



Termalización en el modelo de Aubry-Andre

Javier de la Cruz

En colaboración con Carlos Díaz, Sergio Lerma y Jorge Hirsch

22 de enero de 2023

**6ª Reunión anual del grupo de investigación en caos y
termalización en sistemas cuánticos de muchos cuerpos**

Motivación

Los gases cuánticos ultrafríos son sistemas versátiles que se han usado para probar cuestiones fundamentales en la física de la materia condensada.

1.- Posibles aplicaciones en computo cuántico.

2.- Ultracold quantum gases in optical lattices can in fact be considered as quantum simulators[1]:

a powerful simulator in which a highly controllable quantum system can be used to simulate the dynamical behaviour of another complex quantum system

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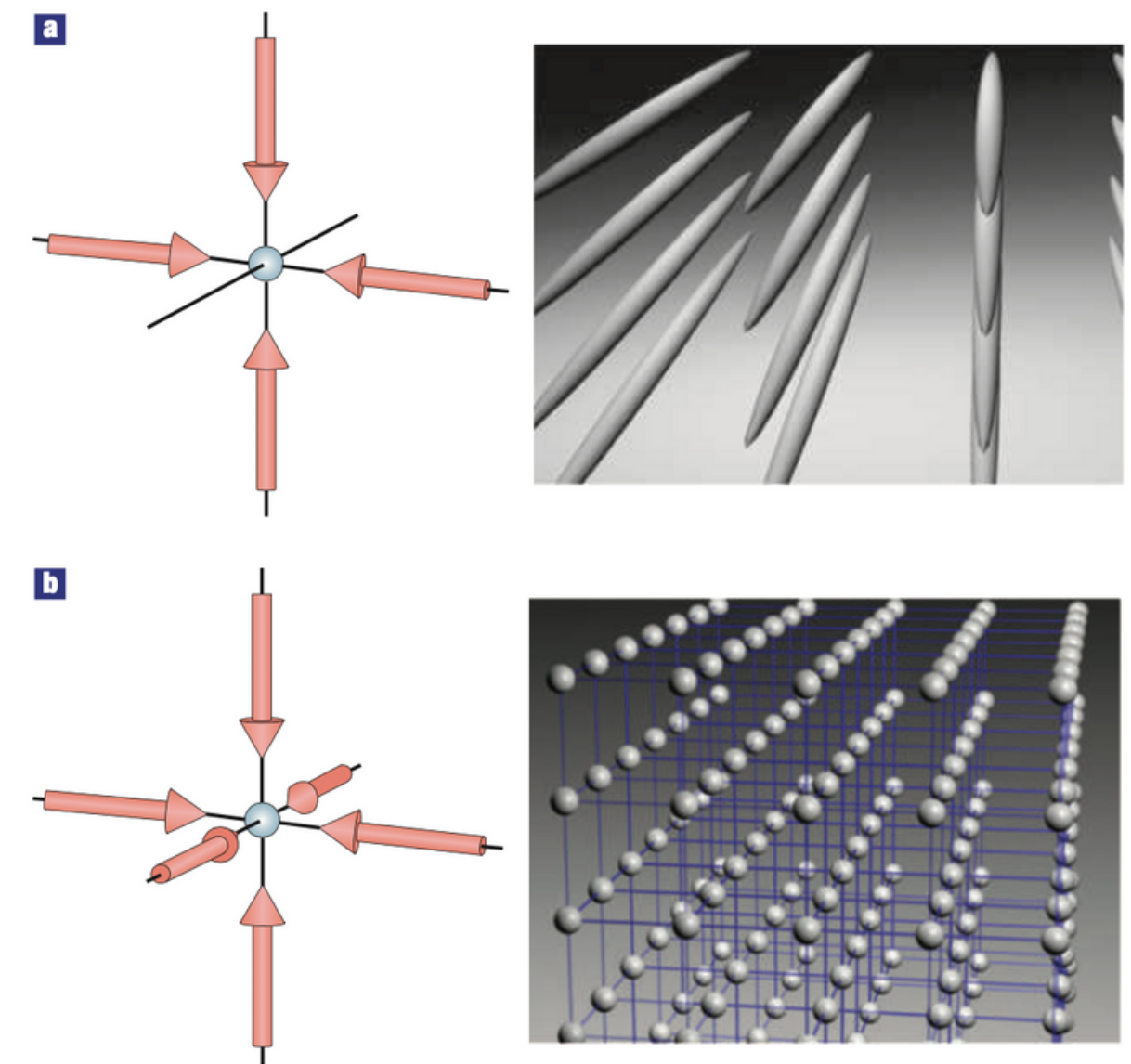


Figure 1 Optical lattice potentials formed by superimposing two or three orthogonal standing waves. **a**, For a 2D optical lattice, the atoms are confined to an array of tightly confining 1D potential tubes. **b**, In the 3D case, the optical lattice can be approximated by a 3D simple cubic array of tightly confining harmonic oscillator potentials at each lattice site.

