Algebraic localization-delocalization transition in a biased 1D disorder potential

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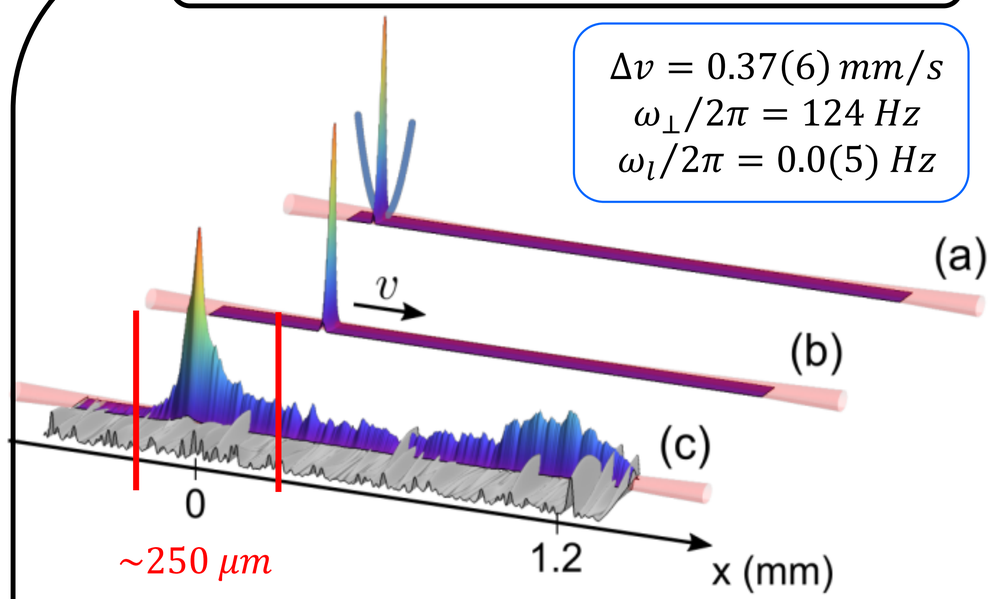
Anderson localization phenomena are strongly modified when adding bias force, that is equivalent to a voltage in condensed matter. Experimentally, we launch a non-interacting ^{39}K Bose-Einstein condensate in a 1D disordered potential induced by a far-off-resonance laser speckle, while controlling a bias force, We observe a transition between algebraic localization and delocalization as a function of our control parameter that is the relative strength of the disorder against the bias force. We demonstrate that the transition is intrinsically energy independent and that the initial velocity of the wave-packet only plays a role through an effective disorder strength due to the correlation of the disorder.

Experiment

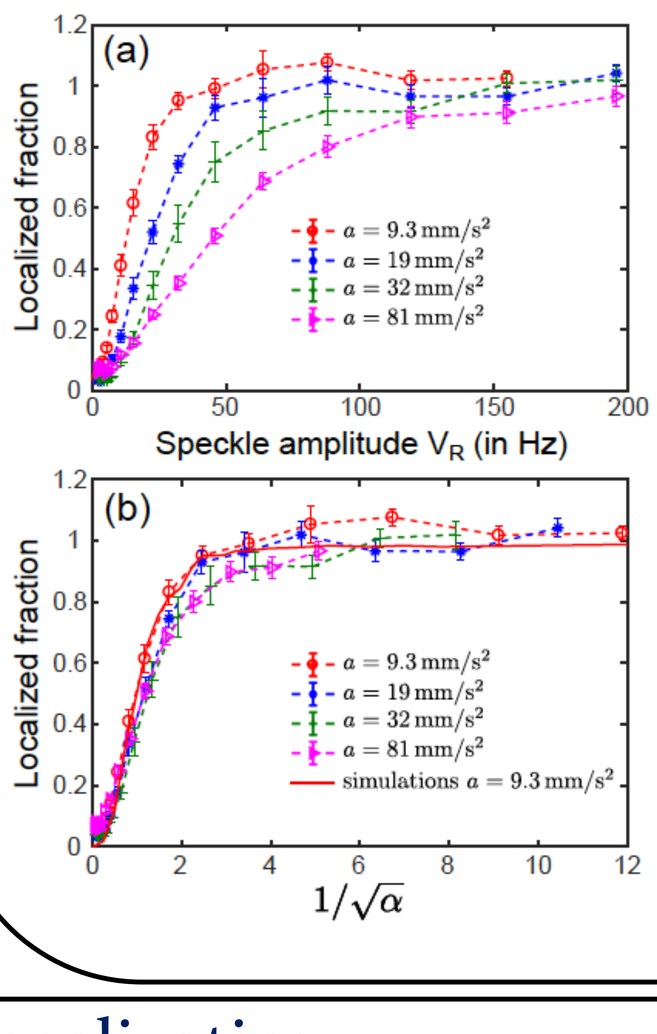


Relevant energy scales:

