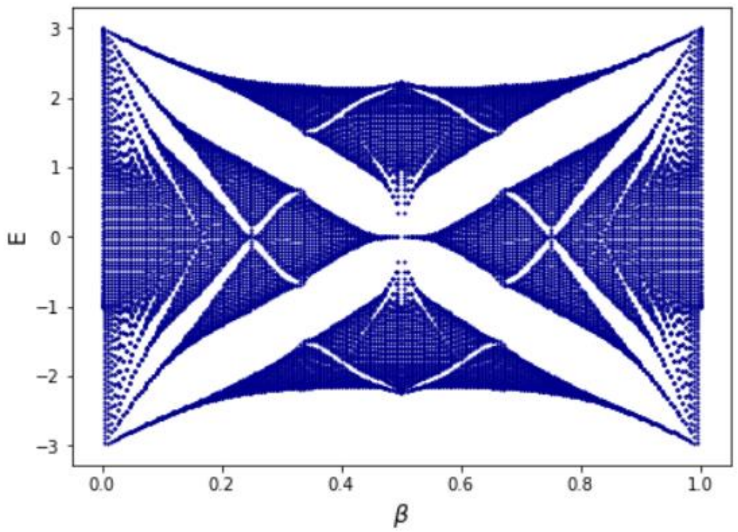
QUANTUM SCARS IN THE INTERACTING AUBRY ANDRE MODEL

Carlos Diaz, Javier de la Cruz, Jorge Hirsch , Sergio Lerma

THE SYSTEM: Interacting Aubry André Model

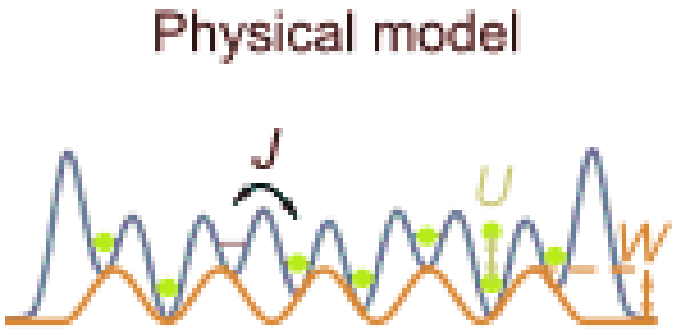
$$H = -J\sum_{\langle i,j\rangle}(b_i b_j^\dagger + h.c.) + W\sum_i \cos(2\pi\beta i + \varphi)\, n_i + U\sum_i n_i(n_i - 1$$



The first term is the kinetic energy with the hoping paramter J which let the bosons to move between the sites.

The W term is responsable for MBL, breaks the symmetry of the chain and U is referred to the potential energy, how much the bosons are likely to stay together.

