Dephasing-enhanced transport in boundary-driven quasiperiodic chains

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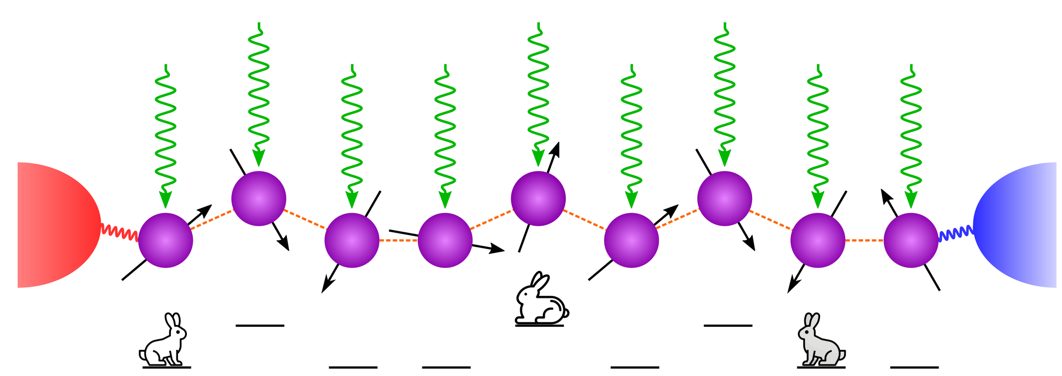
Introduction

- Macroscopic thermal conductors in contact with two baths follow *Fourier's law*: $J = \kappa \Delta T / L$
- On the other hand, non-interacting boundary-driven chains with no potential are *ballistic*.
- Quasiperiodic potentials lead to rich transport properties, even in 1D
- The Fibonacci model can exhibit any type of transport regime
- This model has been used as the working fluid in quantum thermal machines
- The addition of dephasing noise always leads to diffusion. What happens if we add dephasing on top of the Fibonacci potential?

Model & Methods



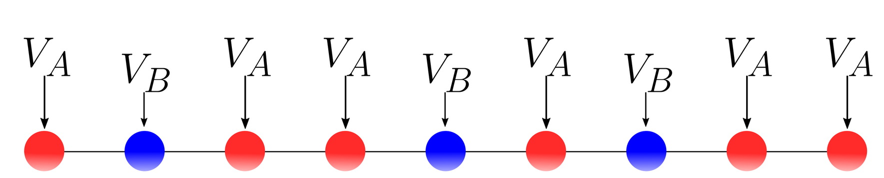
We considered a fermionic tight-binding chain with L modes, subject to an on-site potential:

$$H = -\sum_{i=1}^{L-1} \left(c_{i+1}^\dagger c_i + c_i^\dagger c_{i+1} \right) - \sum_{i=1}^{L} V_i c_i^\dagger c_i.$$

The on-site potential V_i is constructed from the *Fibonacci word*. Starting from A and AB, each word is the concatenation of the two previous ones:

$$A \to AB \to ABA \to ABAAB \to ABAAB \to \dots$$

The potential is constructed by associating each symbol with a value:



The chains is coupled to thermal baths on each end, and is subject to *dephasing*. We model its time evolution by the GKSL master equation:

$$\dot{\rho} = -i[H, \rho] + \mathcal{D}_1(\rho) + \mathcal{D}_L(\rho) + \sum_{i=1}^{L} \mathcal{D}^{\text{deph}}(\rho).$$

The dissipators are

$$\mathcal{D}_\alpha(\rho) = \gamma(1 - f_\alpha) D[c_\alpha^\dagger] + \gamma f_\alpha D[c_\alpha], \quad \alpha = 1, L,$$

$$\mathcal{D}_i^{\text{deph}}(\rho) = \Gamma D[c_i^\dagger c_i], \quad i = 1, \dots, L,$$

where

$$D[L] = L \rho L^\dagger - \frac{1}{2}\left\{ L^\dagger L, \rho \right\}.$$

The main observable of interest is th particle current, defined as

$$J = i \left\langle c_{i+1}^\dagger c_i - c_i^\dagger c_{i+1} \right\rangle$$

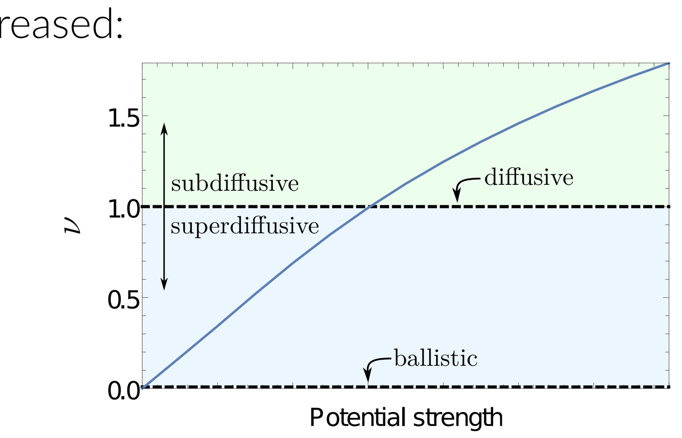
We compute J numerically for increasing values of L, then use the data to fit a power-law of the form