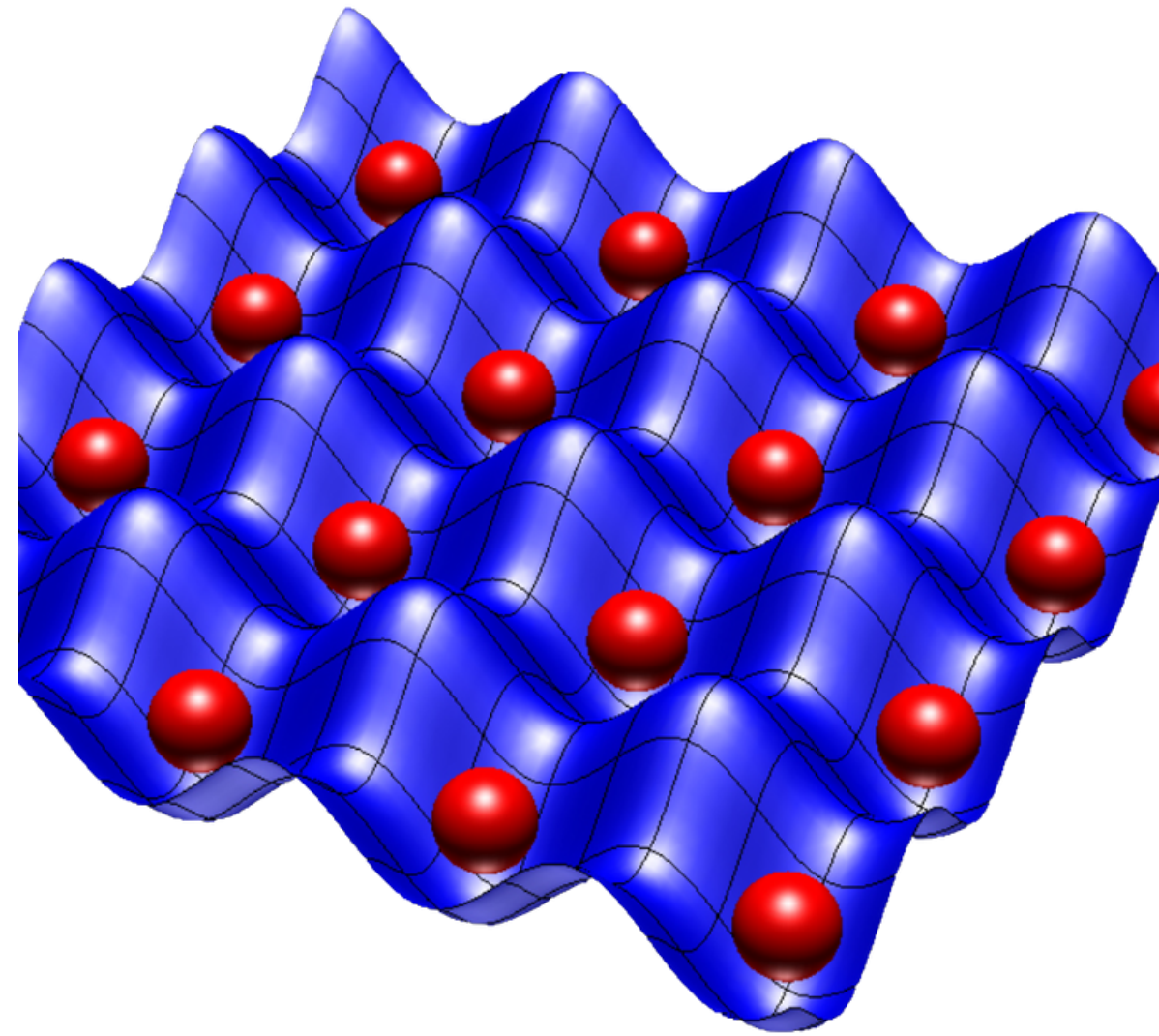
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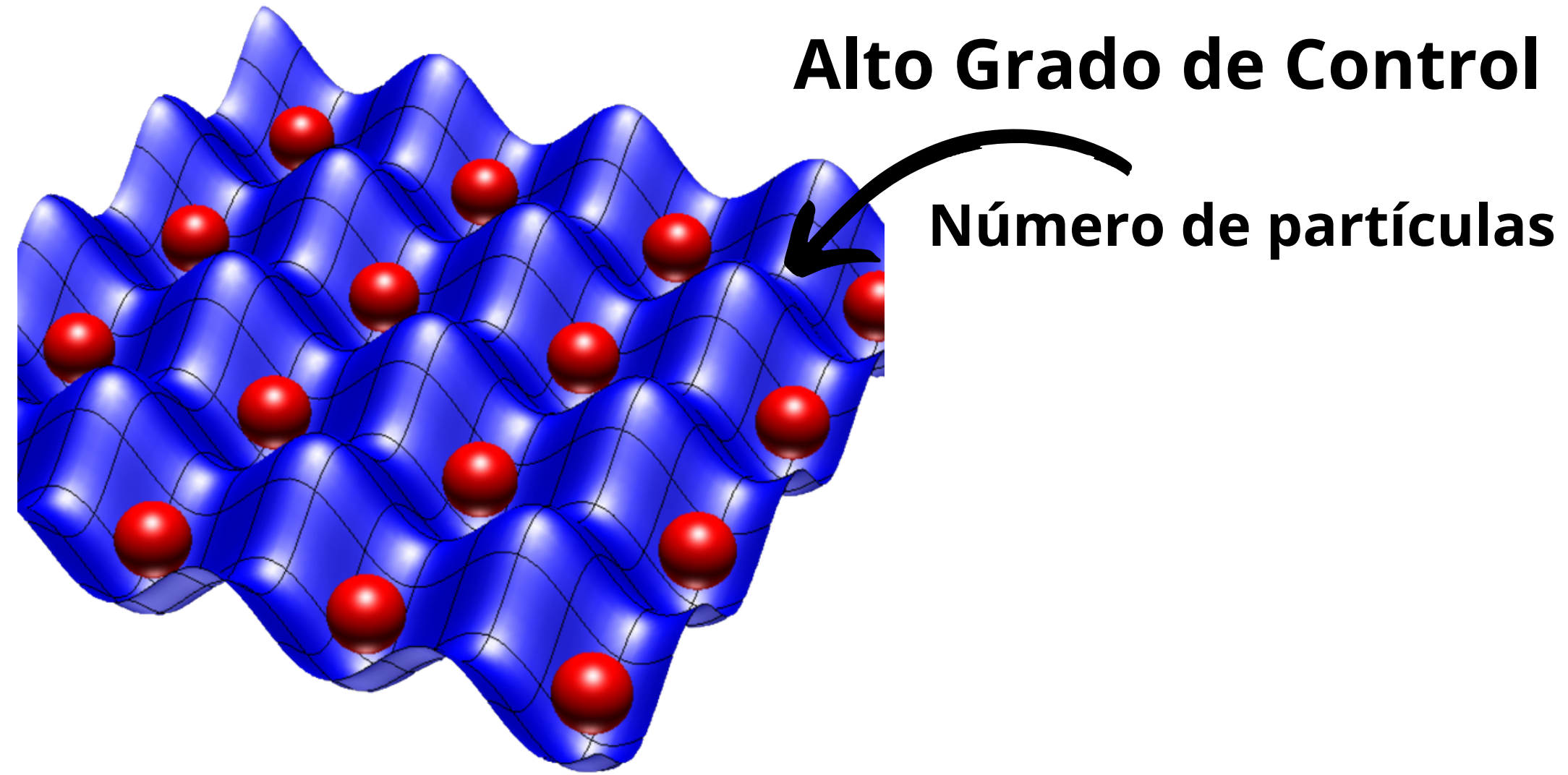
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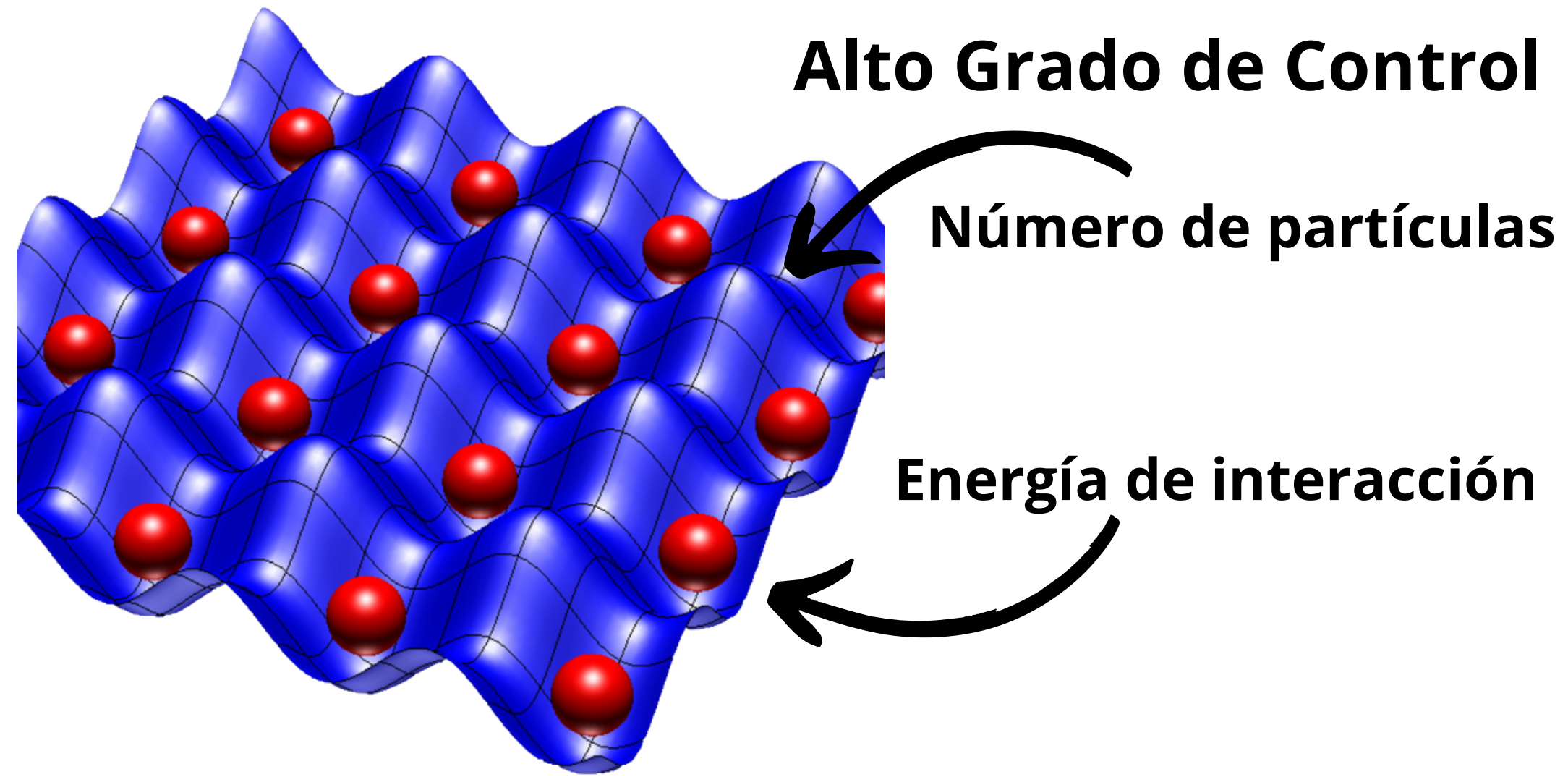
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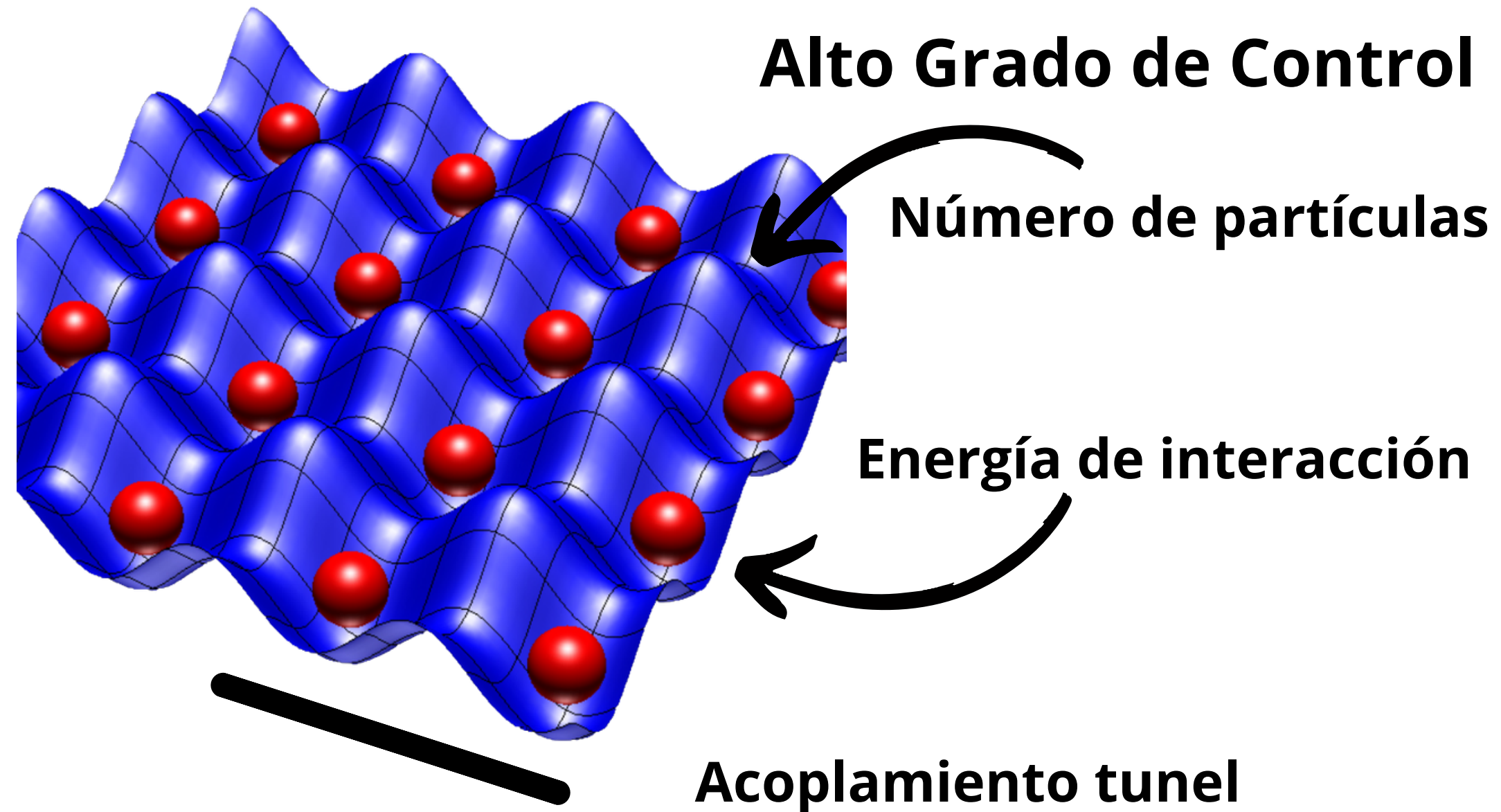
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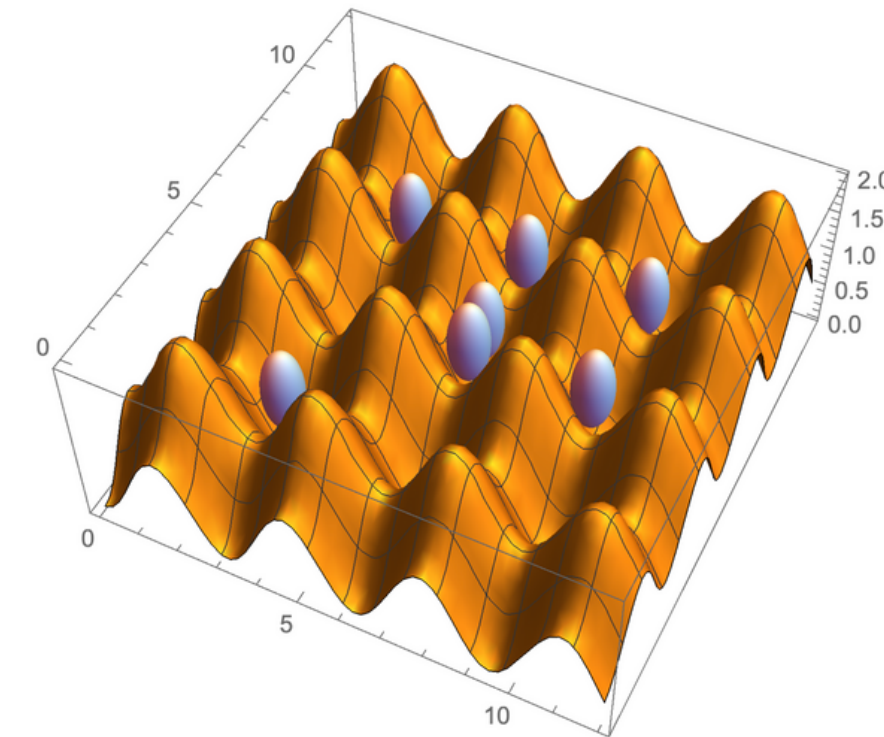