We used 8 sites and 8 bosons for our study



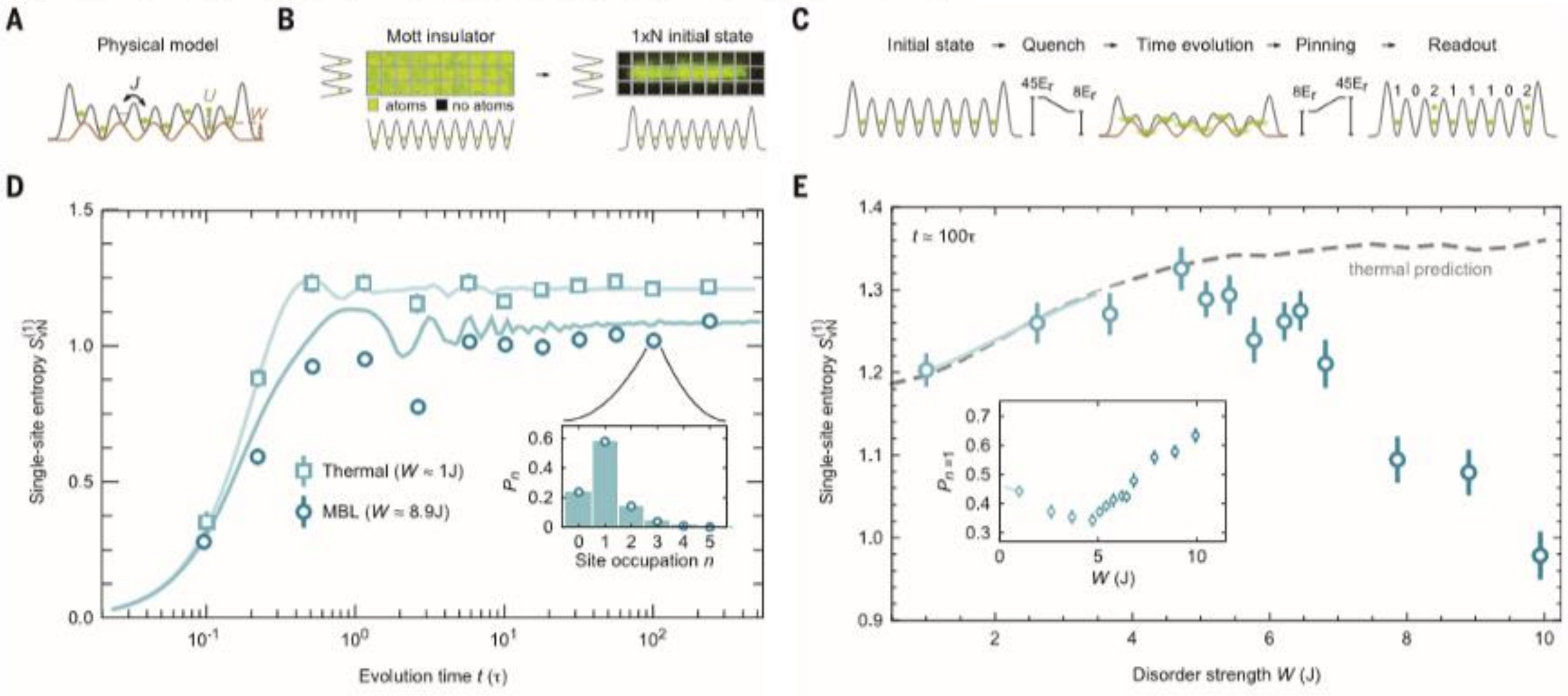
$$N = M = 8$$

$$dim = 6400$$

MOTIVATION

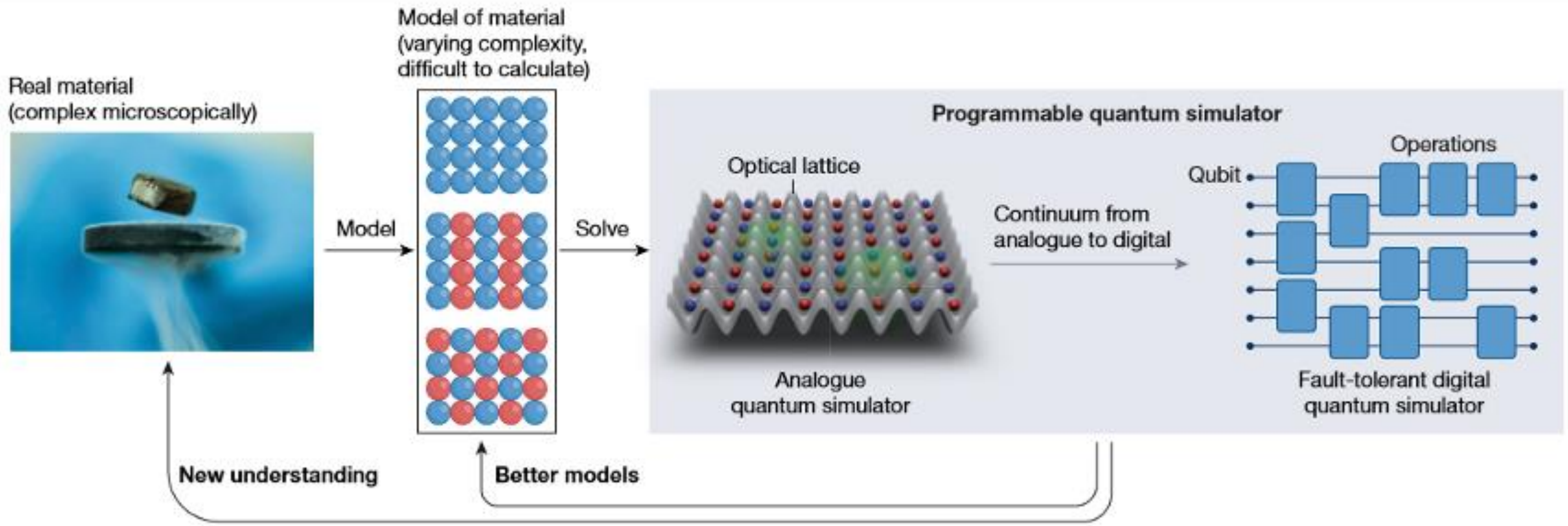
Probing entanglement in a many-body-localized system

