Complex quantum networks as structured environments: engineering and probing

Johannes Nokkala
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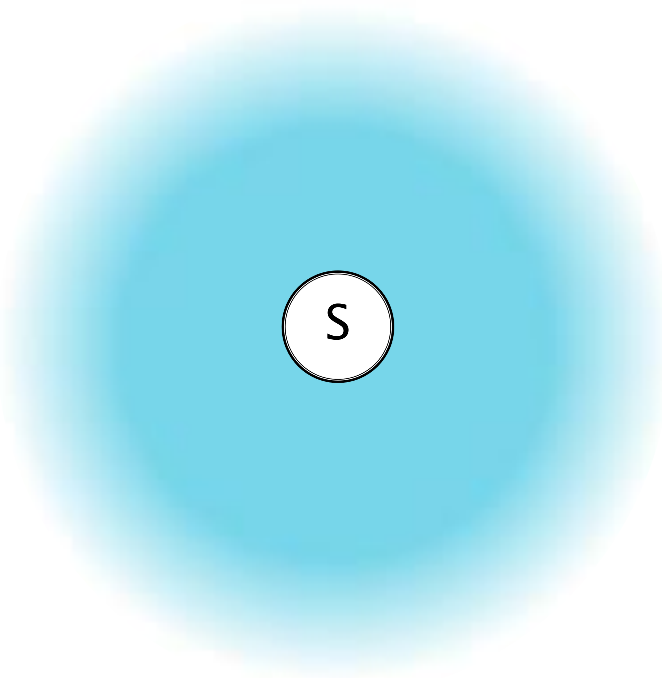
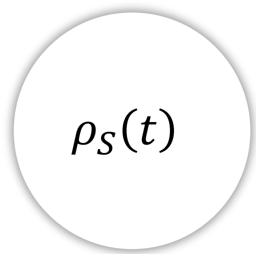
Background

- All realistic quantum systems open
- Want to engineer the quantum noise to protect or generate quantum resources
- Then, need to detect and control the relevant properties of quantum environments



Relevant properties?

- Environment a bosonic heat bath at some temperature T



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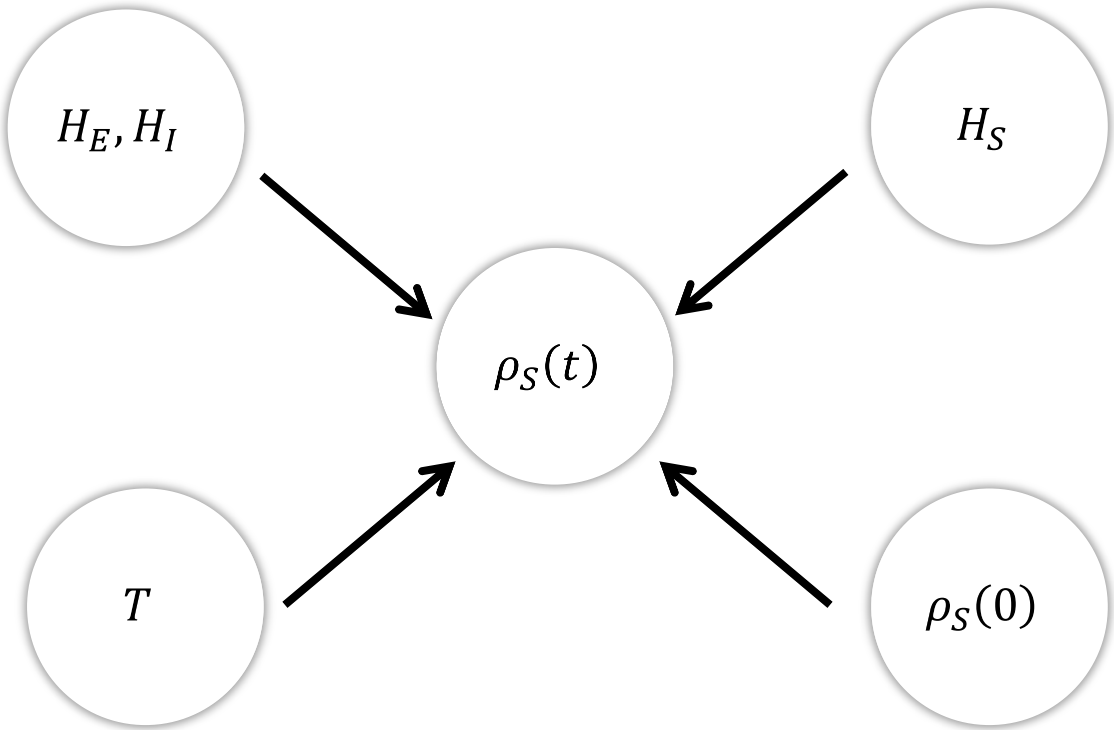