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Modelos con los que estamos trabajando

Bose-Hubbard

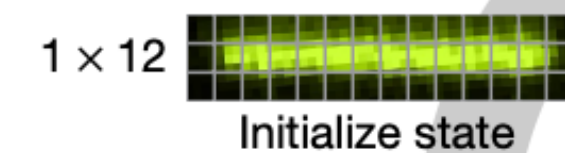
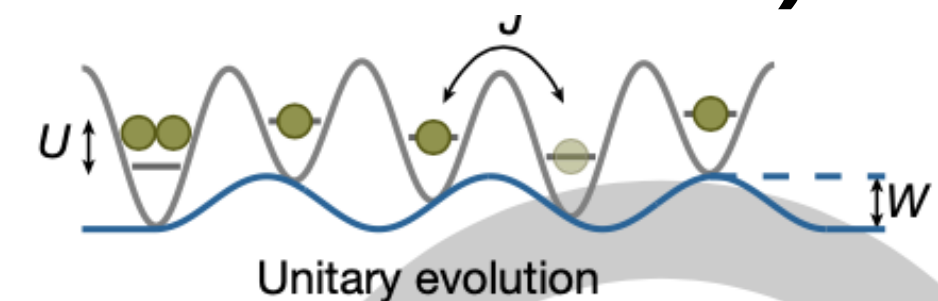
$$\hat{H}_{BH} = \underbrace{-J \sum_{\langle i,j \rangle} \hat{a}_i^\dagger \hat{a}_j}_{\text{Energía Cinética}} + \underbrace{\frac{U}{2} \sum_{i=1}^L \hat{n}_i (\hat{n}_i - 1)}_{\text{Energía Potencial}}$$



Aubry-André (se introduce desorden en el modelo de BH)

$$H = -J \sum_{\langle i,j \rangle} \hat{b}_i^\dagger \hat{b}_j + \frac{U}{2} \sum_i \hat{n}_i (\hat{n}_i - 1) + \underbrace{W \sum_i \cos(2\pi\beta i + \phi) \hat{n}_i}_{\text{Desorden}}$$

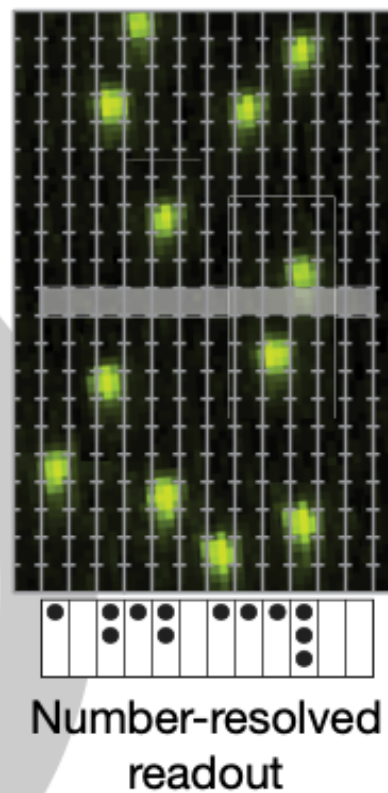
$$D = \frac{(N + L - 1)!}{N!(L - 1)!}$$



1 × 12
Initialize state



680 nm I
Mott insulator



Number-resolved readout

Modelos con los que estamos trabajando

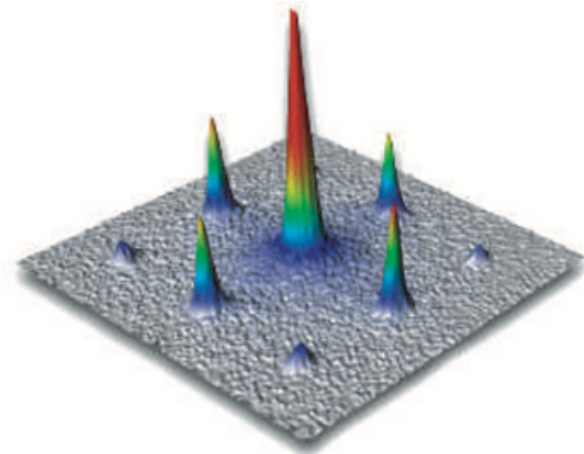
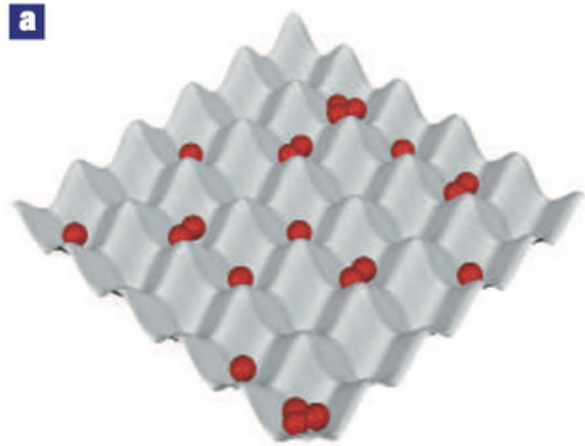
Bose-Hubbard

Energía Cinética

Energía Potencial

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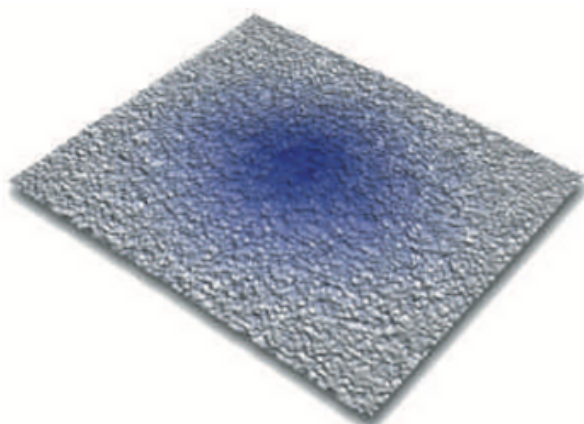
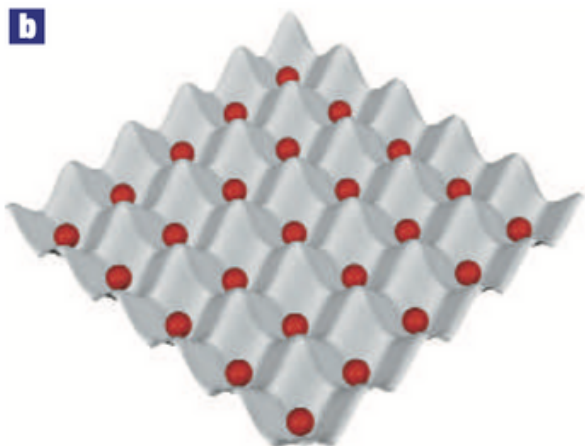
Estado superfluido



$$U/J \ll 1$$

En los dos límites el sistema es integrable.

aislante de Mott



$$U/J \gg 1$$

$$U=0; J=0;$$

[1] Bloch, I. Ultracold quantum gases in optical lattices. Nature Phys 1, 23–30 (2005).

