Low dimensional ultracold atom gases

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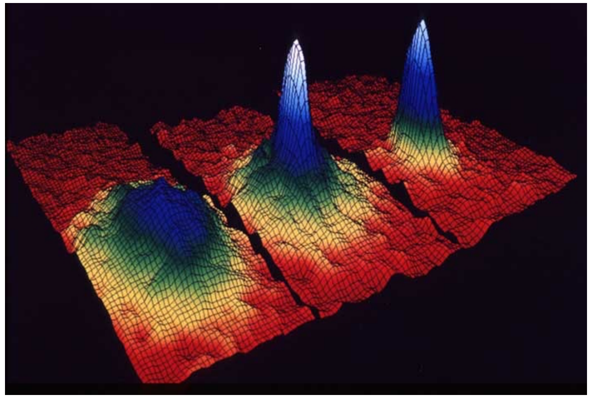
Recall of last year's PhD day's presentation

1. **The system:**
   Low dimensional strongly-interacting ultracold Bose gases

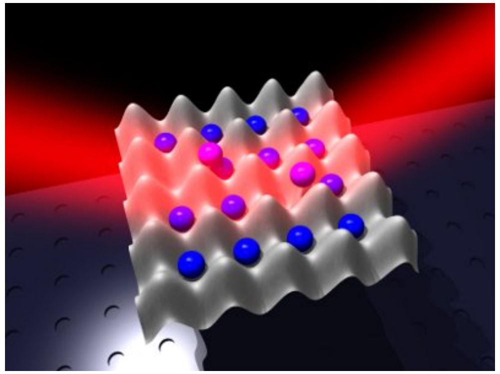


2. **Experimental relevant:**

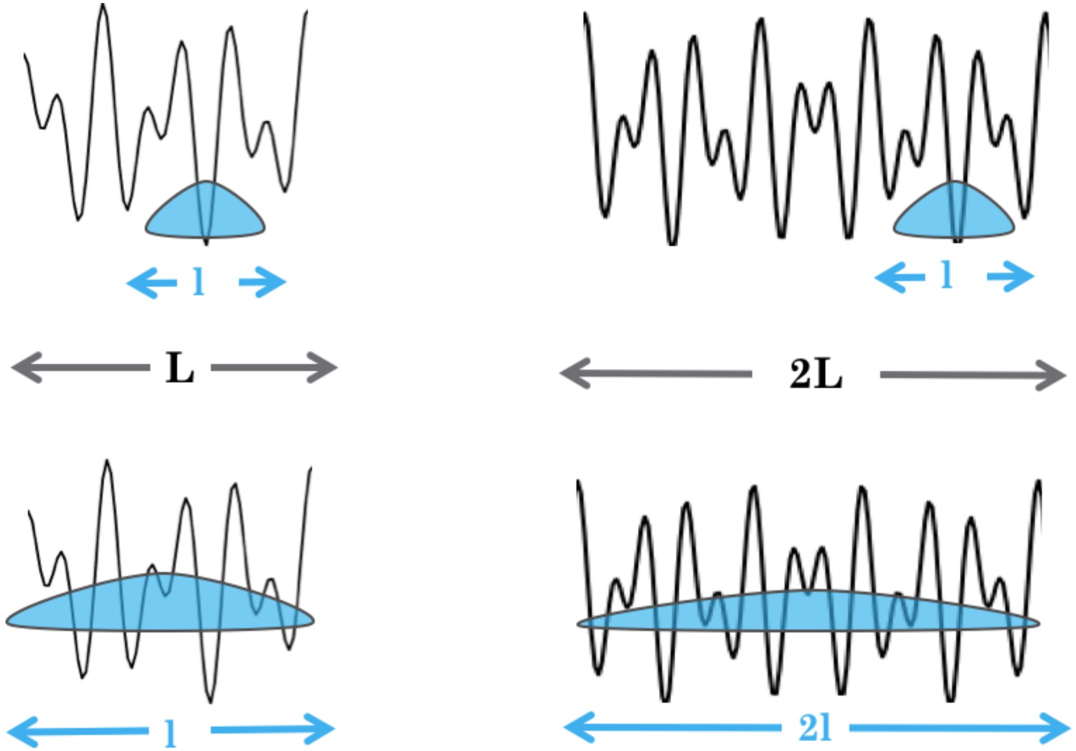
- Controllable and measureable
- Good candidate for quantum simulators

3. **Last year's PhD day:** Tan's contact

- Link to: interaction energy, grand potential, entropy…
- Effect of trap and temperature
- Maximum as a function of temperature: signature the fermionization
- Accepted by PRL



1D quasi-periodic lattices and localization (non-interacting)