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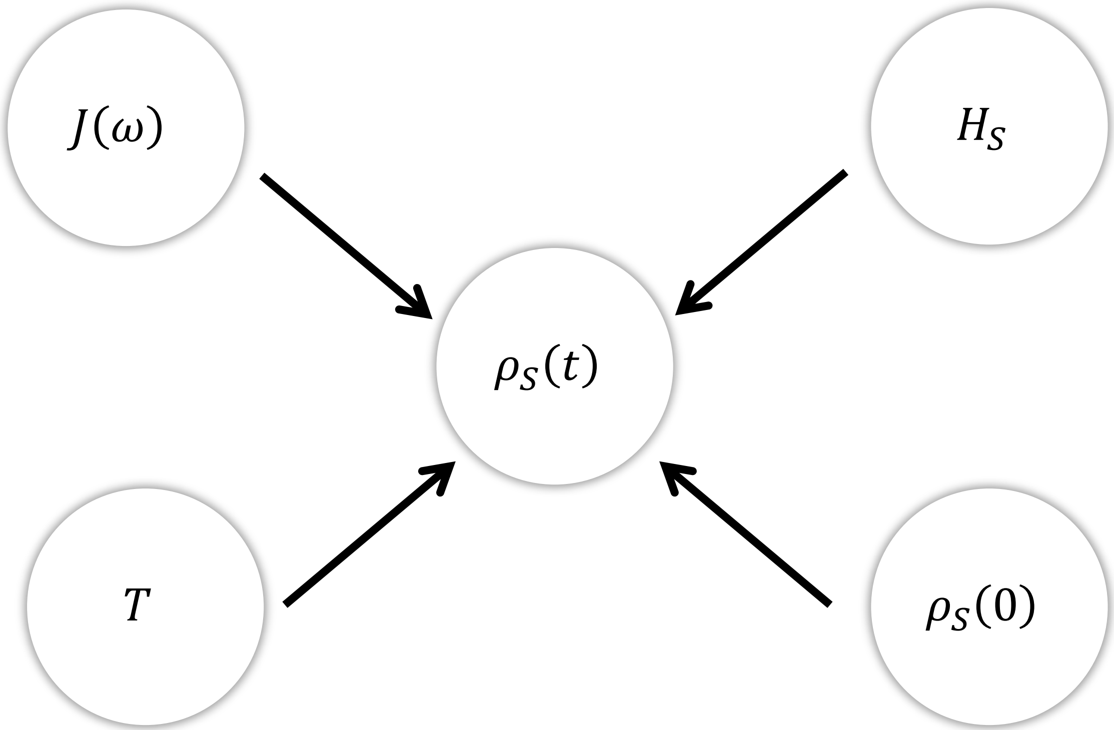
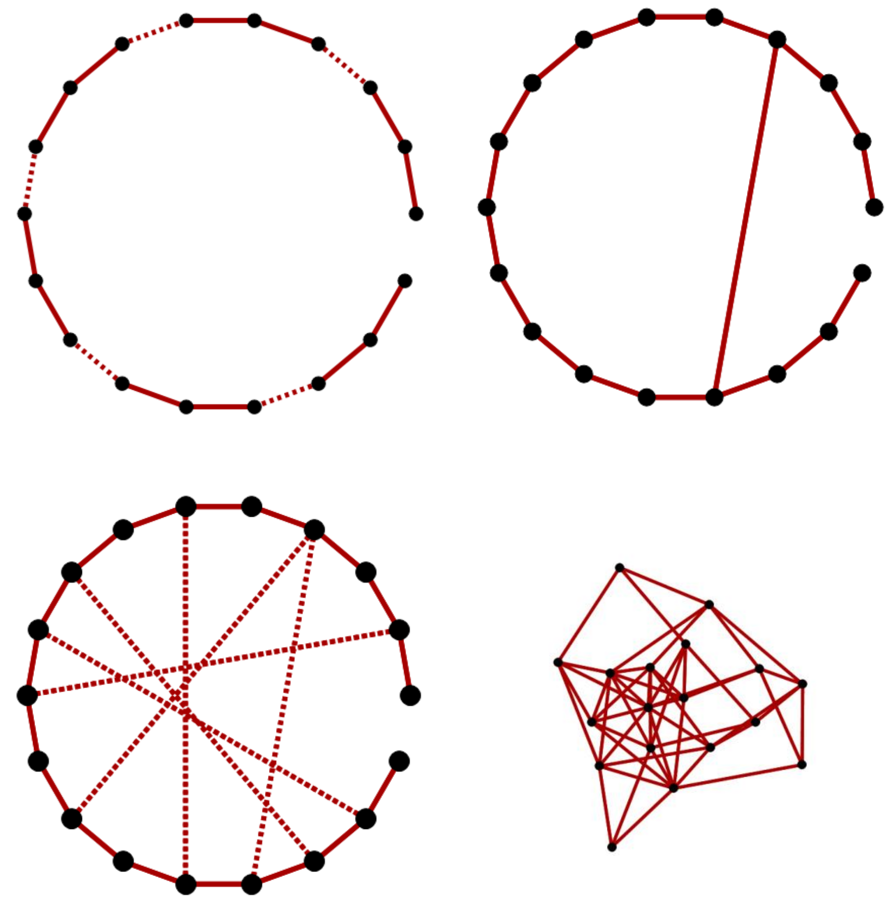