[2] M. Greiner, O Mandel, T Esslinger, I Bloch Quantum phase transition from a superfluid to a Mott insulator in a gas of ultracold atoms - nature, (2002)

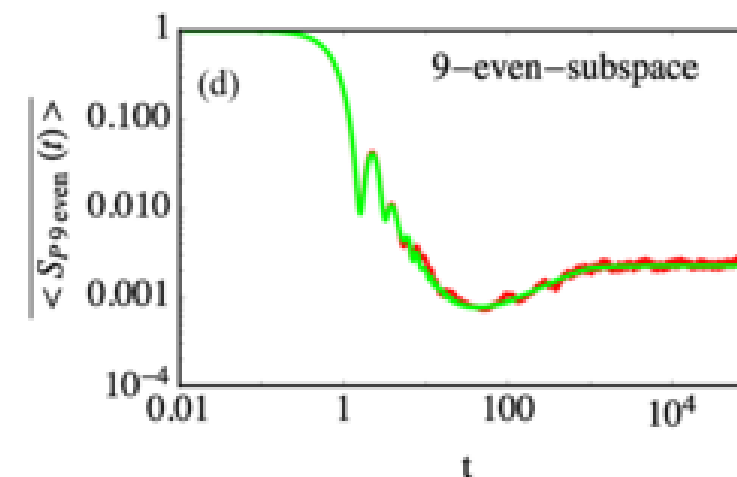
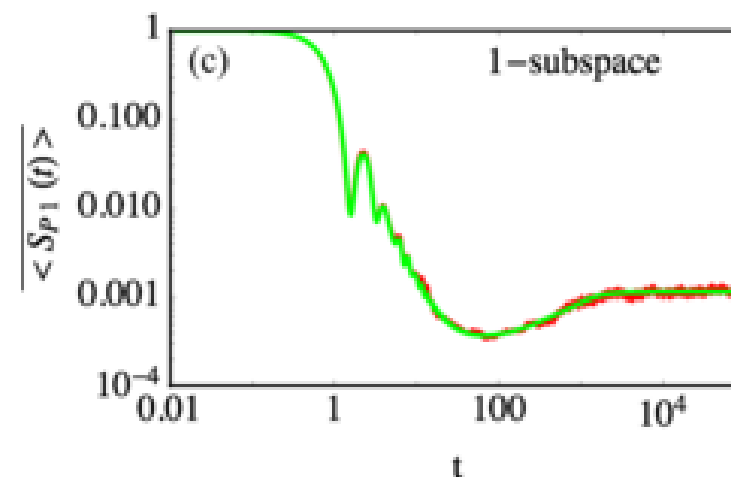
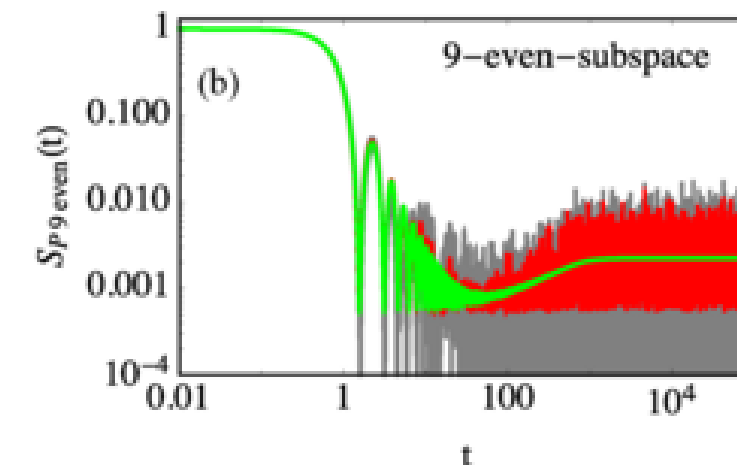
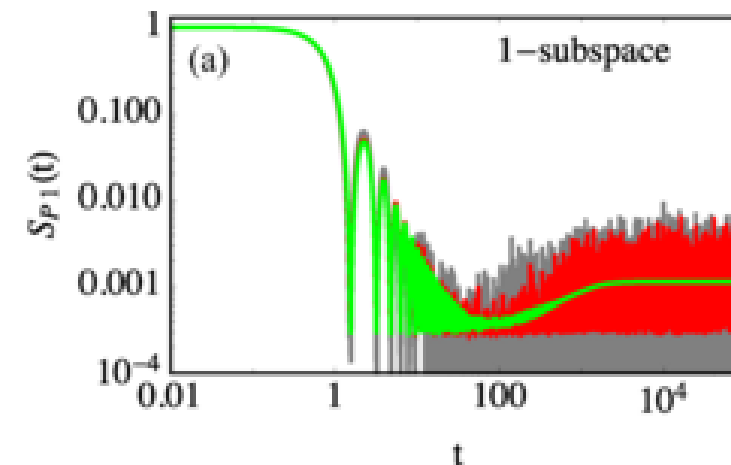
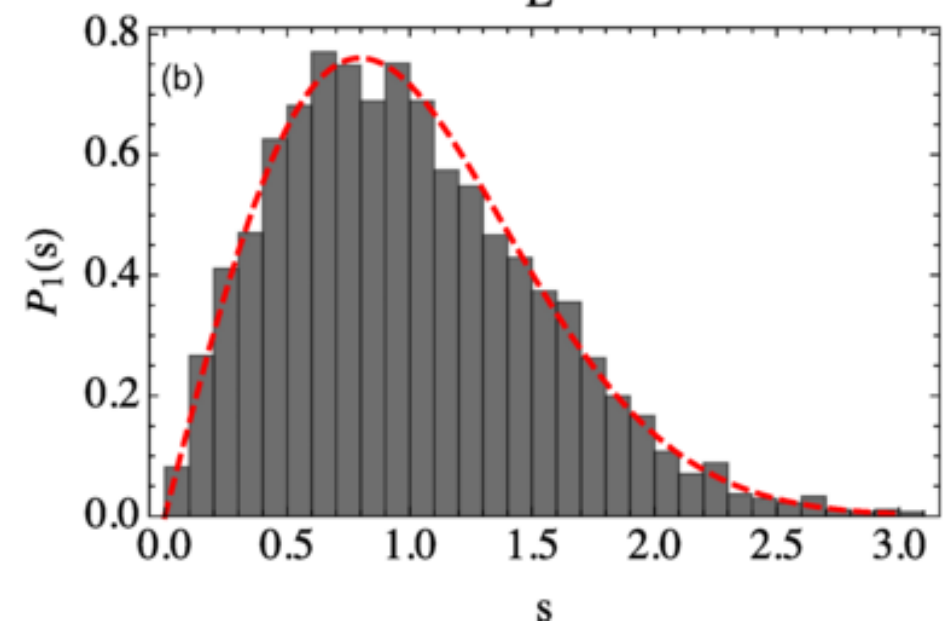
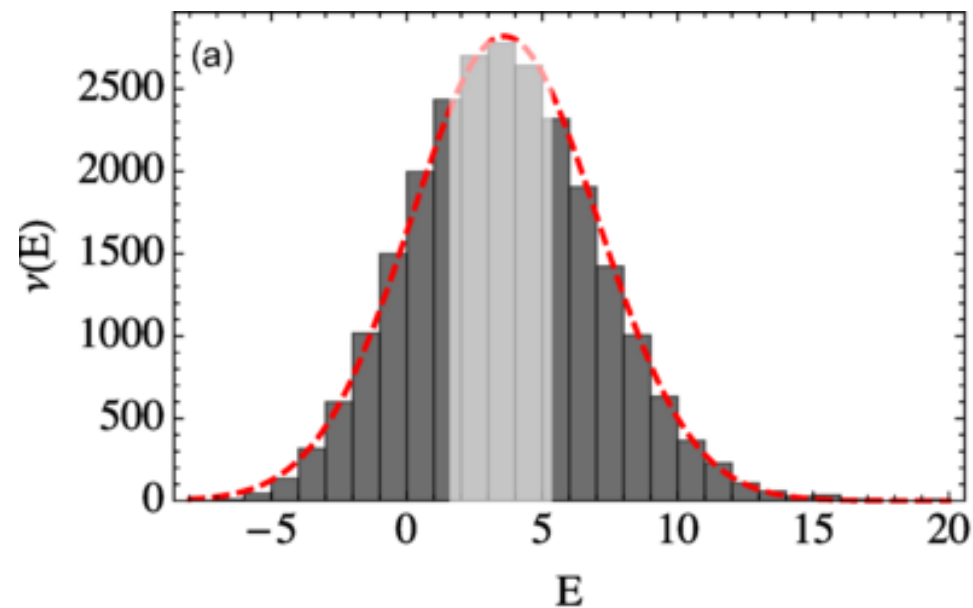
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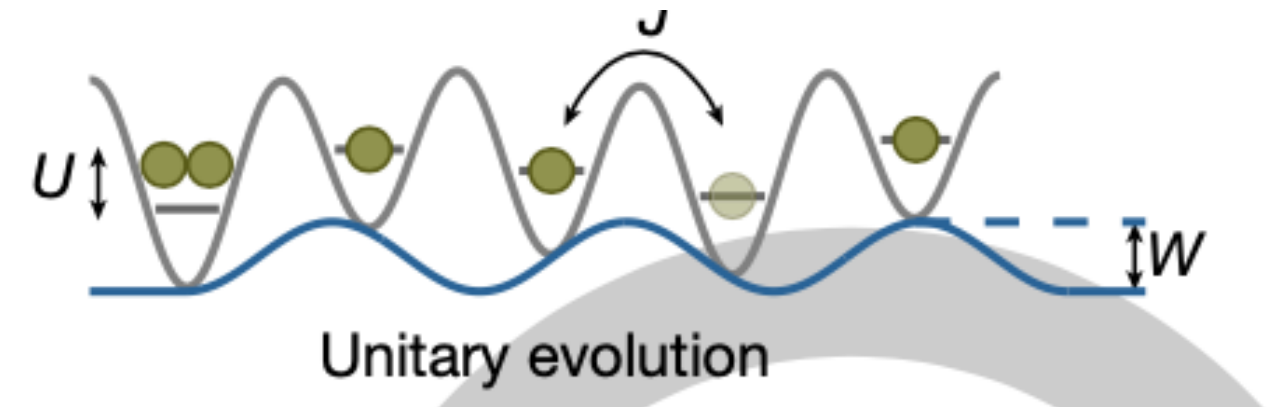