Alexand
Soonwo



Practical quantum advantage in quantum simulation

Perspective



ARTICLE

Check for updates

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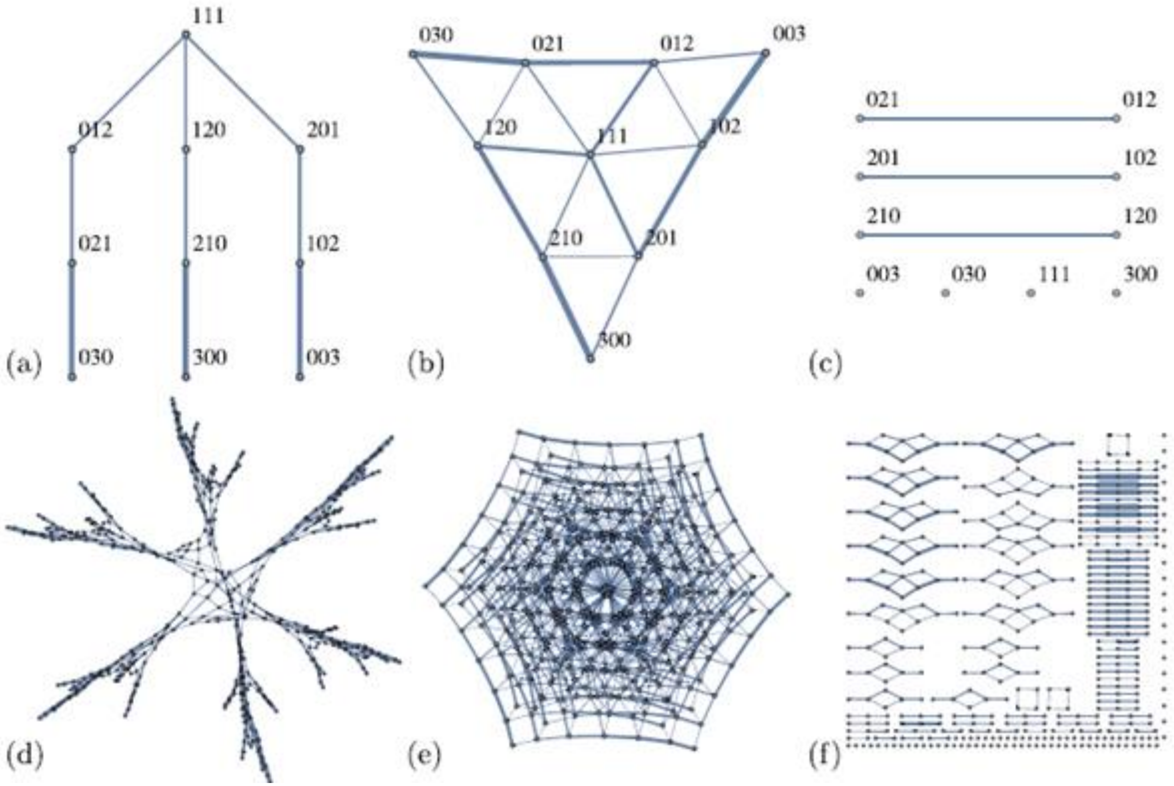
OPEN

Quantum scars of bosons with correlated hopping

Ana Hudomal[1✉], Ivana Vasić[1], Nicolas Regnault[2,3] & Zlatko Papić[4]



The survival probability is an observable defined as **the probability to find the system in the initial state after a time t.**

$$S_P(t) = |\langle \Psi(0)|\Psi(t)\rangle|^2 \qquad |\Psi(0)\rangle = \sum_k c_k |\psi_k\rangle\,, \qquad \sum_k |c_k|^2 = 1$$

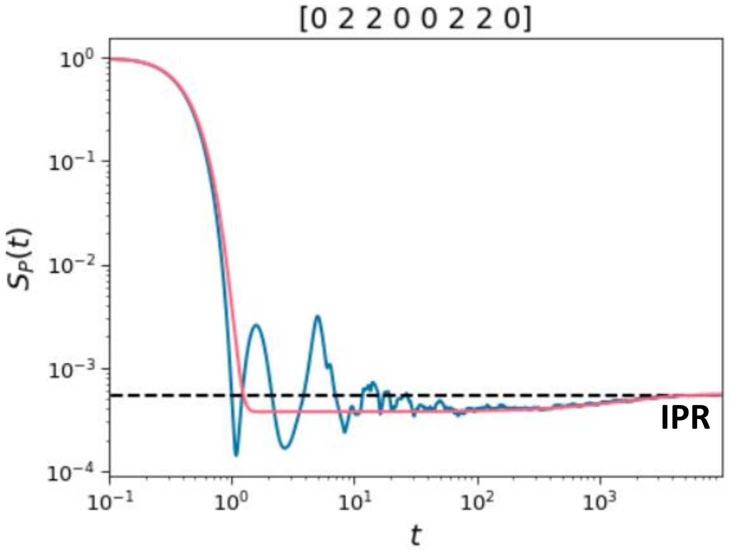
$$S_P(t) = \left| \sum_k |c_k|^2 e^{-iE_k t} \right|^2$$

