Anomalous decay of coherence in a dissipative many-body system[1]

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MSc Seminar, 08 November 2019

[1]Bouganne, R., Aguilera, M. B., Ghermaoui, A., Beugnon, J., Gerbier, F. (2019). Anomalous decay of coherence in a dissipative many-body system. Nature Physics, 1-5.

Decoherence

- Destruction of interference phenomena due to couplings with the environment.
- Should be countered in quantum technology.
- Interaction of particles alters the dissipative dynamics $\Rightarrow$ strongly correlated systems are challenging.
- Experimental realizations: ultracold atoms

$$\mathcal{H}_{\mathrm{BH}} = -J \sum_{\langle i,j \rangle} a_i^\dagger a_j + \sum_i \left(\frac{U}{2} n_i(n_i - 1) + V_i n_i \right) \tag{1}$$

- J: nearest neighbour tunneling energy
- U: repulsive on-site interaction
- V_i: harmonic potential of the lattice

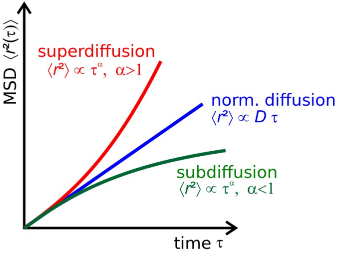
Phase transition:

$\frac{U}{J}$, $\frac{V_i}{J}$ low	$\longleftrightarrow$	$\frac{U}{J}$, $\frac{V_i}{J}$ high
superfluid		Mott insulator
atoms spread out over the lattice		atoms localized at sites
long range coherence		low coherence

Theoretical predictions[2]

For strongly interacting bosonic quantum gases:

- Slowly relaxing states emerge
- Anomalous diffusion in momentum space

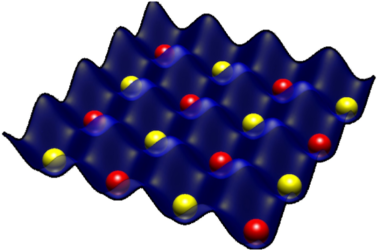


- Nearest neighbour coherence: $C_{\mathrm{nn}} \sim \frac{1}{\sqrt{t}}$
  - algebraic (slow), not exponential (fast) decoherence!

[2] Poletti, D., Barmettler, P., Georges, A., Kollath, C. (2013). Emergence of glasslike dynamics for dissipative and strongly interacting bosons. Physical review letters, 111(19), 195301.

Experimental setup

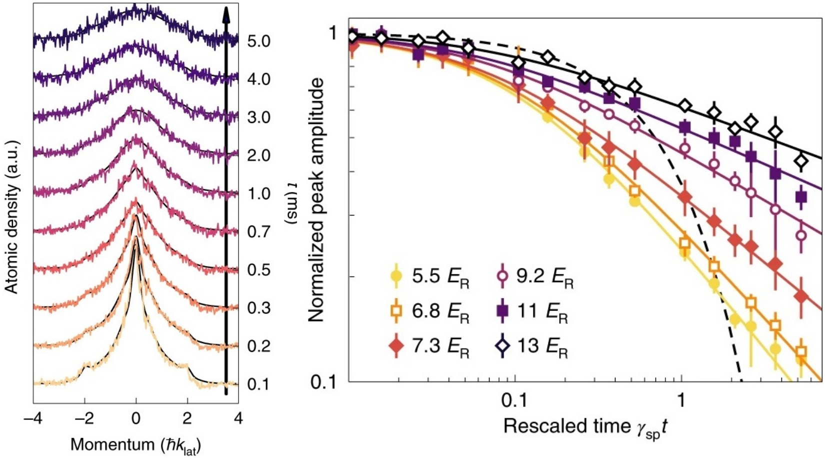
- Ultracold, bosonic ^{174}Yb atoms
- Independent 2 dimensional optical lattices ($V_\perp$ lattice depth)



- Dissipation: laser excitation $\Rightarrow$ repeated absorption - spontaneous emission cycles
- Measuring distribution in momentum space

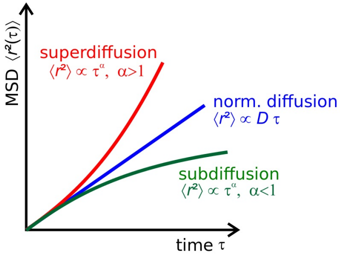
Momentum space

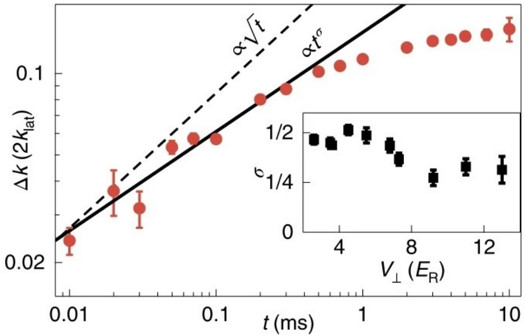
Time evolution of the peak amplitude:



Anomalous diffusion

Time evolution of the momentum width Δk:

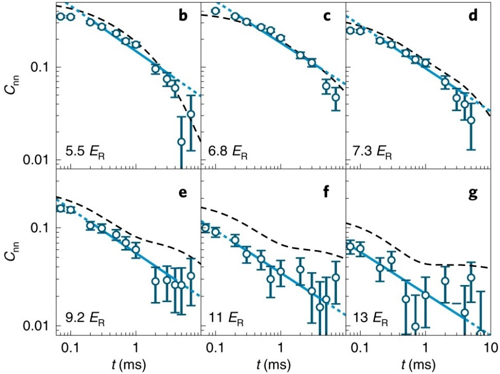


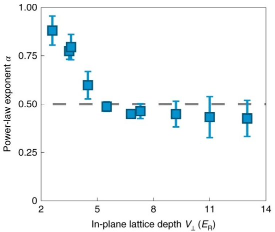


$\Rightarrow$ subdiffusion: lower power law than 1/2

Function fit on the peaks: $n(\boldsymbol{k}) = |W(\boldsymbol{k})|^2 \left(1 + \sum_{\boldsymbol{d}} C_{\mathrm{nn}} \cos(\boldsymbol{kd})\right)$

$C_{\mathrm{nn}} = \frac{1}{N} \sum_{\boldsymbol{r}} \left\langle a^\dagger_{\boldsymbol{r}+\delta} a_{\boldsymbol{r}} \right\rangle_\delta$





$\Rightarrow$ algebraic decoherence: $\sim 1/\sqrt{t}$

Summary

- Bose-Hubbard model: theoretical predictions for dissipative dynamics
- Experimental relization
  - ultracold atoms on optical lattices
  - dissipation: spontaneous emission
- Verified phenomena:
  - subdiffusion ($< \frac{1}{2}$ power law)
  - algebraic decoherence ($1/\sqrt{t}$)