Modelos con los que estamos trabajando



Aubry-André (Modelo de Bose-Hubbard con desorden)

$$H = -J \sum_{\langle i,j \rangle} \hat{b}_i^\dagger \hat{b}_j + \frac{U}{2} \sum_i \hat{n}_i(\hat{n}_i - 1) + \underbrace{W \sum_i \cos(2\pi\beta i + \phi) \hat{n}_i}_{\text{Desorden}}$$



Carlos Diaz Mejia,¹ Javier de la Cruz,¹ Sergio Lerma-Hernández,² and Jorge G. Hirsch¹

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²*Facultad de Física, Universidad Veracruzana,
Circuito Aguirre Beltrán s/n, Xalapa, Veracruz 91000, Mexico*

(Dated: March 18, 2022)

Abstract

$$H = -J \sum_{\langle i,j \rangle} \hat{b}_i^\dagger \hat{b}_j + \frac{U}{2} \sum_i \hat{n}_i (\hat{n}_i - 1) + \underbrace{W \sum_i \cos(2\pi\beta i + \phi) \hat{n}_i}_{\text{Desorden}}$$

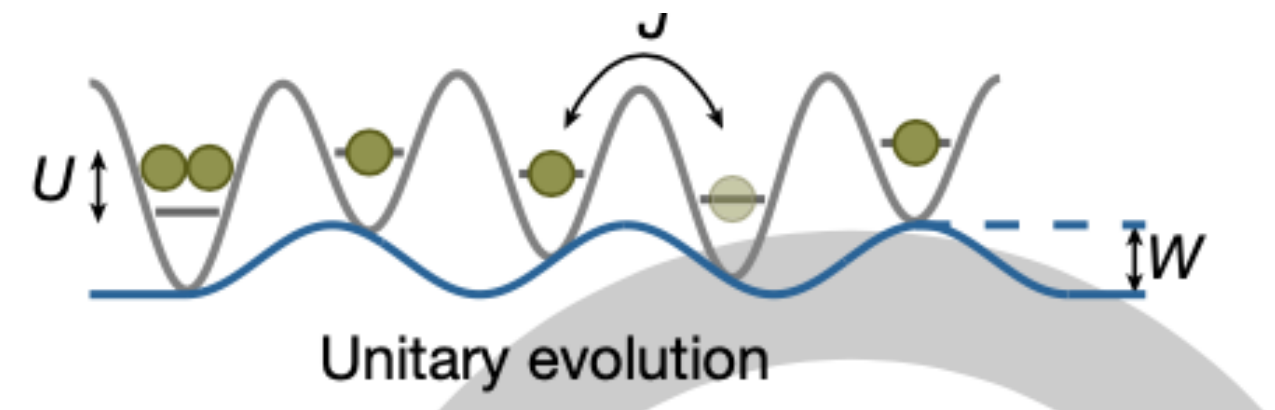
Presentamos un estudio detallado de la evolución temporal de 3 diferentes observables para los estados de número del modelo de Aubry-André

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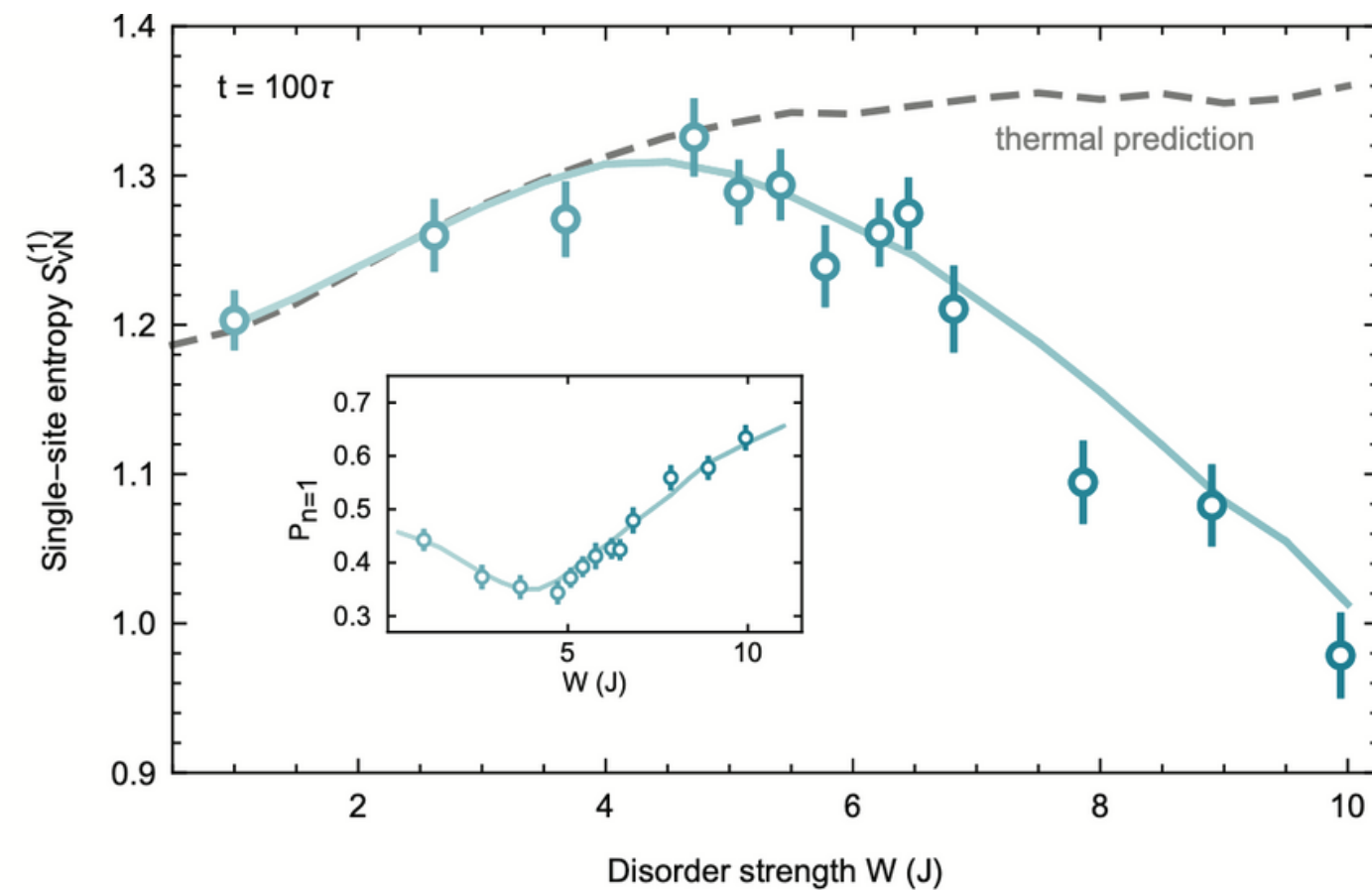
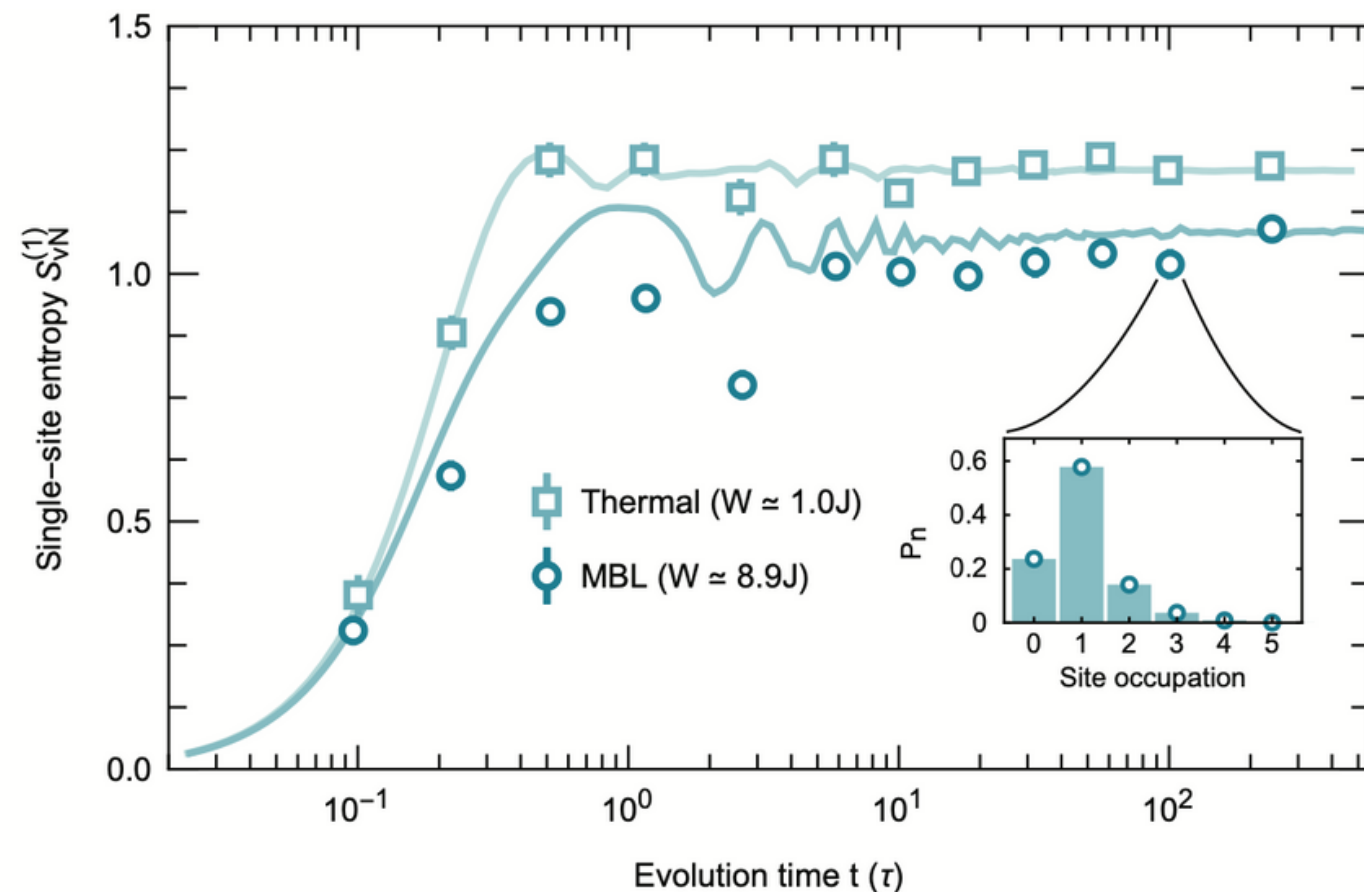
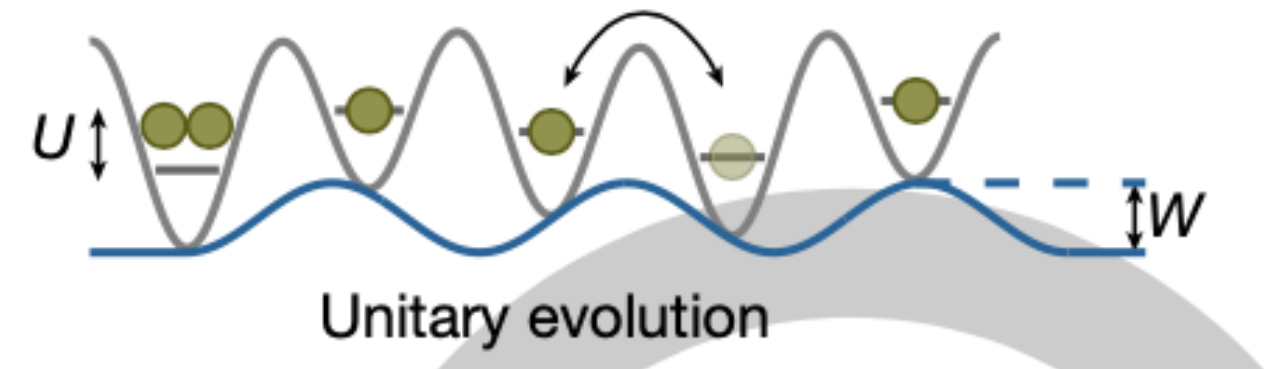
$$n_1^q = \sum_{i=0}^8 i p_i^q, \quad \text{and} \quad S_1^q = - \sum_{i=0}^8 p_i^q \ln p_i^q.$$