Research objectives

- Structured environment modeled by a complex quantum network
- What kind of $J(\omega)$ do they have?
- How can these be controlled and probed?



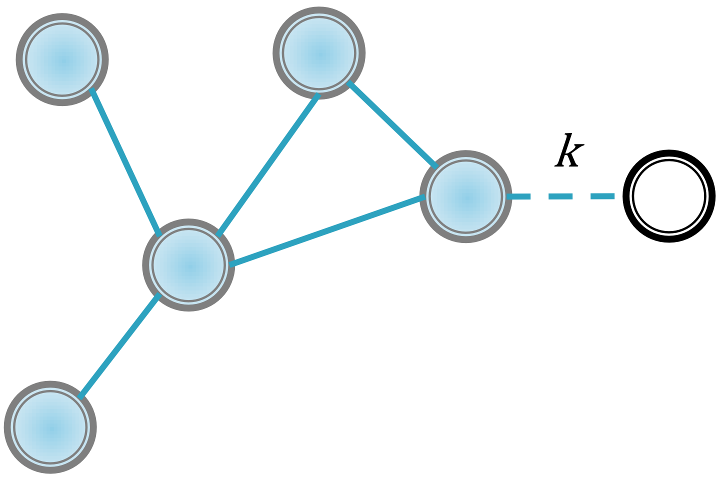
Outline of the talk

- Microscopic model
- Probing and engineering of spectral density
- Summary and outlook

The microscopic model

Total system

- QHO coupled to a thermal network of harmonic bosonic nodes
- $J(\omega)$ can be calculated by diagonalizing the network



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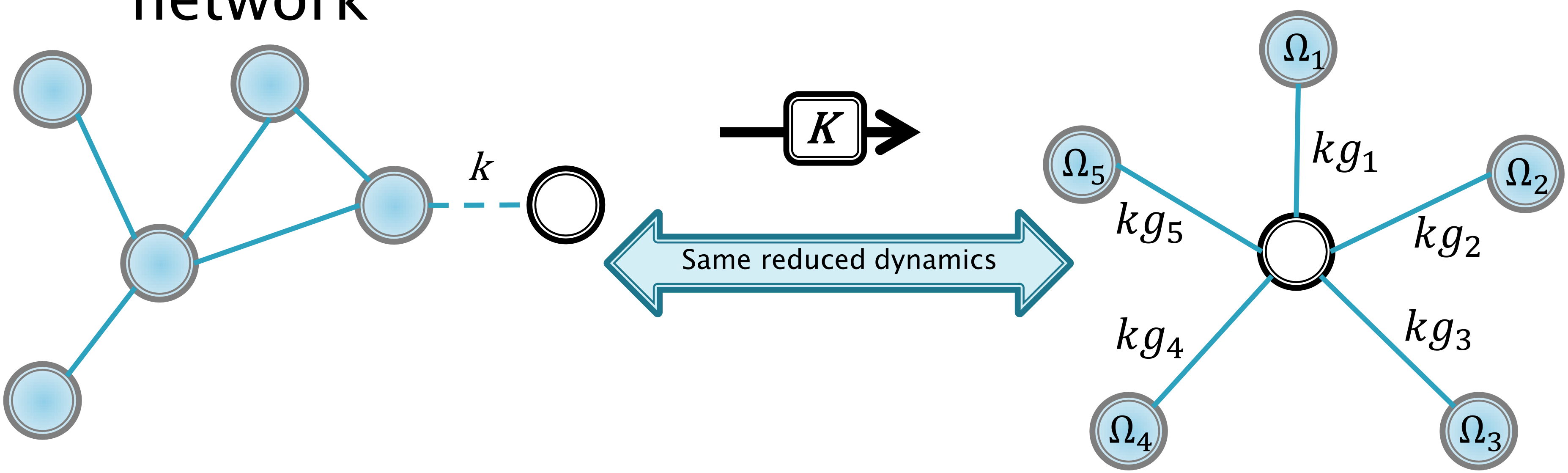

