Measurement catastrophes in quantum jammed states

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Local perturbations in quantum spin chains

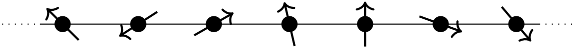
Our specific setup

Some results

Local perturbations in quantum spin chains

About the models we consider

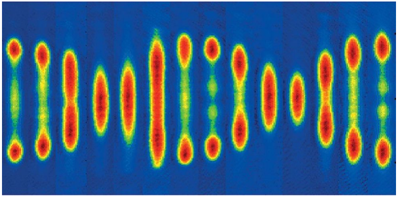
- Quantum spin chains:



- Unitary dynamics:

$$|\psi(t)\rangle = \mathrm{e}^{-\mathrm{i}tH}\,|\psi(0)\rangle$$

- Available experiments:



[T. Kinoshita, T. Wegner, et al (2006)]

Local perturbations: an analogy

[picture by Jonathan Cosens]

Effects of local perturbations are typically *cancelled* by dynamics

Local perturbations: an analogy

[picture by Jonathan Cosens]

- consider a state with clustering of correlations $\langle \sigma_{\ell_1}^{\alpha_1} \ldots \sigma_{\ell_n}^{\alpha_n} \rangle_c \to 0$, $\alpha_j \in \{x, y, z\}$, as $|\ell_i - \ell_j| \to \infty$
- apply an operator to few adjacent lattice sites
- time-evolve

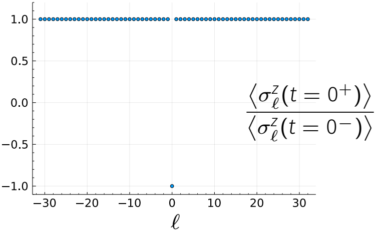
Effects of local perturbations are typically *cancelled* by dynamics

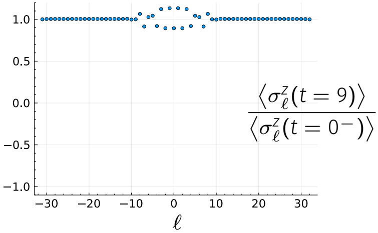
Local perturbations in quantum spin chains

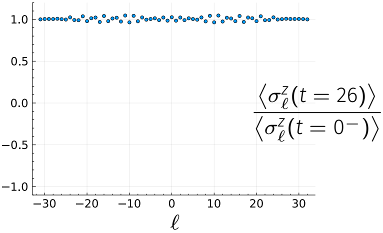
Effects of local perturbations are typically *cancelled* by dynamics

e.g.

$$H = -\sum_\ell \left(\sigma^x_\ell \sigma^x_{\ell+1} + \tfrac{1}{2}\sigma^z_\ell\right)$$
$$|\psi(0^-)\rangle = |GS\rangle$$
$$|\psi(0^+)\rangle = \sigma^x_0\,|\psi(0^-)\rangle$$







Local perturbations with everlasting macroscopic effects

The effects of some special perturbations do not fade away with time

e.g.

$$H = -\sum_\ell \left(\sigma^x_\ell \sigma^x_{\ell+1} + \tfrac{1}{2}\sigma^z_\ell\right)$$
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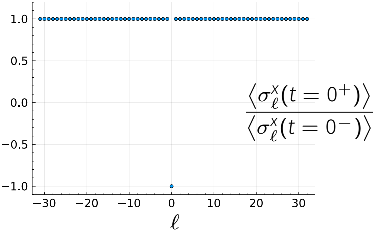
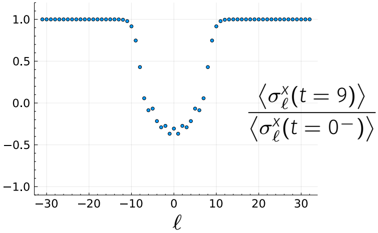
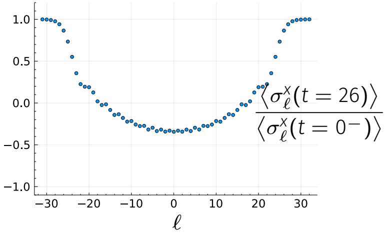






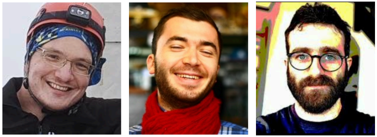
Local perturbations with everlasting macroscopic effects

