Integrability breaking in boundary-driven chains

J.S. Ferreira†, M. Filippone†
† Department of Quantum Matter Physics, University of Geneva

arXiv:2006.13891

We study the role of integrability breaking interactions in the ballistic-to-diffusive crossover in integrable spin chains. We find a universal scaling of the spin current in the XX model. In the XXZ model, universality breaks down and a "quasi-ballistic" regime emerges.

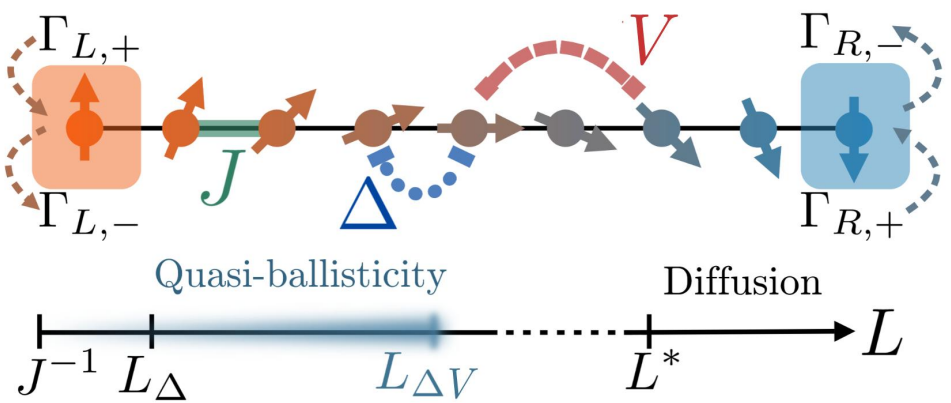
Model

We study the spin transport in an open spin-$\frac{1}{2}$ XXZ chain with next-to-nearest neighbor coupling.

$$H = \sum_i \sigma_i^x \sigma_{i+1}^x + \sigma_i^y \sigma_{i+1}^y + \Delta \sigma_i^z \sigma_{i+1}^z + w \sigma_i^z \sigma_{i+2}^z$$

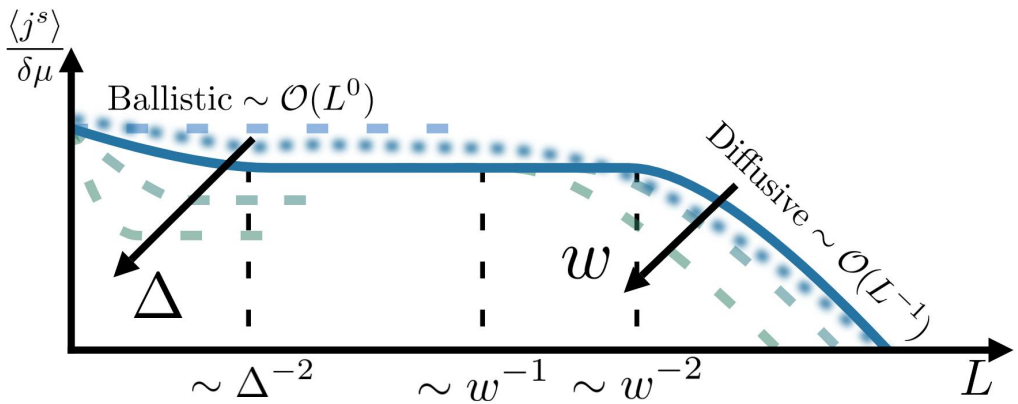
A spin current is induced by two reservoirs at each end and imposing a small bias in the magnetization [1], $\delta\mu$. The density matrix of the system, ρ, evolves according to:

$$\frac{d\rho}{dt} = -i[\mathcal{H}, \rho] + \sum_{\substack{\alpha=L,R \\ \tau=\pm}} 2\Gamma_{\alpha\tau}\rho\Gamma_{\alpha\tau}^\dagger - \left\{\rho, \Gamma_{\alpha\tau}^\dagger\Gamma_{\alpha\tau}\right\}$$



Spin Current

For small bias (linear regime) we probe the spin transport at high temperatures.