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Desorden



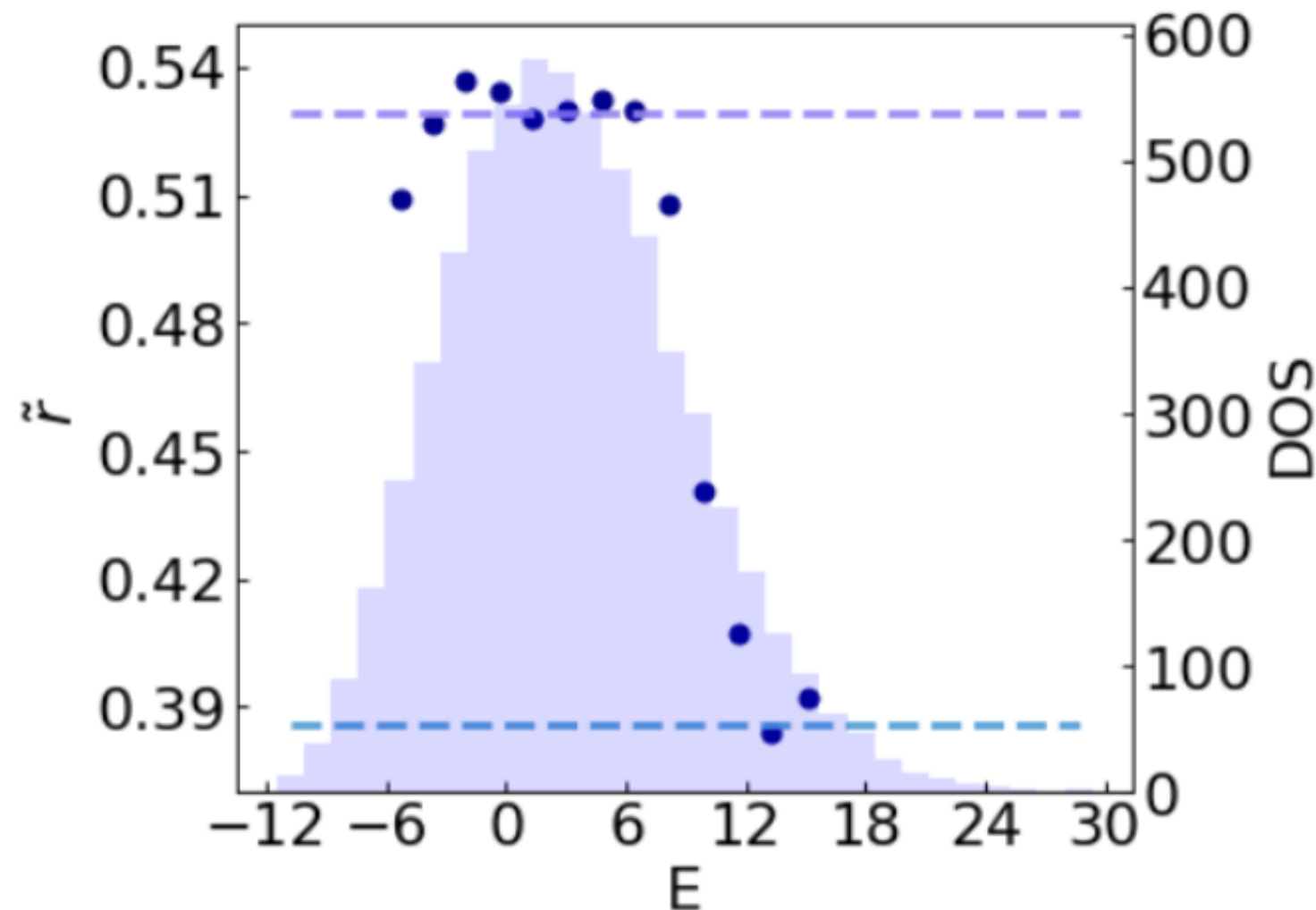
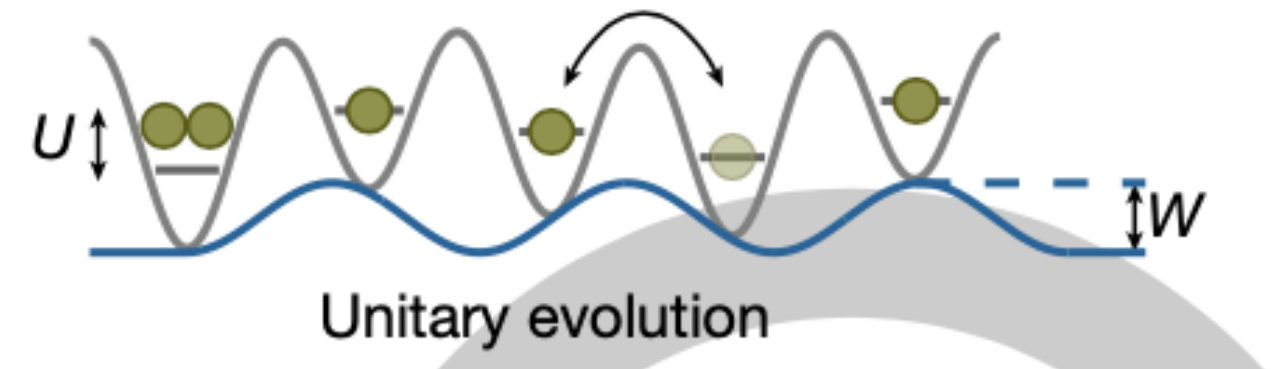
Probing entanglement in a many-body-localized system
 A Lukin, M Rispoli, R Schittko, ME Tai, AM Kaufman...
 Science, 2019

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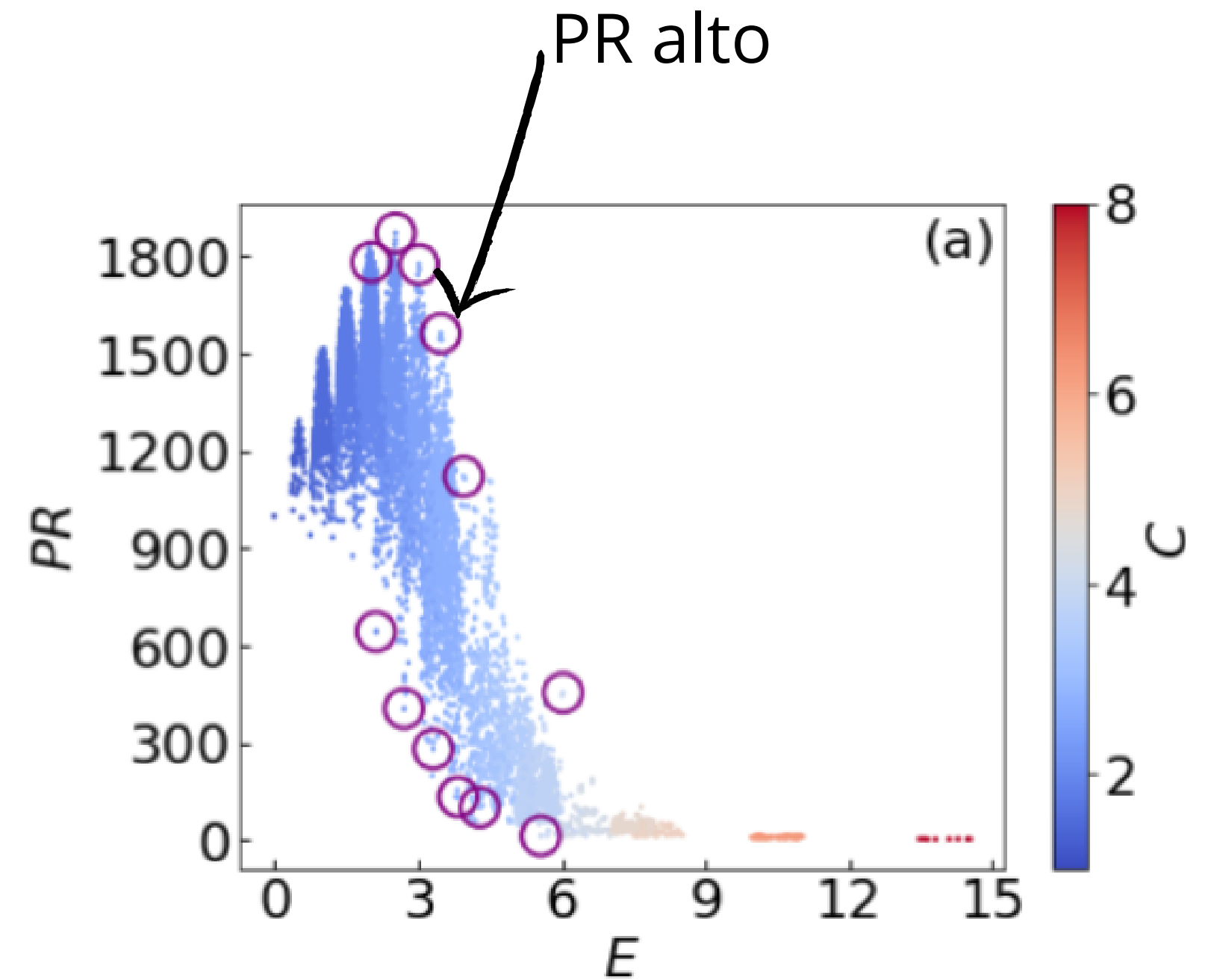