- local transformation linking different symmetry broken GSs

Zauner, Ganahl, Evertz, Nishino, 2015
Eisler, Maislinger, 2020

- quantum jammed states

Zadnik, SB, Bidzhiev, Fagotti, 2021



- global quenches with semi-local charges

Fagotti, 2021

Our specific setup

Dual folded XXZ and jammed states

$$H = \mathcal{J} \sum_{\ell} \frac{1-\sigma^z_{\ell+1}}{2} (\sigma^x_\ell \sigma^x_{\ell+2} + \sigma^y_\ell \sigma^y_{\ell+2})$$

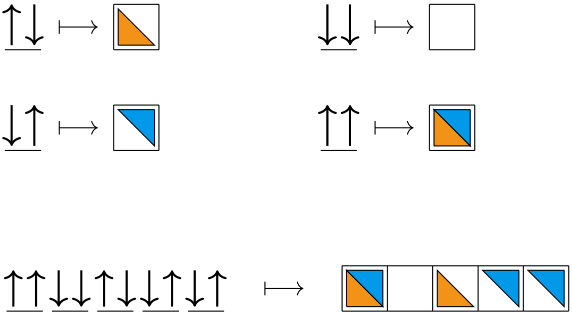
Interacting integrable model, special point of Bariev model

Constrained hopping:

Mapping to quasi-particle picture

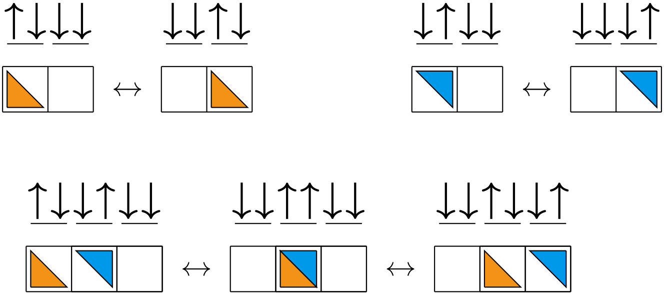
- divide the spins in couples
- associate a macro-site do each couple
- look at the spin-ups for the quasi-particle of the macro-site

e.g.



Mapping to quasi-particle picture: dynamics

$\uparrow\downarrow\downarrow \quad \longleftrightarrow \quad \downarrow\downarrow\uparrow$ translates to nearest-neighbor hopping with hardcore constraint



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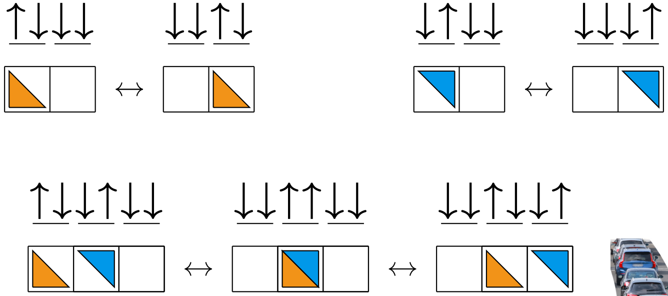
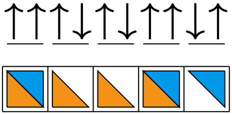


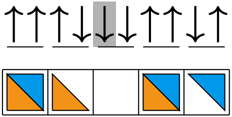
- the sequence of particles is preserved
- no possible move $\Rightarrow$ jammed state

Local-measurement protocol

1. Start from a jammed state



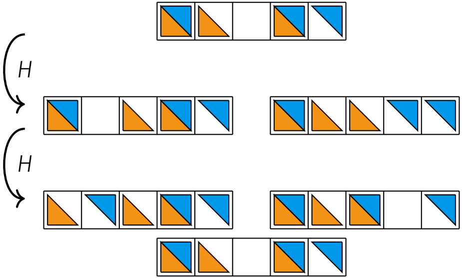
2. Flip a spin (it can be seen as the outcome of measure of σ^x, followed by measure of σ^z)