$$J \sim \frac{1}{L^\nu}$$

The transport coefficient ν is used to classify the transport regime:

Transport regime	Transport coefficient
Ballistic	$\nu = 0$
Superdiffusive	$0 < \nu < 1$
Diffusive	$\nu = 1$
Subdiffusive	$\nu > 1$
Localized	$\nu = \infty$

Without dephasing, the Fibonacci model goes continuously from ballistic to subdiffusive when the potential strength is increased:



What happens with dephasing?

When dephasing present, transport is always diffusive for sufficiently large L, for any $\Gamma > 0$.

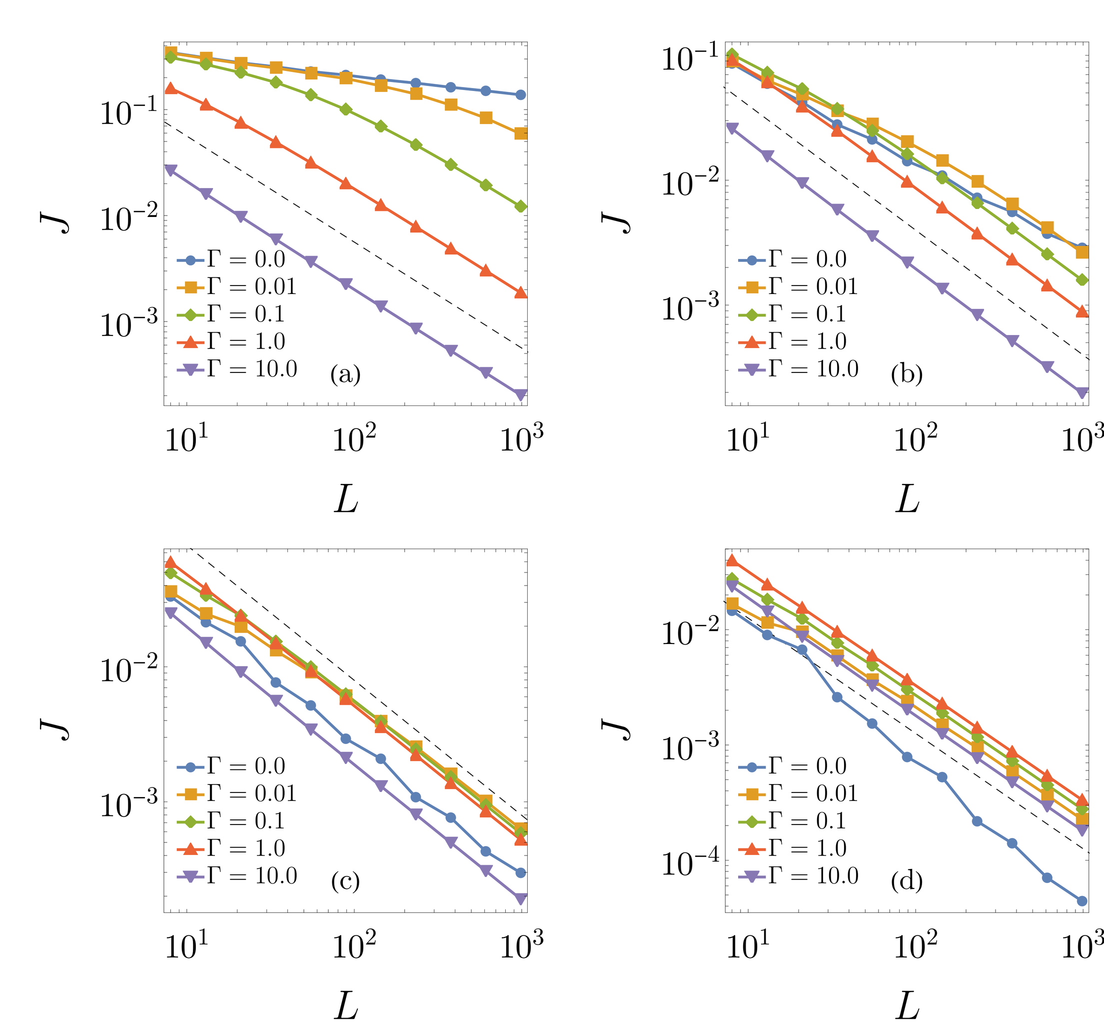


Figure 1. J vs. L with different dephasing strengths Γ. (a) $\lambda = 0.5$; (b) $\lambda = 1.0$; (c) $\lambda = 2.0$; (d) $\lambda = 4.0$.