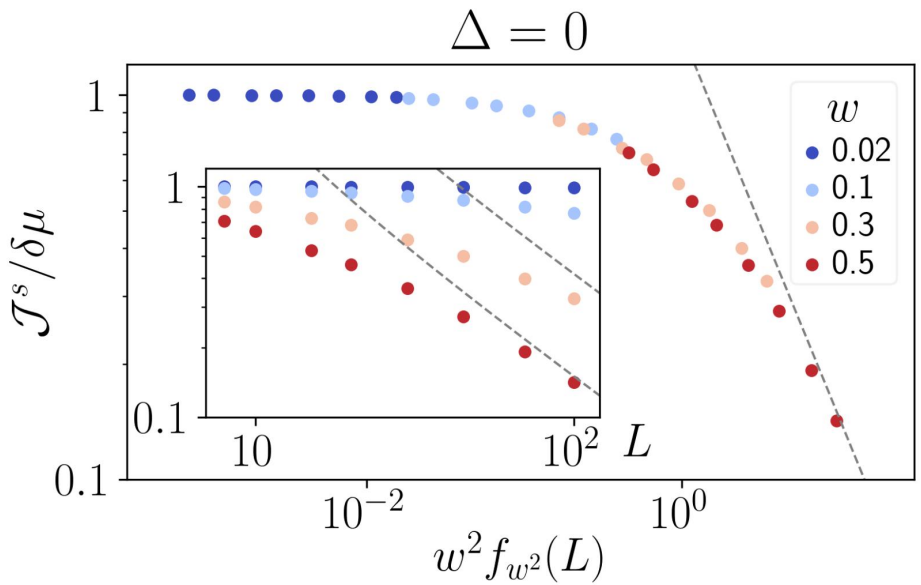


In the absence of an exact solution for $w>0$, we perturbatively [3, 4] compute the second-order expansion of the steady-state and spin current for small Δ and w (blurred line).

$$\frac{\langle j^s \rangle}{\delta\mu} \approx j_0 - w^2 j_{w^2} - \Delta^2 j_{\Delta^2} + w\Delta j_{w\Delta}$$

XX Model

Without nearest-neighbor interactions, deviations from the ballistic nature of transport occur at $w^2 j_w{}^2(L)\sim 1$. Relying on PT, we find a perfect universal scaling with the variable $w^2 j_w{}^2$, for small w.

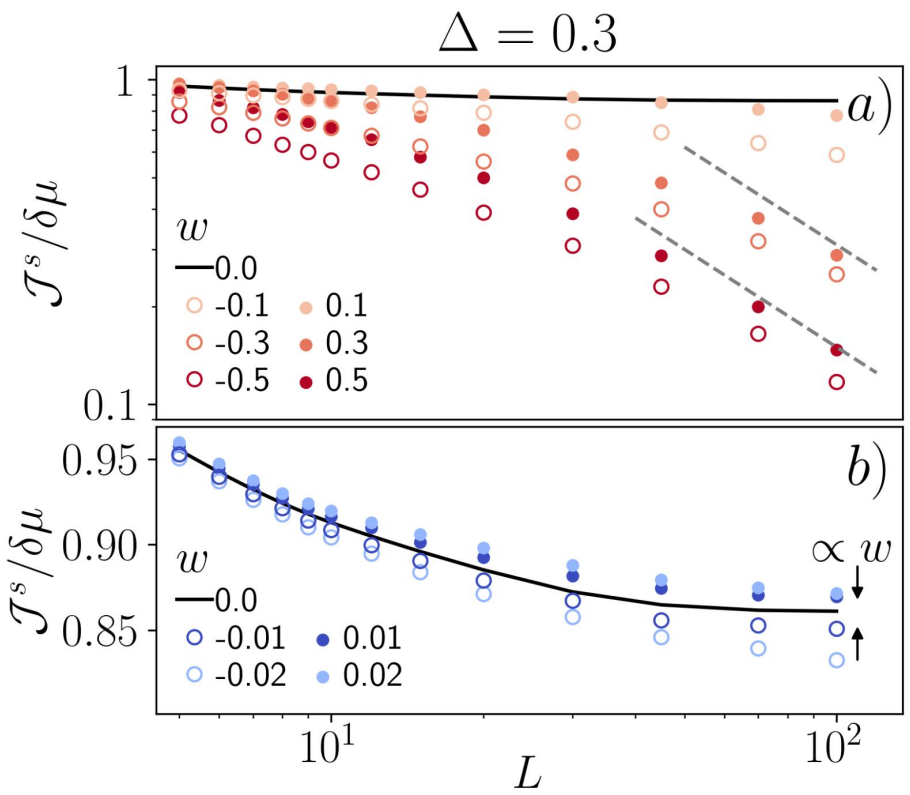


For the non-interacting model, the onset of diffusion coincides with deviations from ballisticity. For small w and large L , we extract a diffusion constant $\sigma=3.75/w^2$.

XXZ Model

In the presence of nearest interactions, corrections to the current become linear in w. For large systems, deviations from the ballistic regime take place before the onset of diffusion, $L{\sim}1/w^2$.

A "quasi-ballistic" regime emerges up to $L{\sim}1/w$.



Conclusion

- We calculated perturbative corrections to the current in the presence of an integrability breaking parameter.
- For Δ =0, we unveiled a universal scaling with a non-trivial parameter $w^2 j_w{}^2(L)$. Here, deviations from ballisticity mark the onset of diffusion.
- For finite Δ, integrability breaking can assist the spin transport. A " quasi-ballistic" regime emerges until parametrically large lengths scales.

[1] P. Tomaž & M. Žnidarič, JSTAT, P02035 (2009)
[2] R. Steinigeweg et al., PRB 90.9, 094417 (2014)
[3] A. Li et al, Scientific reports 4, 4887 (2014)
[4] C. Guo et al., PRA 95, 052107 (2017)

arXiv:2006.13891

FNSNF DQMP