3. Time-evolve

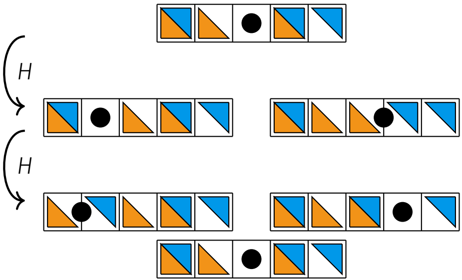
Some results

All reduces to a single hopping impurity



- sequence of particles is preserved by dynamics
- after each application of the Hamiltonian, the state is jammed except for an *interface*

All reduces to a single hopping impurity



- sequence of particles is preserved by dynamics
- after each application of the Hamiltonian, the state is jammed except for an *interface*
- single particle problem (dim=$O(L)$ instead of $O(2^L)$)
- non-local mapping

Asymptotic profile of magnetisation: an example

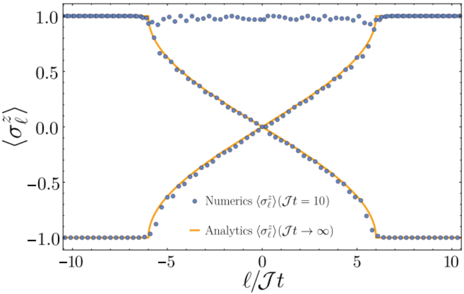
Scaling limit $t \to \infty$, $\ell/t = constant$, $x(\ell) \sim \#spins\ up\ between\ the\ origin\ and\ \ell$:

$$\langle \sigma_\ell^z \rangle_t \sim \begin{cases} 1\,, & \text{for } |\cdots \bullet \cdots \uparrow_\ell \updownarrow \uparrow \cdots\rangle \vee |\cdots \uparrow \updownarrow \uparrow_\ell \cdots \bullet \cdots\rangle \\ \frac{2}{\pi} \arcsin\left(\frac{x(\ell)}{4\mathcal{J}t}\right), & \text{for } |\cdots \bullet \cdots \uparrow_\ell \uparrow \downarrow \cdots\rangle \vee |\cdots \uparrow \uparrow \downarrow_\ell \cdots \bullet \cdots\rangle \\ -\frac{2}{\pi} \arcsin\left(\frac{x(\ell)}{4\mathcal{J}t}\right), & \text{for } |\cdots \bullet \cdots \downarrow_\ell \uparrow \uparrow \cdots\rangle \vee |\cdots \downarrow \uparrow \uparrow_\ell \cdots \bullet \cdots\rangle \\ -1\,, & \text{for } |\cdots \bullet \cdots \downarrow_\ell \uparrow \downarrow \cdots\rangle \vee |\cdots \downarrow \uparrow \downarrow_\ell \cdots \bullet \cdots\rangle\,, \end{cases}$$

e.g. $\cdots\uparrow\uparrow\downarrow\uparrow\uparrow\downarrow\uparrow\uparrow\downarrow\uparrow\uparrow\downarrow\cdots$

$(x(\ell) \sim \frac{2}{3}\ell)$

The effects of a local measurement does not fade away with time!



e.g. the current associated to the magnetization (globally conserved)

$$\frac{\mathrm{d}}{\mathrm{d}t}\sigma^z_\ell(t)\Big|_{t=0} = -\underbrace{\mathcal{J}\frac{\mathrm{i}}{2}(\sigma^+_\ell\sigma^-_{\ell+2}-\sigma^-_\ell\sigma^+_{\ell+2})\frac{1-\sigma^z_{\ell+1}}{2}}_{j_{\ell+1}} + \underbrace{\mathcal{J}\frac{\mathrm{i}}{2}(\sigma^+_{\ell-2}\sigma^-_\ell-\sigma^-_{\ell-2}\sigma^+_\ell)\frac{1-\sigma^z_{\ell-1}}{2}}_{j_\ell}$$

$$\implies \quad \begin{array}{ll} \langle j_\ell\rangle_t = 0, & \text{for jammed states} \\ \langle j_\ell\rangle_t = \mathcal{O}(1/t), & \text{in our case} \end{array}$$

Conclusions

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- Ballistic profiles emerging from a local perturbation
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- Ballistic profiles emerging from a local perturbation
- No genuine spin transport occurs

- Measurement catastrophe as a universal feature of constrained models?
- Universal mechanism(s) behind local perturbation with everlasting macroscopic effects?
- Macroscopic entanglement structure?

Thank you!