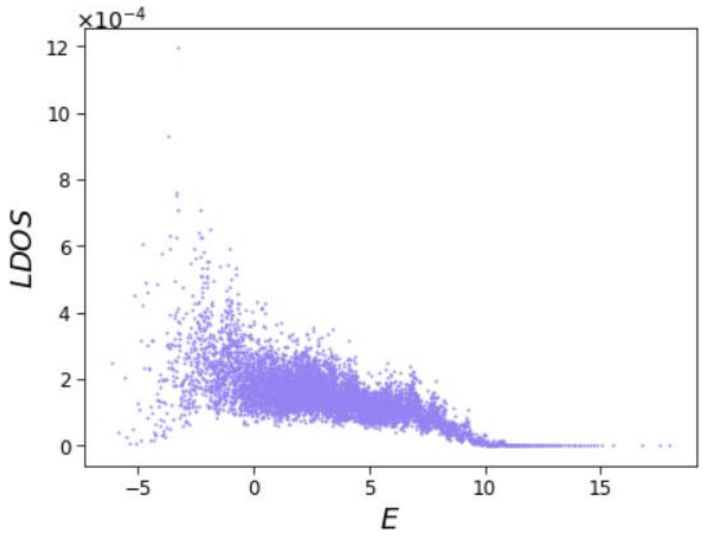
$$+\,RMT$$

$$\langle S_P(t)\rangle = \frac{1-\mathrm{IPR}}{\eta-1}\left[\eta S_P^{bc}(t) - b_2\left(\frac{t}{2\pi\bar{\nu}}\right)\right] + \mathrm{IPR}$$

$$IPR = \sum_k |c_k|^4$$

The correlation hole is a dip of the SP at middle time before its relaxation value



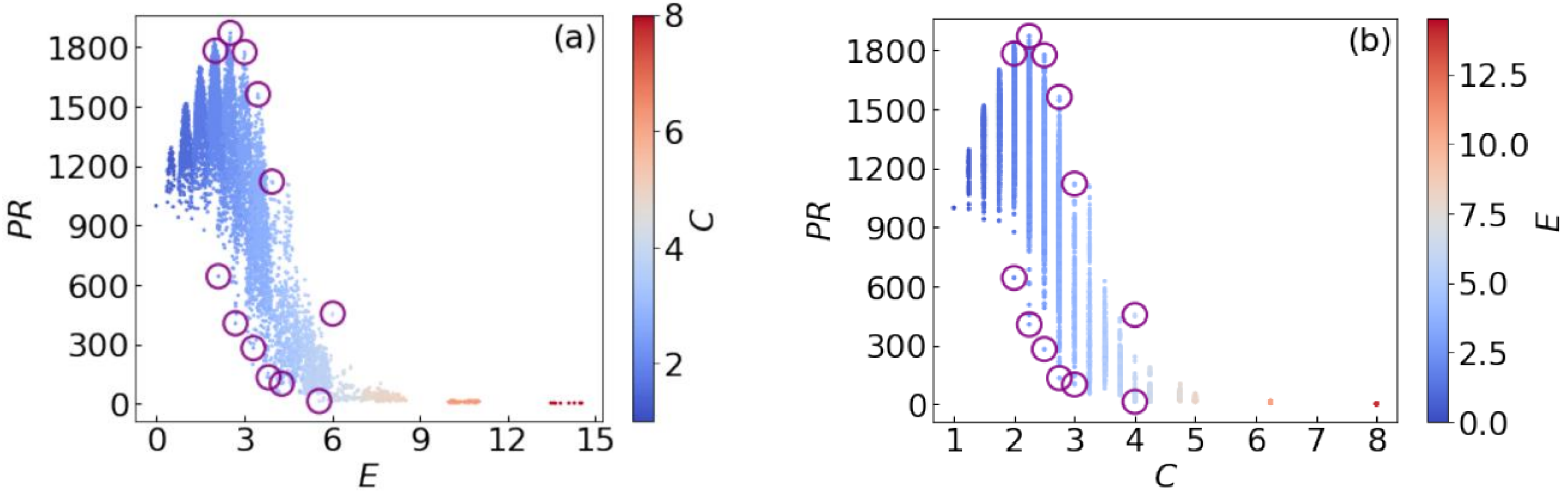


WHICH STATES SHOW THE CORRELATION HOLE?

$$H = -J\sum_{\langle i,j\rangle}(b_i b_j^\dagger + h.c.) + W\sum_i \cos(2\pi\beta i + \varphi)\, n_i + U\sum_i n_i(n_i - 1)$$