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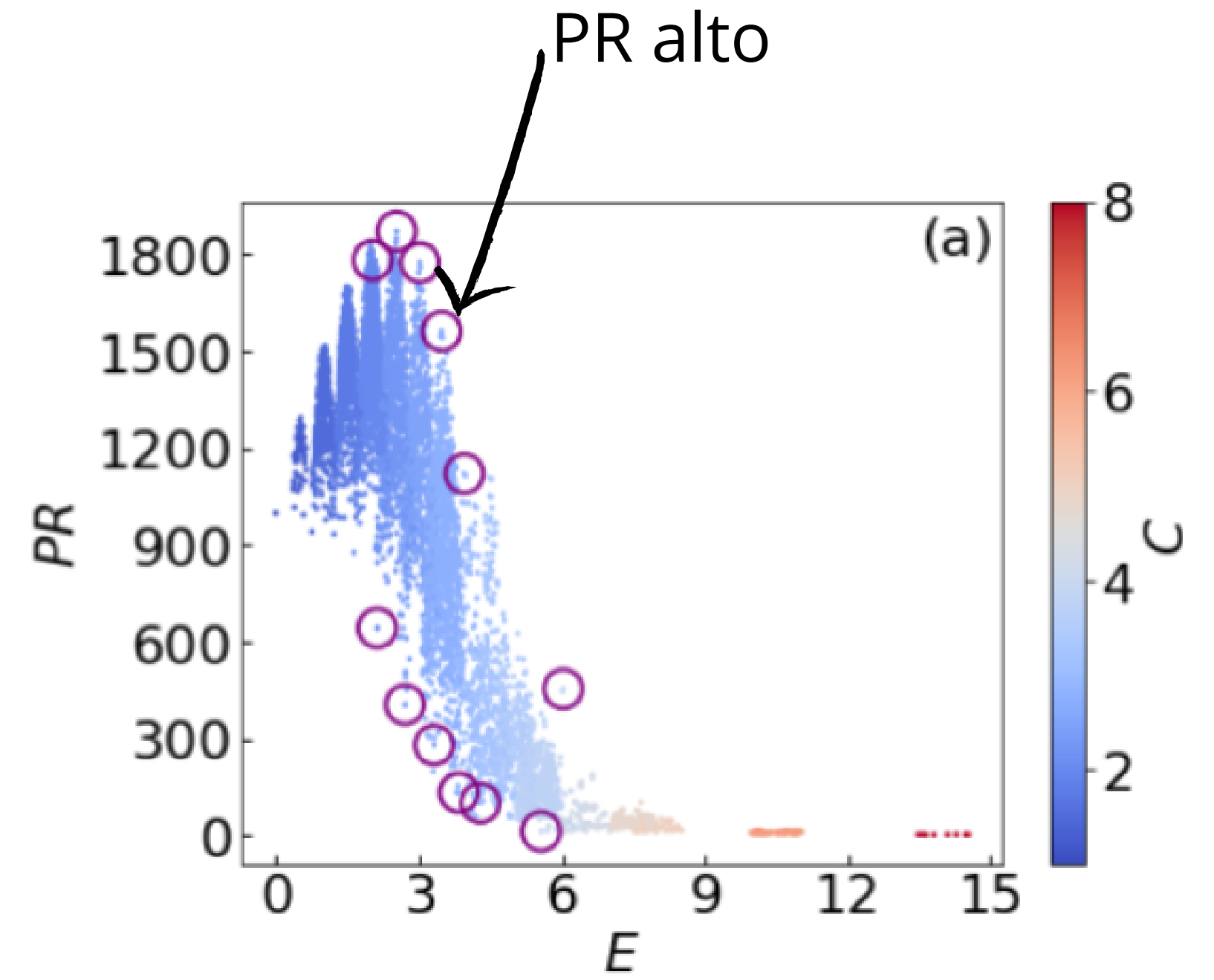
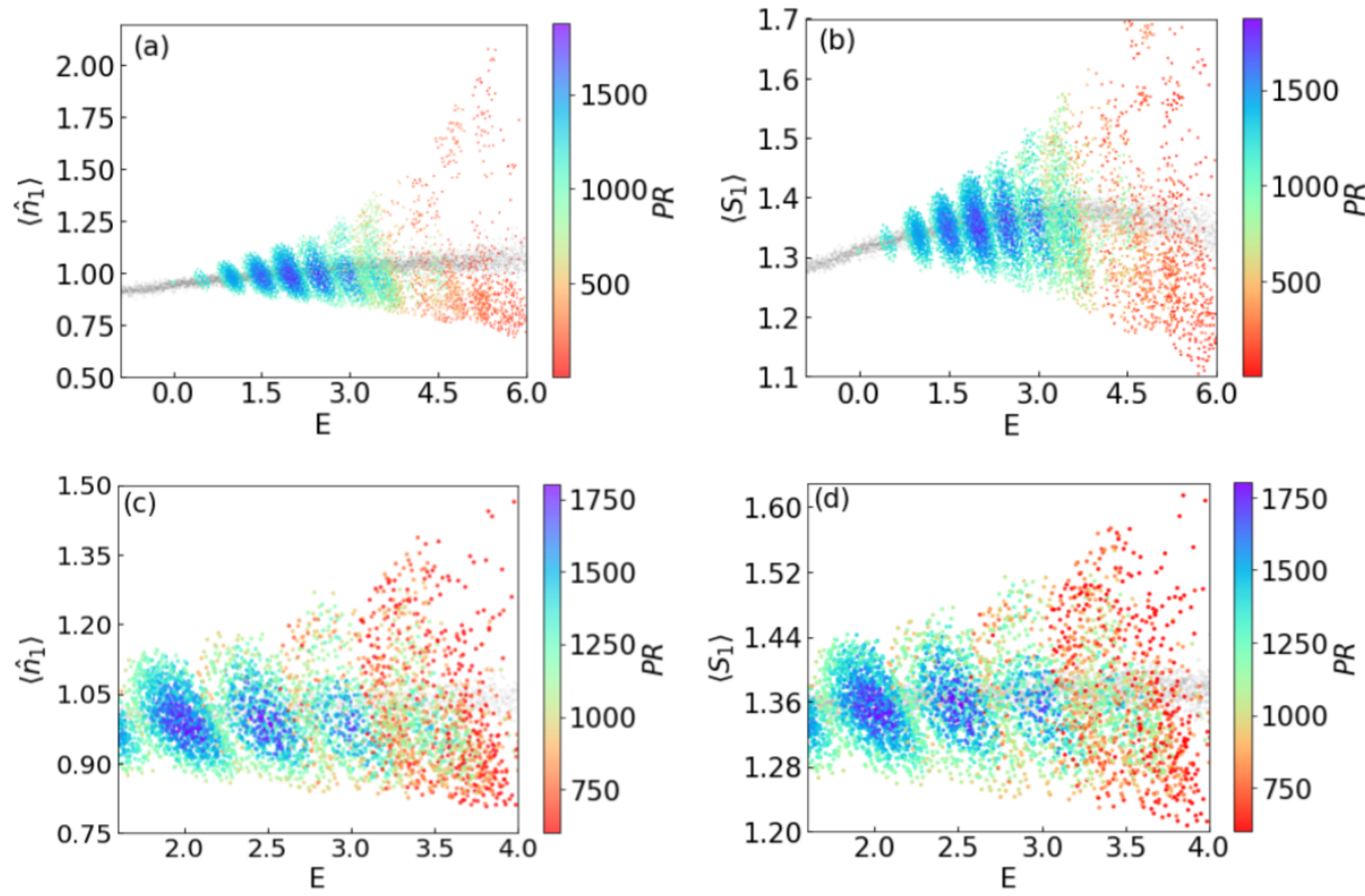
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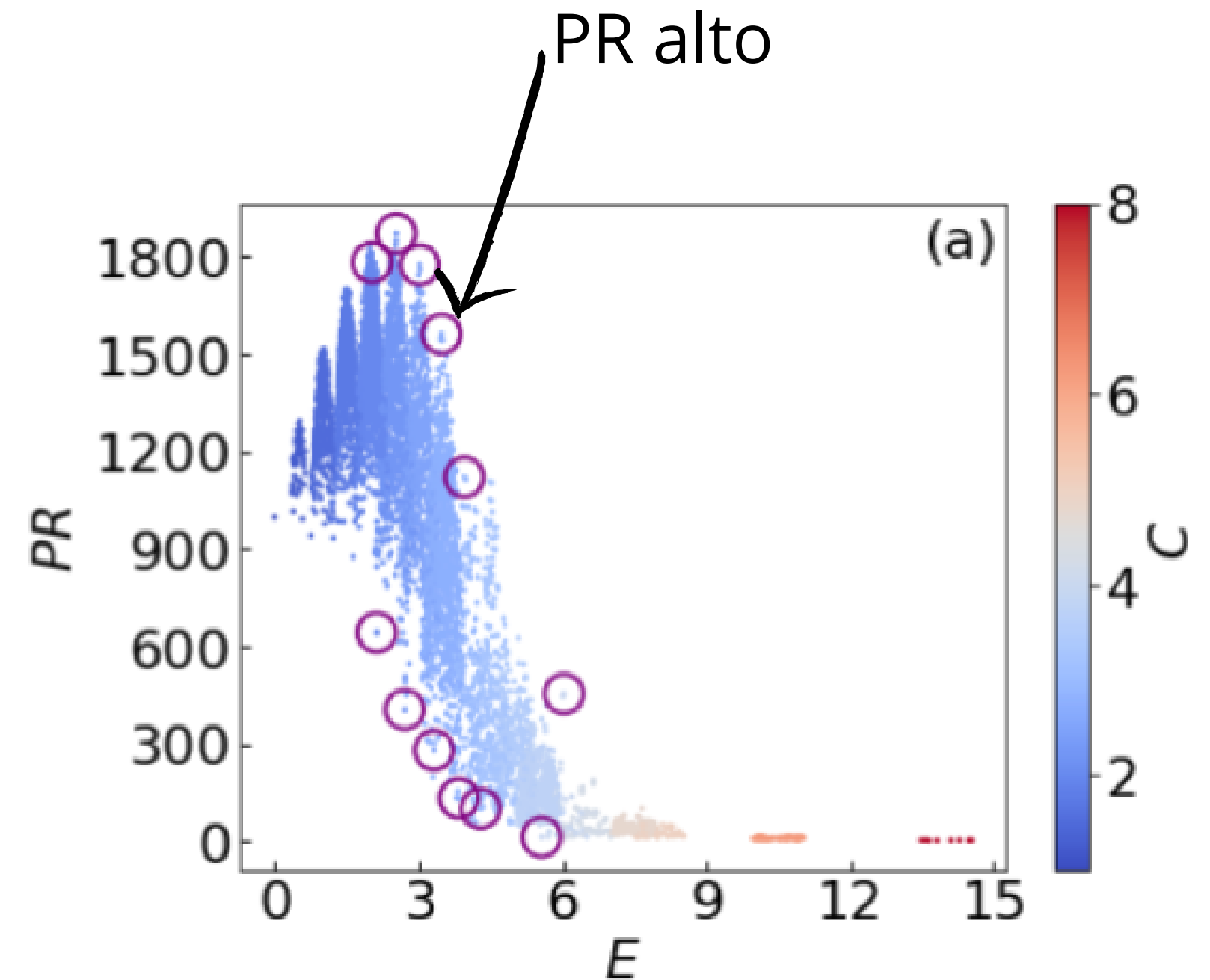
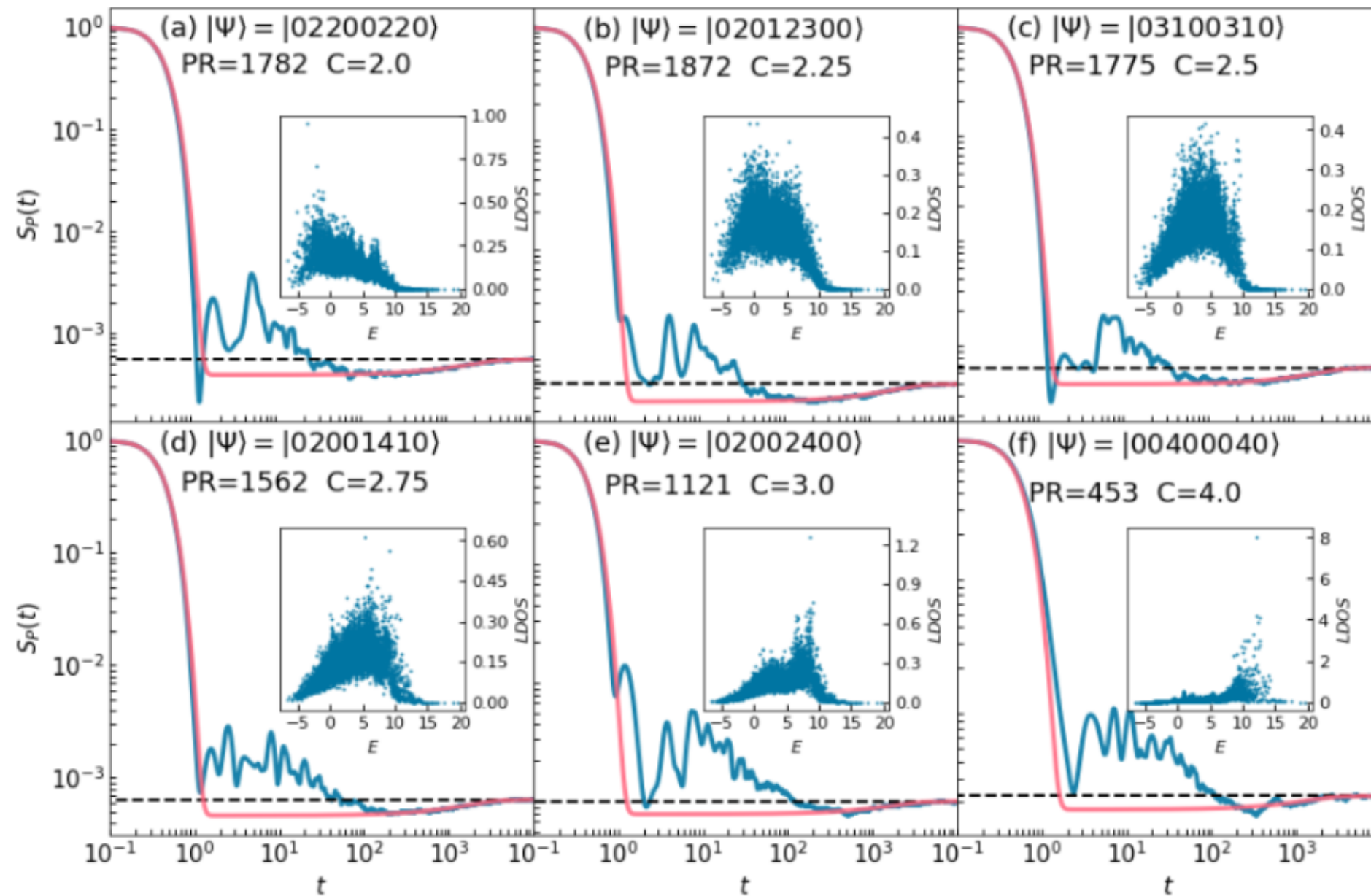
Estados Térmicos