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The diagonalized Hamiltonian

$$H = H_S + H_E + kH_I$$

- QHO $H_S = (p_s^2 + \omega_s^2 q_s^2)/2$
- Network eigenmodes $H_E = \sum_i (P_i^2 + \Omega_i^2 Q_i^2)/2$
- Interaction $H_I = q_s \sum_i g_i Q_i$

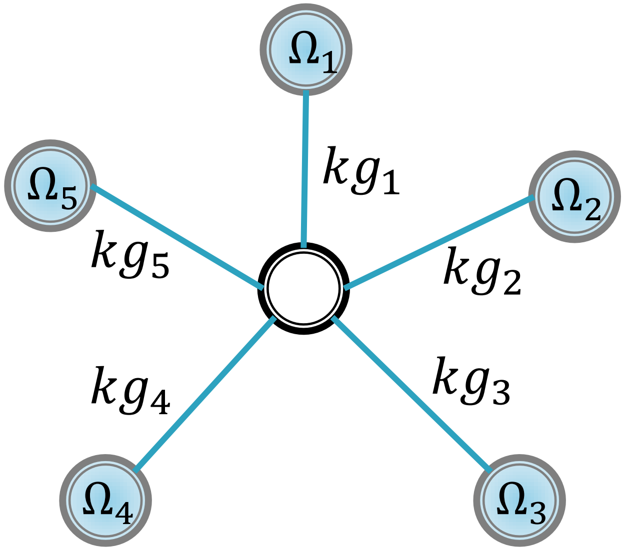
Calculation of $J(\omega)$

- Can be calculated from the damping kernel $\gamma(t)$ given by

$$\gamma(t) = \sum_i \frac{k^2 g_i^2}{\Omega_i^2} \cos(\Omega_i t)$$

- $J(\omega)$ is then

$$J(\omega) = \omega \int_0^\infty \gamma(t) \cos(\omega t) dt$$



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Probing and engineering of the spectral density

Average energy

- Can be used to probe $J(\omega)$
- $\langle n \rangle = \langle a^\dagger a \rangle$
- Has been experimentally measured
- When probing: weak coupling and an appropriate interaction time
- Continuum limit: connection known
- Complex networks: previously unexplored

Equations for probing

For dissipation ($T = 0$, $\langle n(0) \rangle > 0$)