- Correlation energy $E_\sigma = \hbar^2/2m\sigma^2$
- Force $E_a = \hbar^{2/3} m^{1/3} a^{2/3}$
- Disorder strength V_R
- $V^* = \hbar^{-2/3} m^{1/3} \hat{C}(0)^{2/3}$
- Propagation time energy $E_\tau = \hbar/\tau$
- Dimensionless relevant parameter $\alpha = \frac{\hbar^2 a}{\hat{C}(0)}$

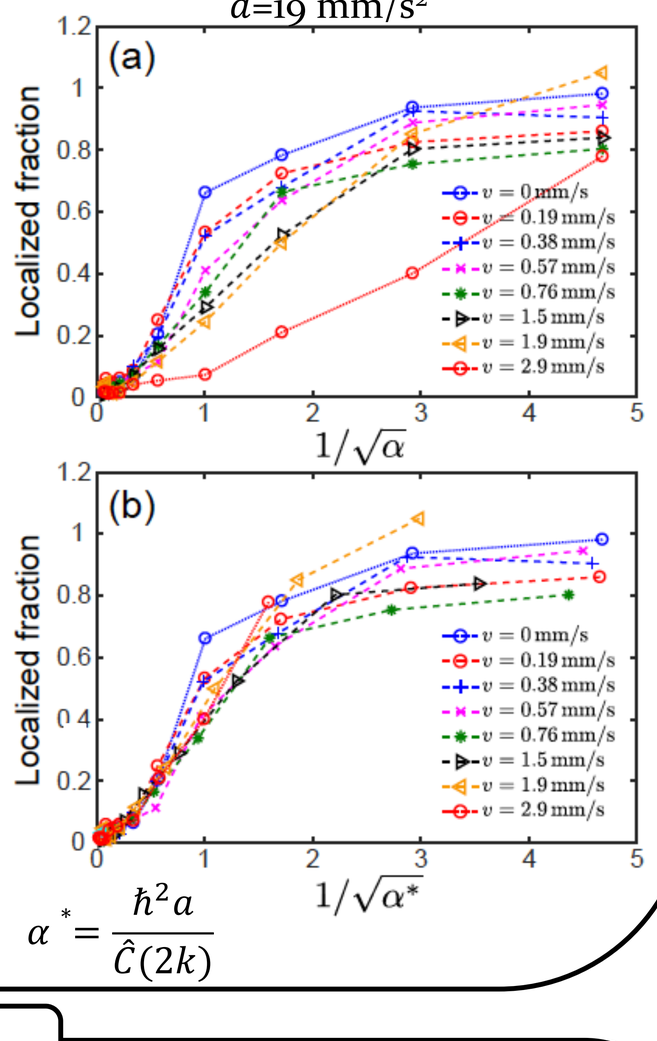
Localized/Delocalized transition

Without initial velocity



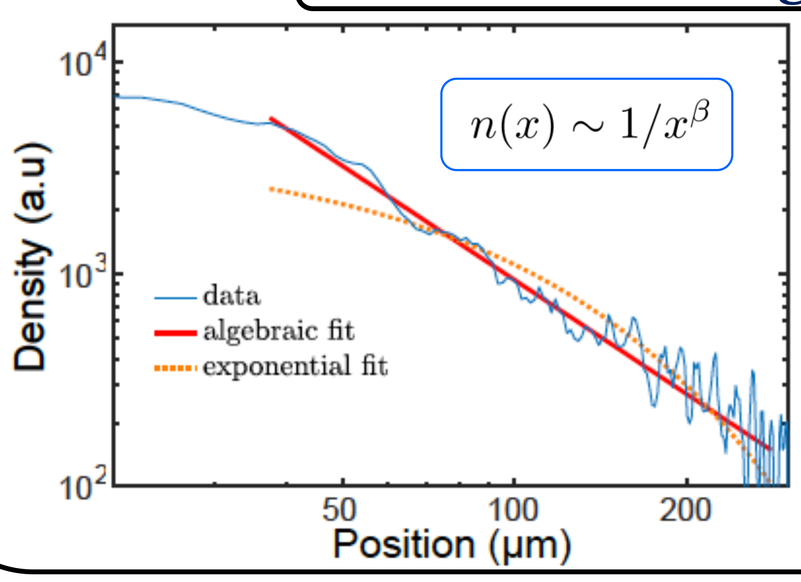
With initial velocity

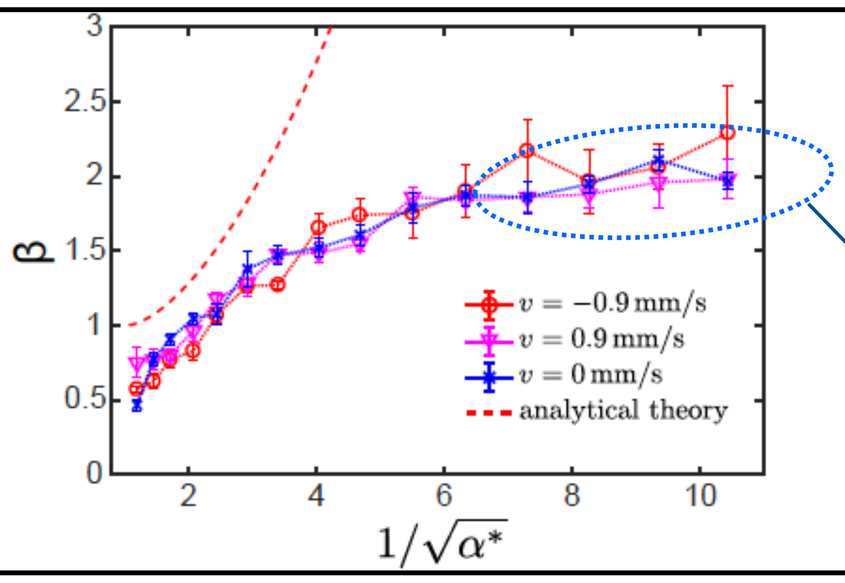
a=19 mm/s²



$$\alpha^* = \frac{\hbar^2 a}{\hat{C}(2k)}$$

Algebraic localization

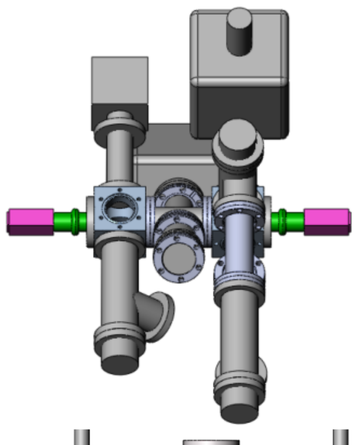




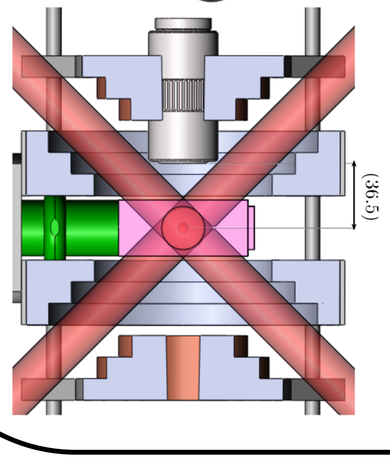
Difference with theory:
- Finite time
- Correlation disorder effect

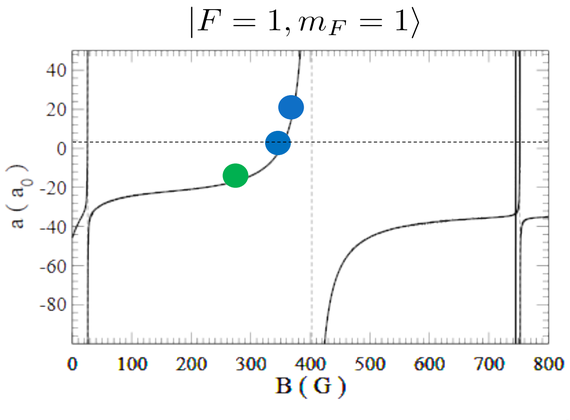