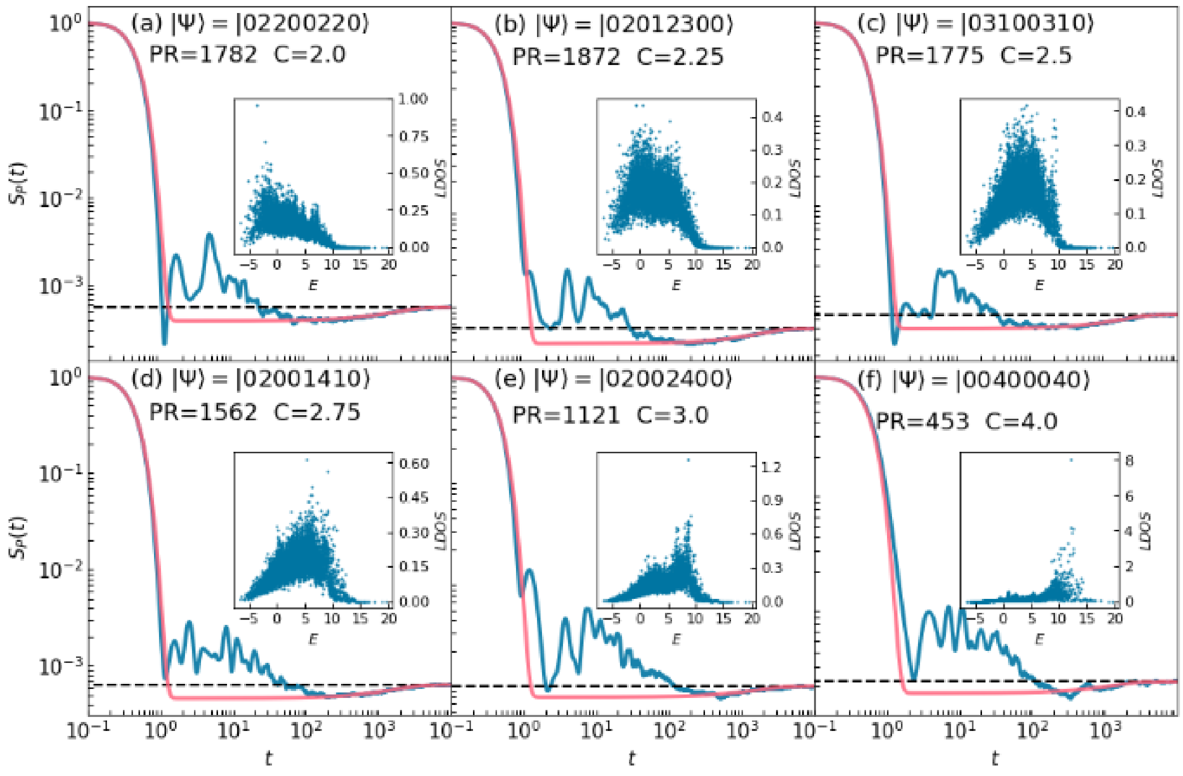
$$C = \sum_i \frac{n_i^2}{N} \qquad PR = \sum_k \frac{1}{|c_k|^4}$$

$[1,1,1,1,1,1,1,1] \Rightarrow C = 1.0$
$[2,0,0,1,2,0,2,2] \Rightarrow C = 1.25$
$[2,0,2,0,2,0,2,0] \Rightarrow C = 2.0$