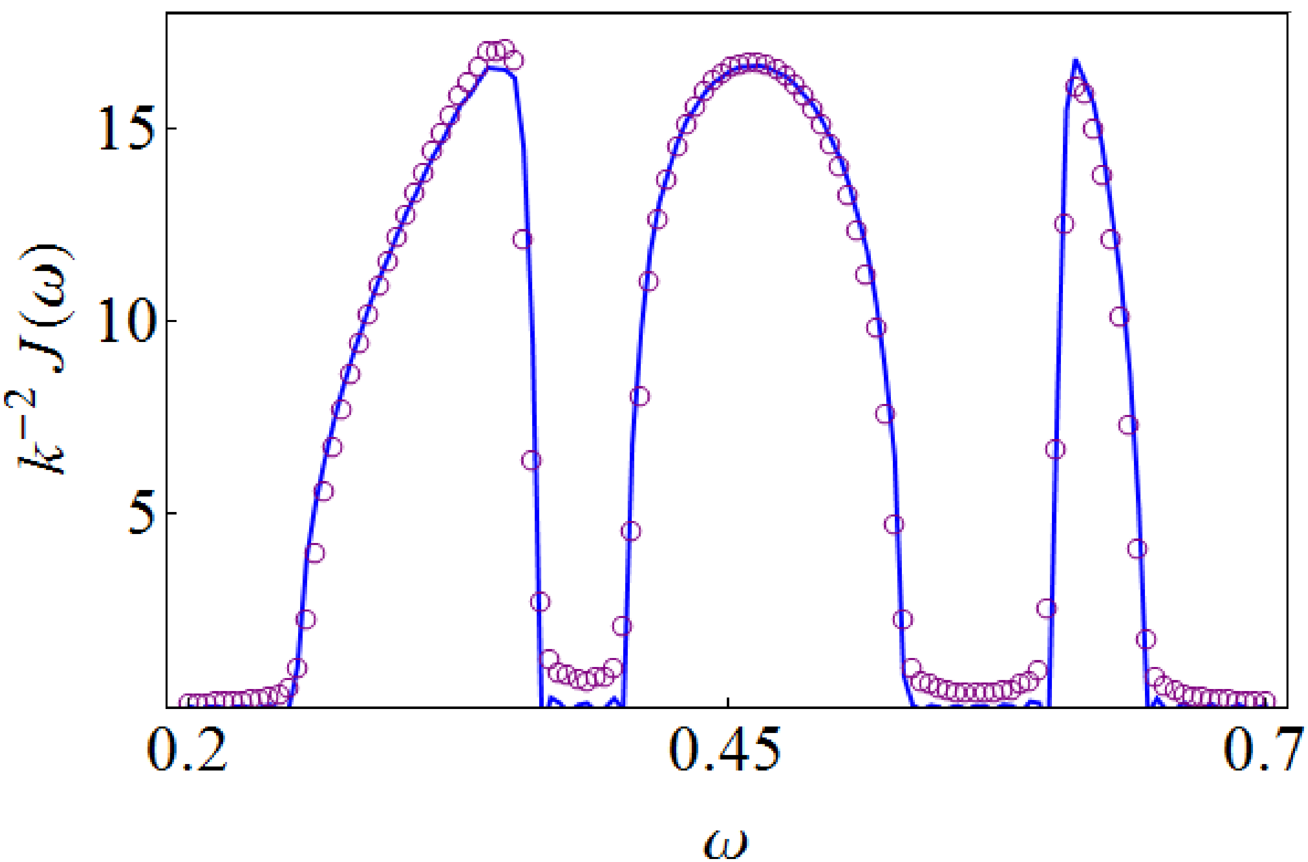
$$J(\omega_S) = -\frac{\omega_S}{t} \ln\left(1 - \frac{\Delta n}{\langle n(0) \rangle}\right)$$

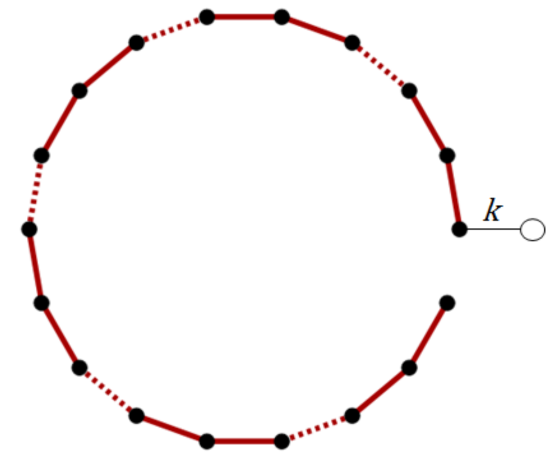
$$\Delta n = |\langle n(t) \rangle - \langle n(0) \rangle|$$

For heating ($T > 0$, $\langle n(0) \rangle = 0$)

$$J(\omega_S) = -\frac{\omega_S}{t} \ln\left(1 - \frac{\Delta n}{N(\omega_S)}\right)$$