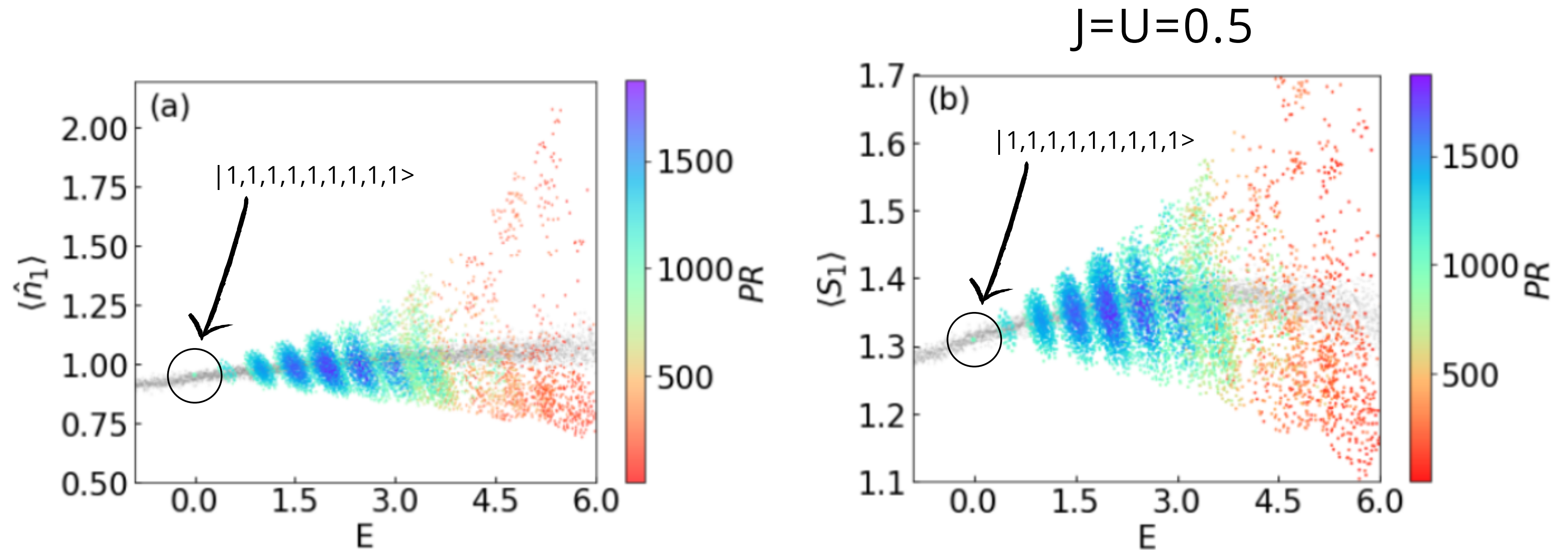
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Número de partículas y entropía de entrelazamiento para los autoestados del sistema (gris) y para los estados de Fock (color) a $t= 10^5$

!Gracias!