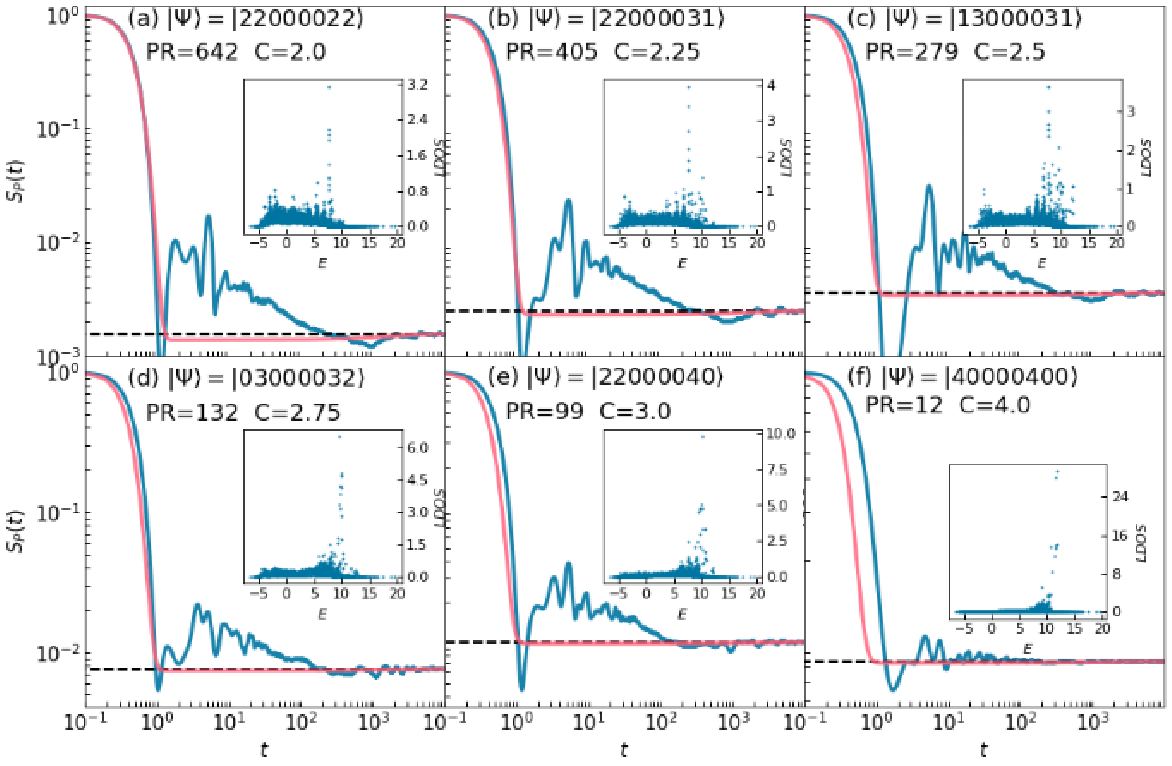


SELECTED STATES WITH CORRELATION HOLE

HIGHEST PR



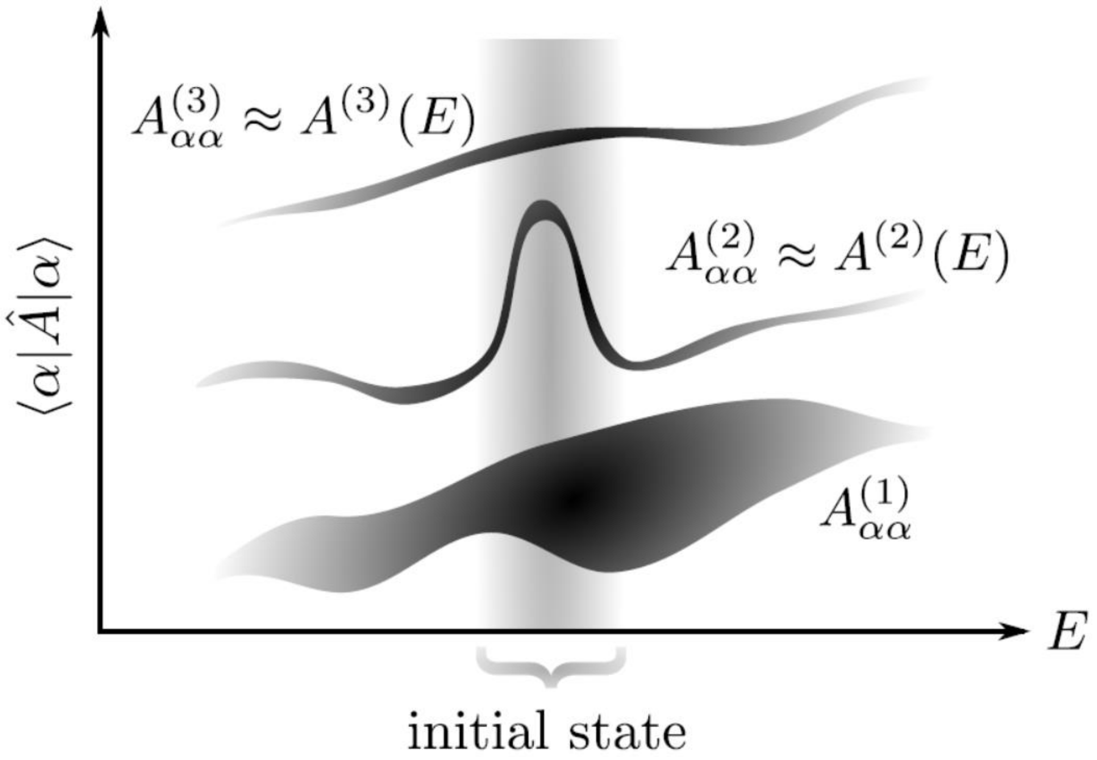
LOWEST PR



$$A(t) = \sum_m |C_m|^2 A_{mm} + \sum_{m,n\neq m} C_m^* C_n e^{i(E_m - E_n)t} A_{m,n}$$

El valor esperado, $\langle E_k | A | E_k \rangle$ *de una observable de pocos cuerpos A en un eigenestado* $|E_k\rangle$ *con energía* E_k *de un sistema de muchos cuerpos es igual al promedio térmico de A con energía promedio* E_k