Example: periodical chain

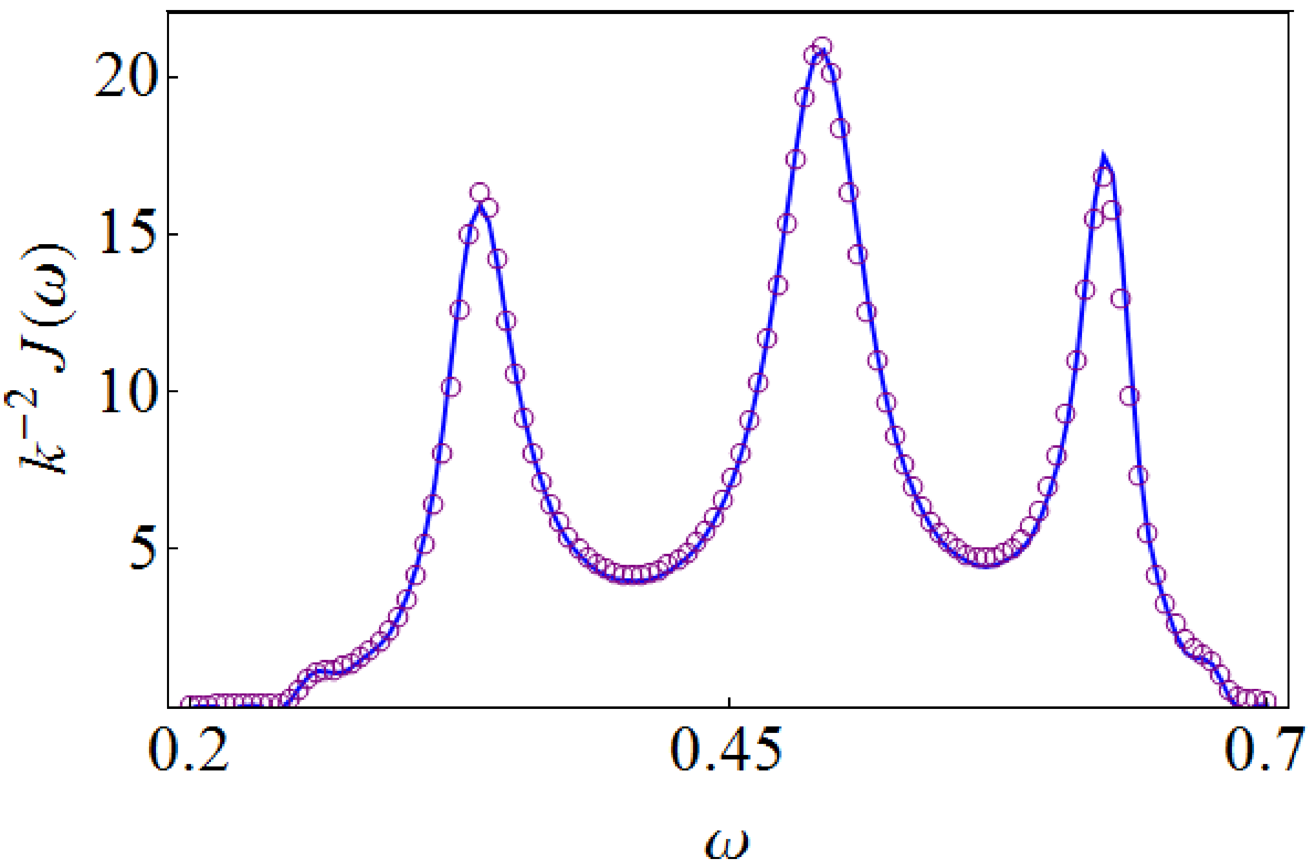


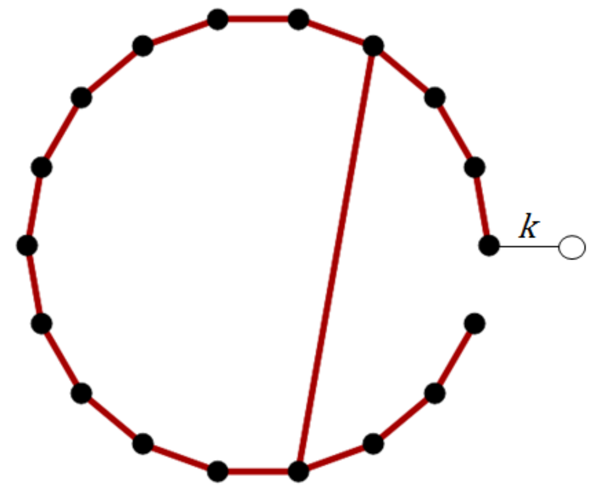


Calculated from $H_E + H_I$

Calculated from $J(\omega_S) = -\frac{\omega_S}{t} \ln\left(1 - \frac{\Delta n}{\langle n(0) \rangle}\right)$

