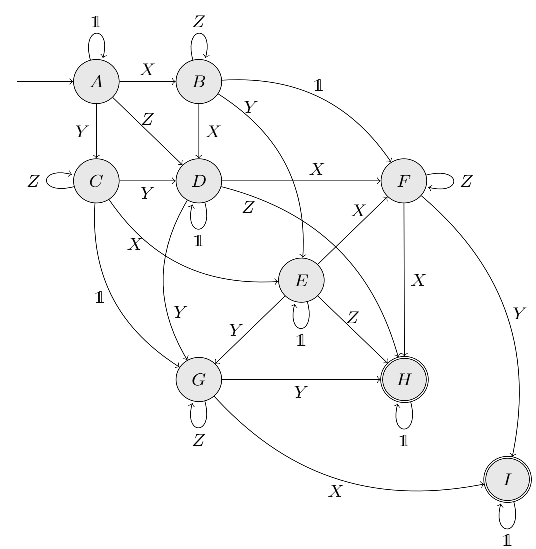
Weight on quadratic fermion operators

Norm of the LIOM

Even on ED sizes, convenient to use matrix product operators

(Sadly, TEBD not useful here, time scales are too long to converge)

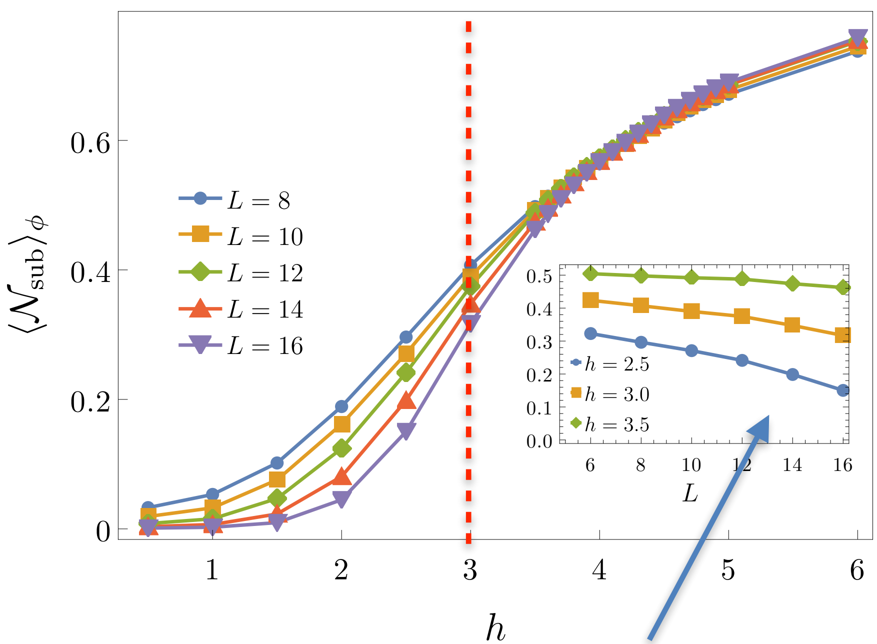


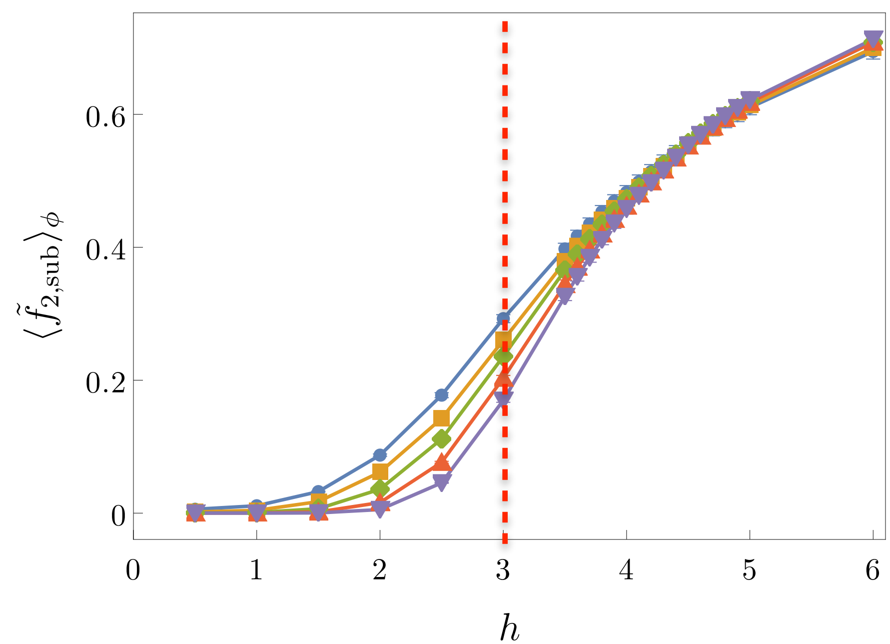


Hydrodynamic projections

Subtract off hydro modes: $\mathcal{P} = \sum_{l,k=1,2} |I_k\rangle\rangle C^{-1}_{kl} \langle\langle I_l|$ $\qquad \bar{O}_{\text{sub}} \equiv \dfrac{\bar{O} - \mathcal{P}(O)}{\|O - \mathcal{P}(O)\|}$