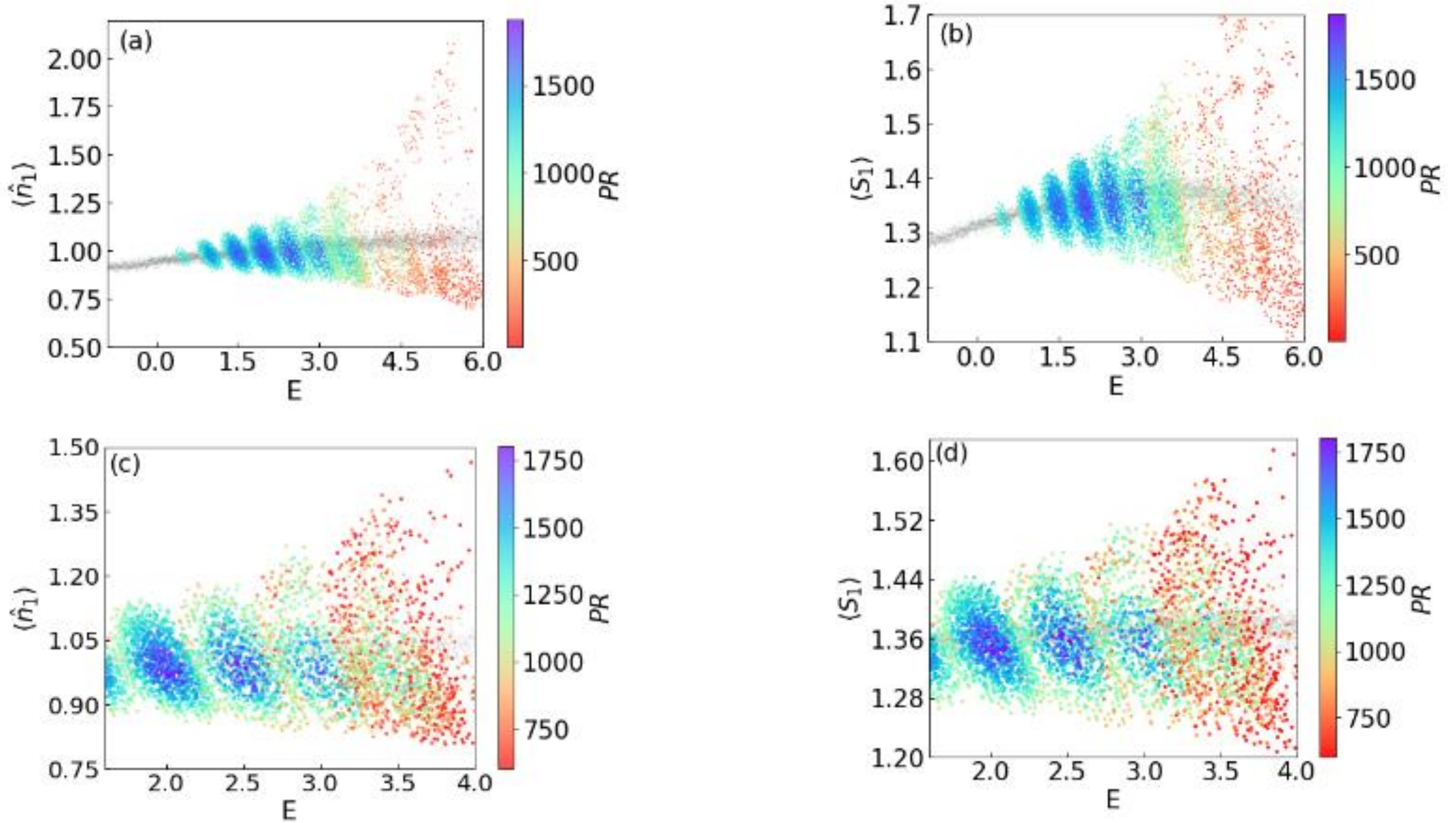
La ETH dice que todos los eigenestados en una ventana pequeña de energía con energía similar a la del estado inicial, ya son térmicos.



$$\langle \Psi_\alpha | \widehat{A} | \Psi_\alpha \rangle = \frac{1}{\mathcal{N}_{E_0,\,\Delta E}} \sum_{\substack{\alpha \\ |E_0 - E_\alpha| < \Delta E}} A_{\alpha\alpha}$$ **ETH**

$$\sum_\alpha |C_\alpha|^2 A_{\alpha\alpha} = \frac{1}{\mathcal{N}_{E_0,\,\Delta E}} \sum_{\substack{\alpha \\ |E_0 - E_\alpha| < \Delta E}} A_{\alpha\alpha}$$ **TERMALIZACIÓN**