Example: chain with shortcut





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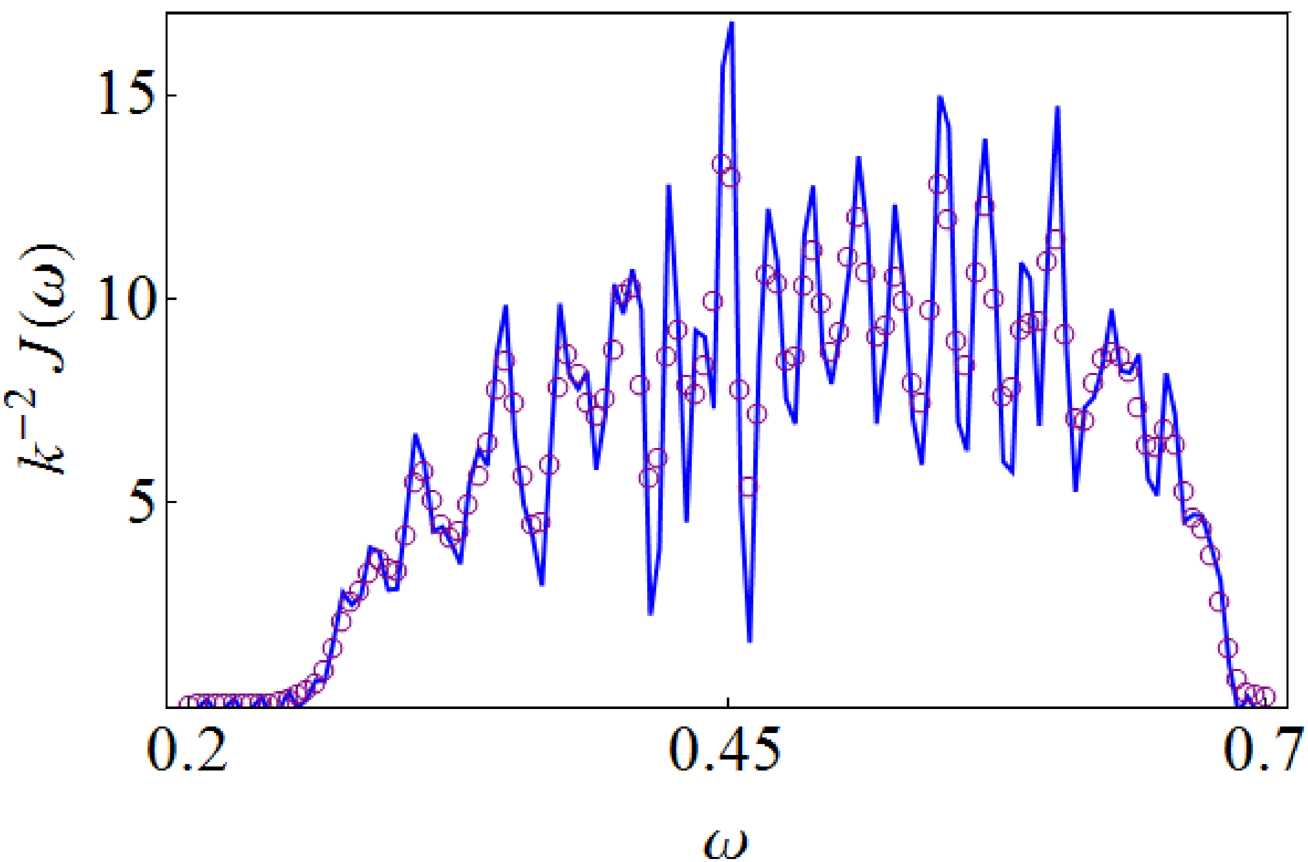
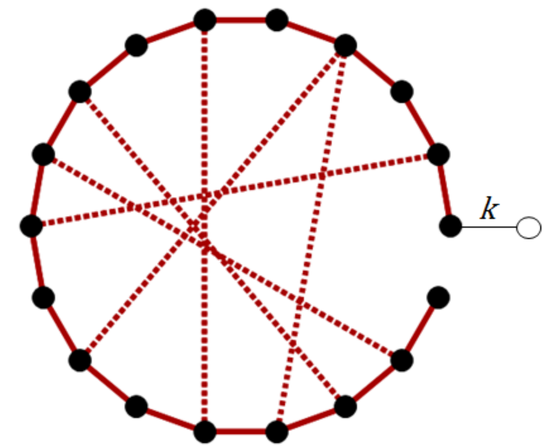
Example: small world