Algebraic exposant saturation in strong disorder
J. Billy et. al, Nature 453, 891 (2008)

New experimental setup

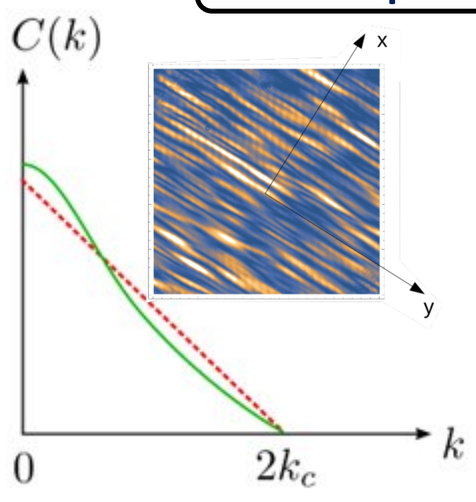


New sience chamber
-Simple 2D-3D MOT compact design
-D1 Gray molasses cooling
-Intermediate magnetic trapping
-Rapid evaporation close to a Feshbach resonance (few seconds)
-Little eddy currents
-Diffraction-limited imaging along two axes (NA 0.28)





1D speckle disorder



$$\sigma_y, \sigma_z \gg \sigma_x, l_\perp$$
$$l_\perp = \sqrt{\hbar/2m\omega_{r1D}} \approx 1\,\mu m$$

$\sigma_x = 1/k_c = 0.34(1)\,\mu m$
$\sigma_y = 4.3(1)\,\mu m$
$\sigma_z = 4.7(1)\,\mu m$

$\hat{C}(k=0) = cV_R^2 \pi \sigma_x$
with $c = 1.26$

Perpectives

-Introducing interactions (many-body localization)
-AC conductivity measurements

-Spin mixtures
-1D quantum droplets