Localizied state : IPR $\sim L^0$

Inverse partition ratio (IPR):

$$\mathrm{IPR} = \frac{\int dx\, |\psi(x)|^4}{\left[\int dx\, |\psi(x)|^2\right]^2}$$

~ inverse of the typical size of the state

Extended state : IPR $\sim L^{-1}$

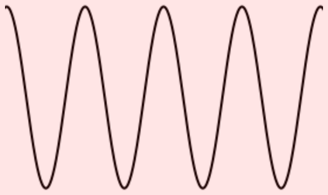
- **What we study: 1D quasi-periodic system:**

$$V(x) = \frac{V_1}{2}\cos(2k_1 x) + \frac{V_2}{2}\cos(2k_2 x + \varphi)$$

Interest!
Can be realized by ultracold atom experiment

-- Collaboration with Group of Prof. M. Inguscio and G. Modugno (Italy)

1D periodic lattices

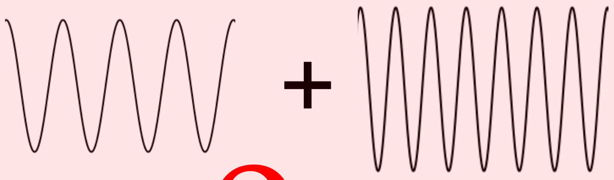


→ All state are extended

1D disordered system

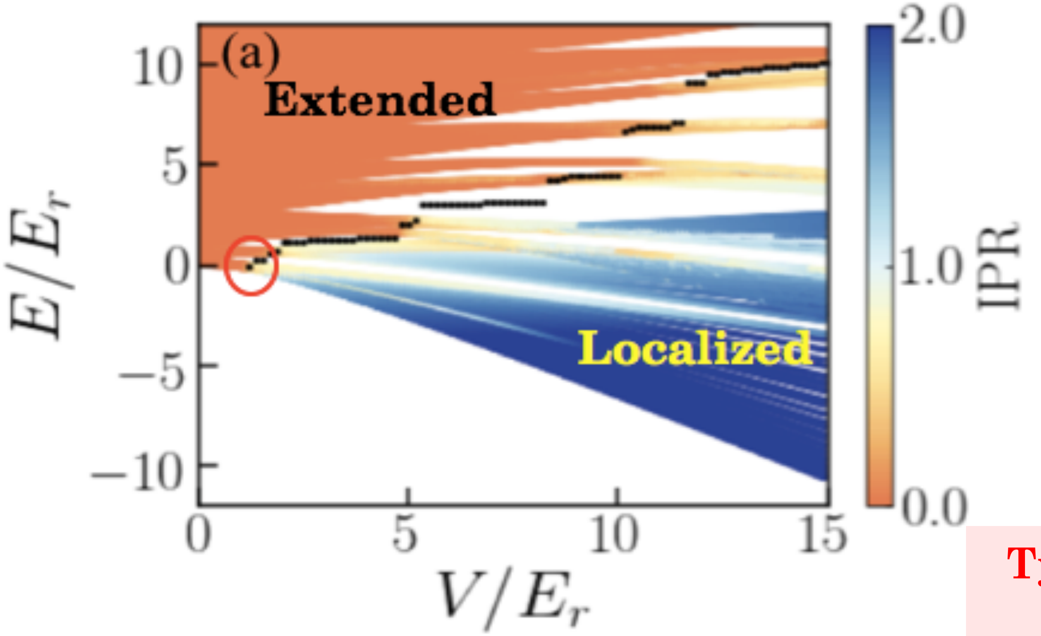
→ All state are localized

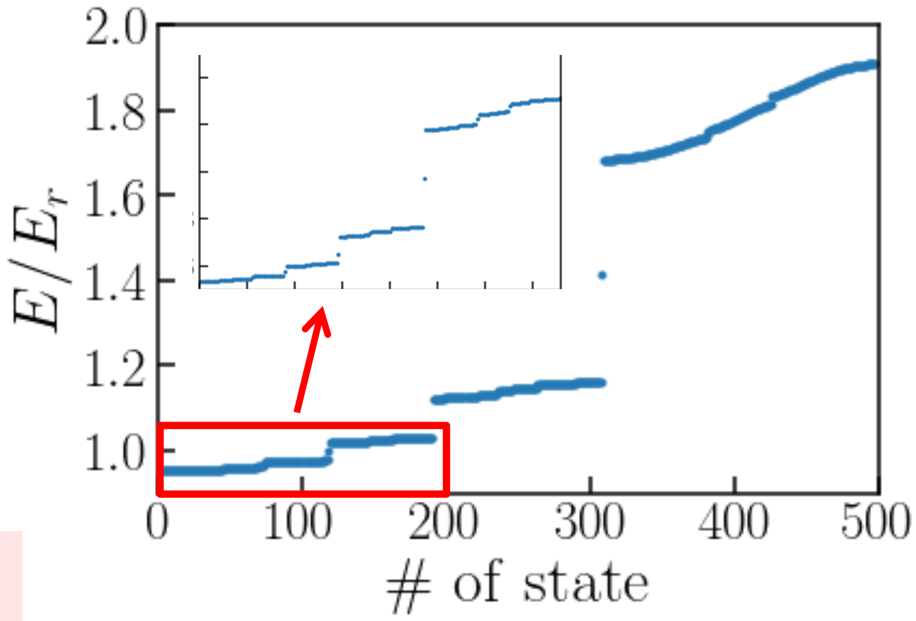
1D quasi-periodic lattices

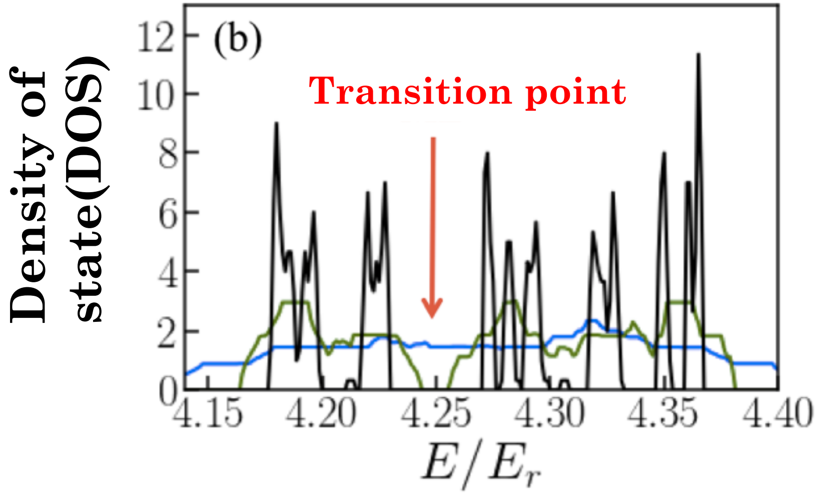


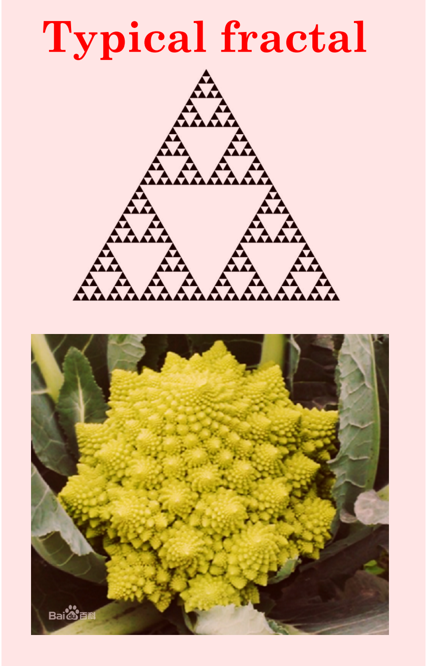
→ ?

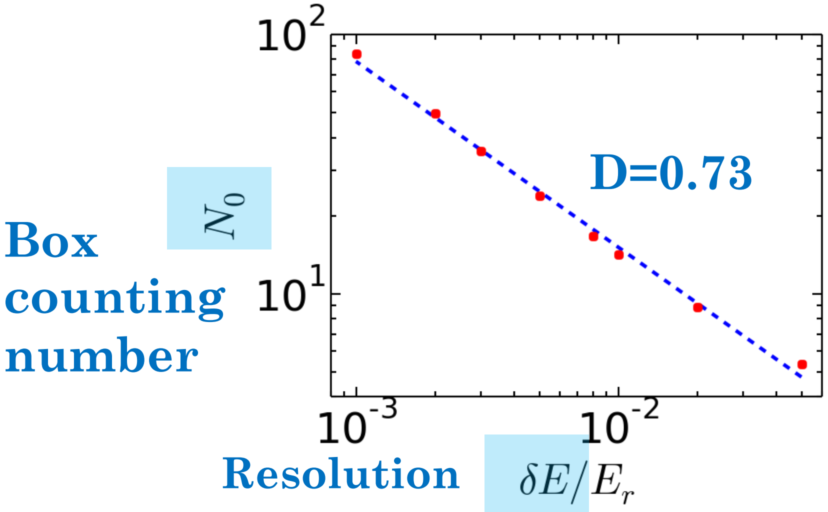
The energy spectrum and fractal behavior (non-interacting)