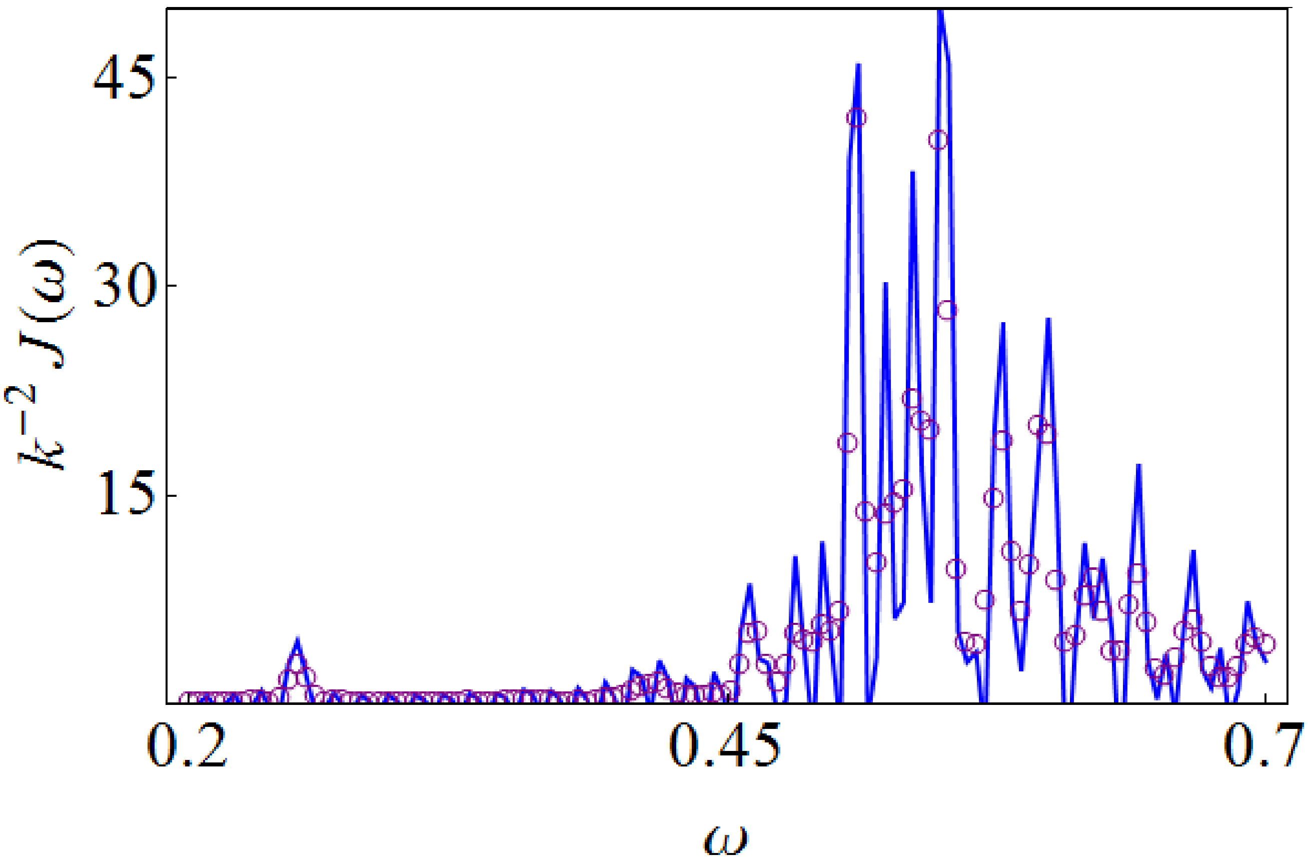


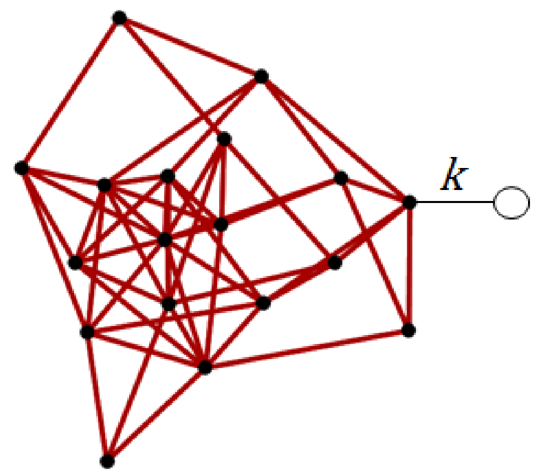


Calculated from $H_E + H_I$

Calculated from $J(\omega_S) = -\frac{\omega_S}{t}\ln\left(1 - \frac{\Delta n}{\langle n(0)\rangle}\right)$

Example: random network





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Summary and outlook

- Spectral density $J(\omega)$ is crucial in determining reduced dynamics of an OQS
- We considered structured thermal environments modeled by quantum networks
- Our results show how to engineer and probe the network $J(\omega)$ when it's temperature is known
- Next step: probe the structure instead of just $J(\omega)$

arXiv:1503.04635

Thank you! Questions?

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