Dephasing-enhanced transport

Alternatively, the transport regime can also be classified trough the system's finite-size conductivity $\kappa(L)$, defined from

$$J = \kappa(L) \frac{\Delta f}{L}.$$

- For ballistic systems, $\kappa(L) \to \infty$ as $L \to \infty$
- For diffusive systems, $\kappa(L)$ approaches a constant when $L \to \infty$
- For subdiffusive systems, $\kappa(L) \to 0$ as $L \to \infty$

In order to study the interplay between dephasing and the quasiperiodic potential, we analyzed how the conductivity scales with the dephasing strength:

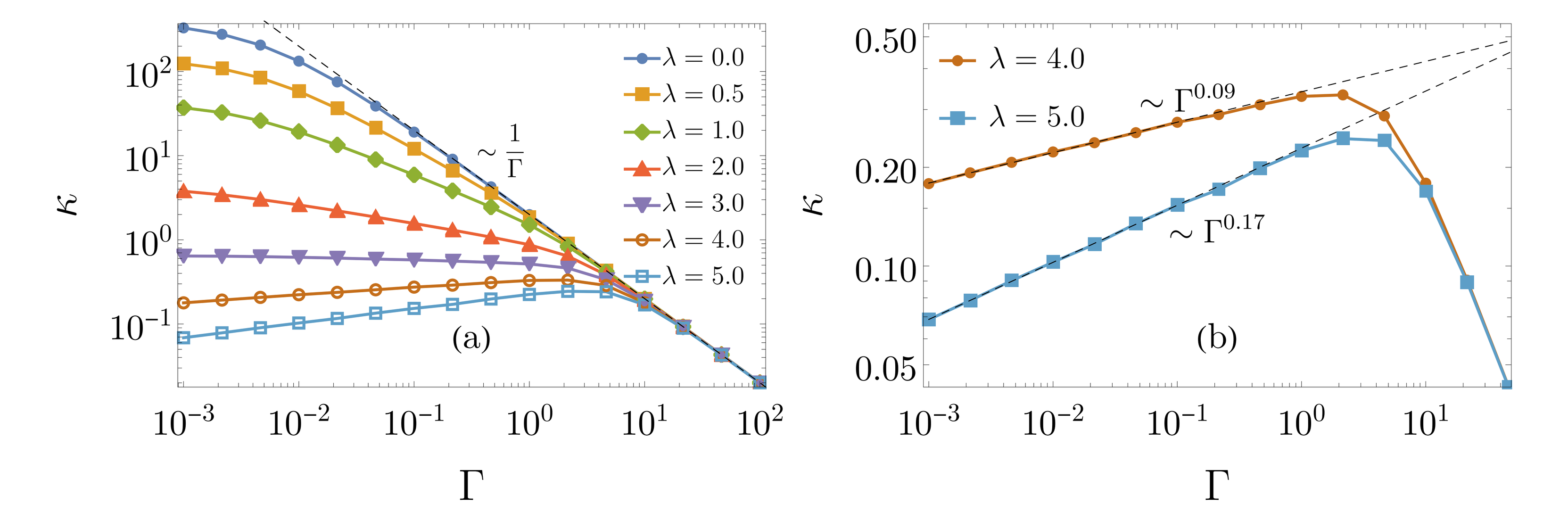


Figure 2. (a) κ vs. Γ for the Fibonacci model, with $L = 987$. (b) Same, but focusing on the curves for $\lambda = 4$ and $\lambda = 5$, for improved visibility.

Conclusion

- We made thorough review of the transport properties of the Fibonacci and AAH model without dephasing.
- We performed a detailed analysis of the scaling of the conductivity in the Fibonacci model under the present of dephasing.
- Our results also show that when the dephasing strength is sufficiently low, the conductivity behaves in a piece-wise fashion as a function of the system size
- We have shown that in the subdiffusive phase of the model, the addition of dephasing can actually lead to an increase in the absolute value of the current.

Download the paper!

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