EIGENSTATE THERMALIZATION HYPOTESIS



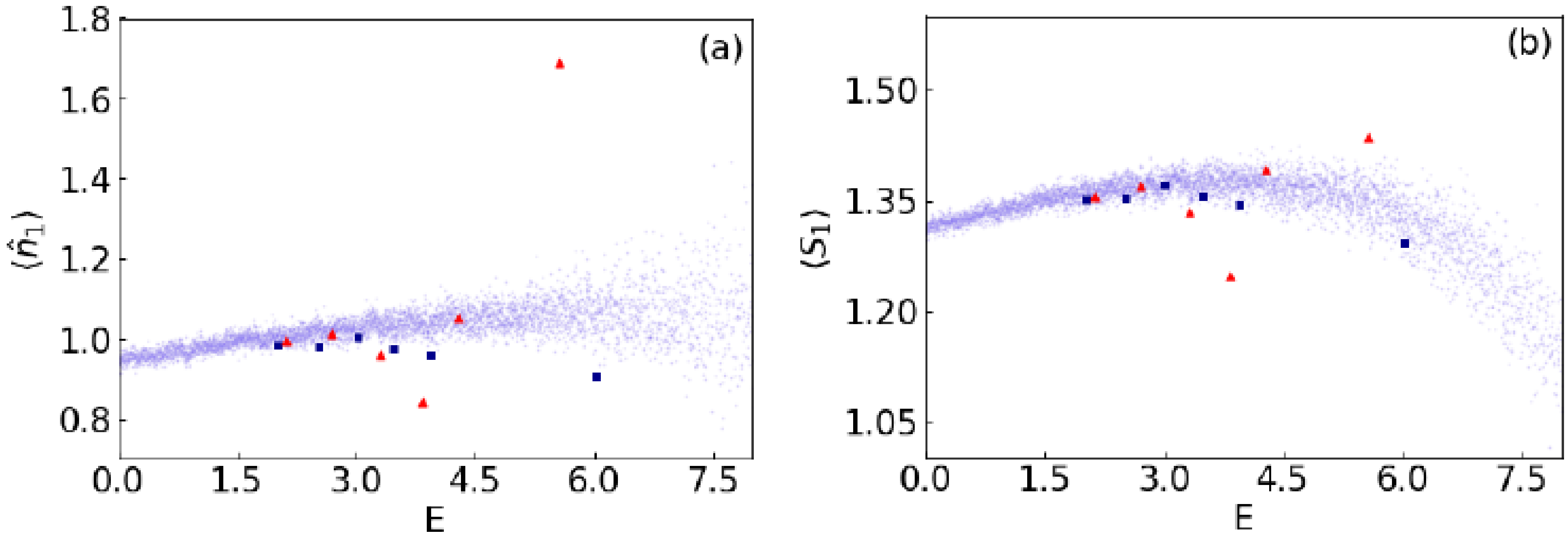


FIG. 16. (a) Relaxation values($t \approx 10^3$) for the high PR (blue squares) and low PR states(red triangles) of the first- site occupation. In purple the average occupation for energy eigenstates. (b) The same analysis but for the entanglement entropy of the first site.

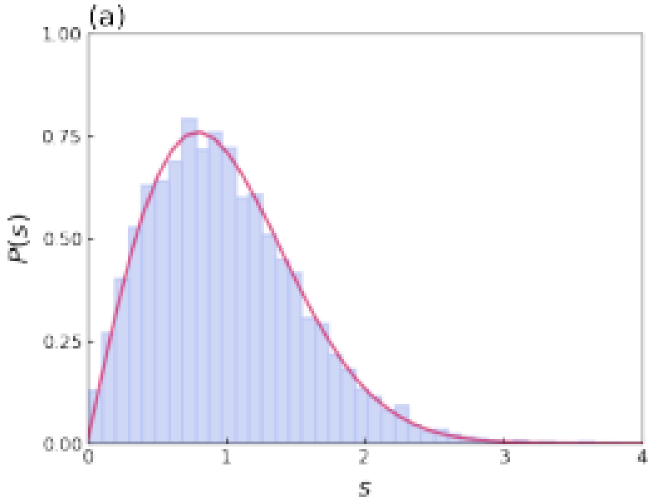
GRACIAS!

Facts:
Wigner and Dyson studied the energy statistics of heavy nuclei with Random Matrix Theory (RMT) by using the energy differences

BGS conjecture: Classical chaotic systems with quantum contrapart, also obeys RMT

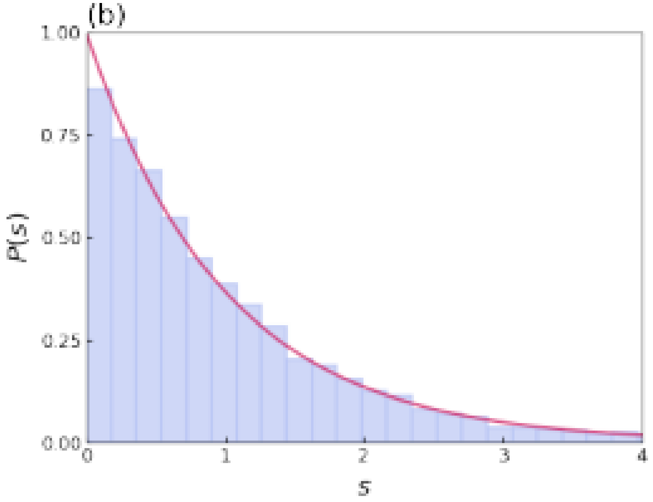
$$H = -J \sum_{\langle i,j \rangle} (b_i b_j^\dagger + h.c.)$$
$$+W \sum_i \cos(2\pi\beta i + \varphi)\, n_i + U \sum_i n_i(n_i - 1)$$

Quantum Chaos



$$P(s) = \frac{s}{2\sigma^2} e^{-s^2/4\sigma^2}$$

Regular



$$p(s) = e^{-s}$$

$$\tilde{r} = \frac{min(s_n, s_{n-1})}{max(s, s_{n-1})}$$

$$\langle \tilde{r} \rangle_W = 4 - 2\sqrt{3} \approx 0.535$$

$$\langle \tilde{r} \rangle_P = 2 \ln 2 - 1 \approx 0.386$$

LEVEL SPACING RATIO

$$\tilde{r} = \frac{min(s_n, s_{n-1})}{max(s, s_{n-1})}$$

We are looking for initial states that manifest quantum chaos

[1,1,1,1,1,1,1,1]
[2,0,0,1,2,0,2,2]
[2,0,2,0,2,0,2,0]
[3,0,2,0,0,0,0,3]

....