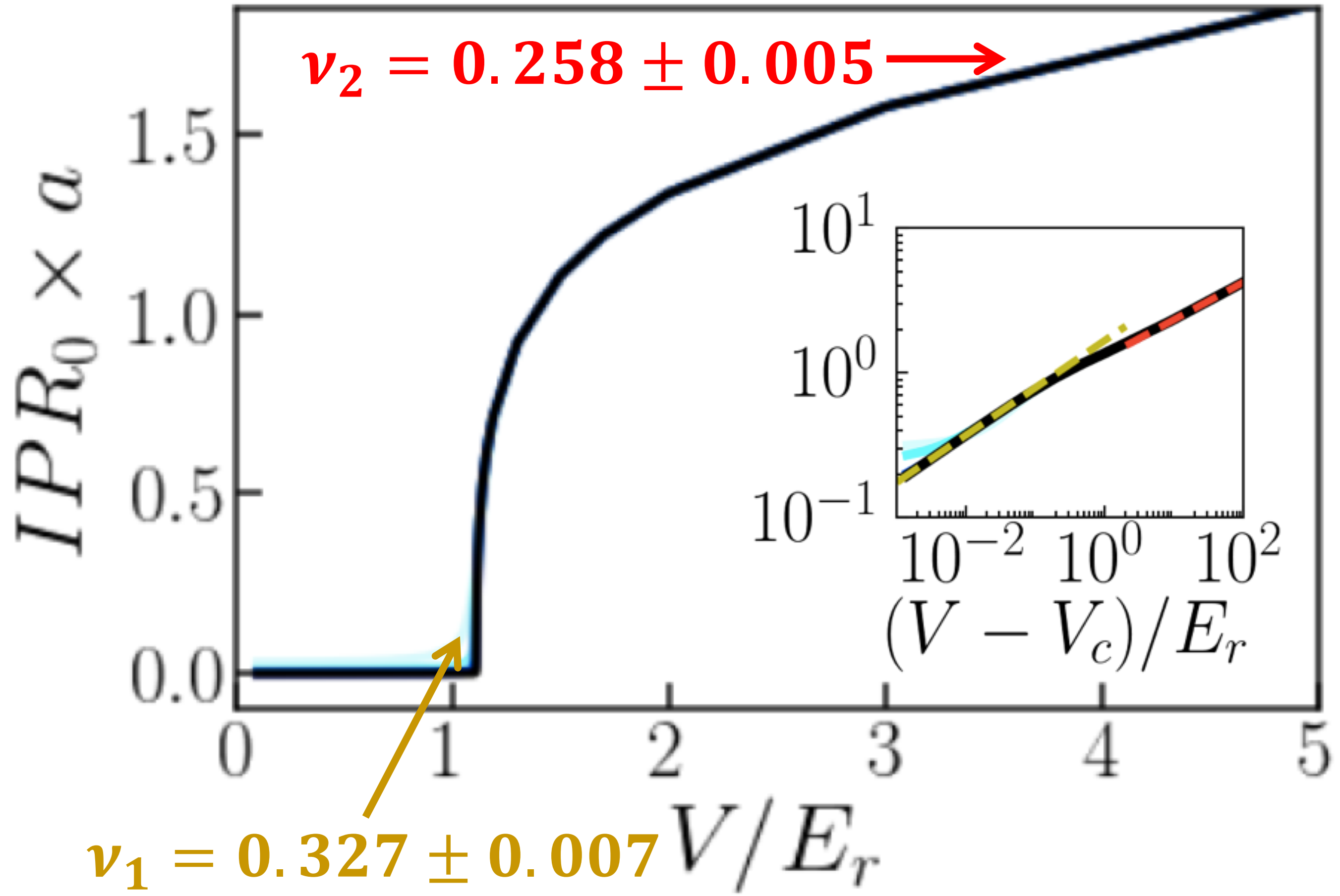








The energy spectrum and critical potential (non-interacting)



Critical potential:

$$V_c/E_r \simeq 1.112 \pm 0.002$$

Perform a fit:

$$\mathrm{IPR}_0 \sim (V - V_c)^{\nu}$$

Ground state of a harmonic trap:

$$l \simeq a/\pi V^{1/4}$$

→ Useful for the next step: Consider **interaction**

The Bose-glass state (interacting case)

- Considering interactions
- Cold atoms in optical lattices can simulate electrons in solid

Single lattice

	Localized?	Gap?	Superfluid density ρ_s	Compressibility $\kappa = \frac{\partial n}{\partial \mu}$
Superfluid	No	Gapless	>0	>0
Mott-insulator	Yes	Gap	=0	=0
Bose-glass	Yes	Gapless	=0	>0

Quasi-periodic lattices

- Possible to calculate with quantum Monte-Carlo (QMC)

Questions?

- Recall of the low dimensional system and Tan‘s contact

- 1D quasi-periodic system:
- -- Fractal like energy spectrum
- -- Critical potential for localization

- Next step:
- -- Many-body case: Bose-glass state