Transition based on eigenstate probes

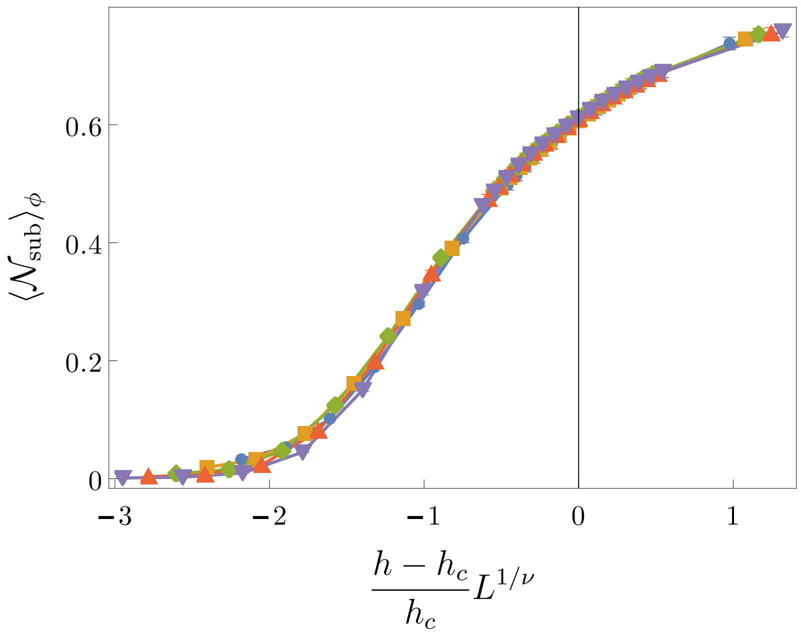


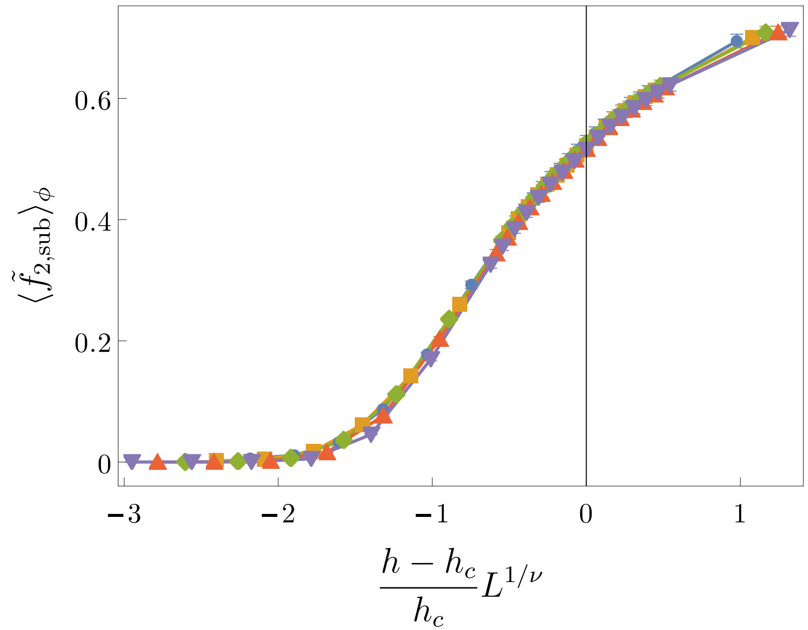


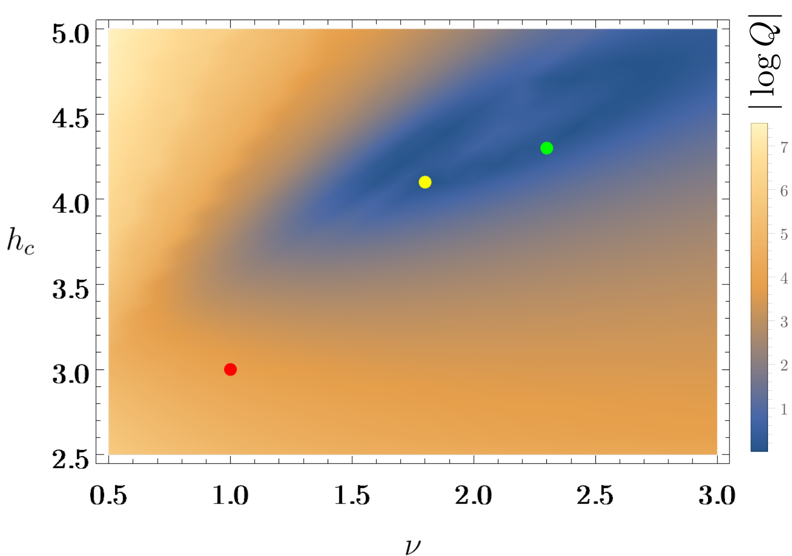
Accelerating approach to thermalization!

Simple, mostly 2-body LIOMs all the way to the transition…

Scaling collapses







$\nu \gtrsim 2 \qquad h_c \gtrsim 4$

Contrary to earlier expectations,
finite size drifts in the QP case too

Conclusion

- Quasiperiodic transition looks more similar to the random case than previously anticipated

- QP transition stable to randomness???

- MBL phase appears strongly localized all the way to the apparent transition. Finite localization length at the transition.

- Suggestive of some avalanche-like instability? Mechanism?