Efficient quantum transport in disordered interacting many-body networks

Quantum-Classical Transition in Many-Body Systems

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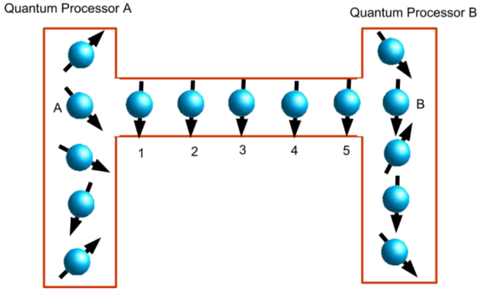
Physical disordered networks



The model - Embedded gaussian ensemble (EGE)

Quantum many-body fermionic interacting system. Parameters: n-number of particles, k-rank of interaction, l-sp states.
The interaction hamiltonian is

$$
\begin{aligned}
V_k &= \sum_{\alpha,\gamma} v_{k;\alpha,\gamma} \Psi^\dagger_{k;\alpha} \Psi_{k;\gamma} \\
\Psi^\dagger_{k;\alpha} |0\rangle &= \underbrace{|0,1,1,0,\ldots,1,0\rangle}_{k\text{-particles } \gamma \text{ distributed}} \\
v_{k;\alpha,\gamma} &= \mathrm{gauss}(0,1)
\end{aligned}
\tag{1}
$$

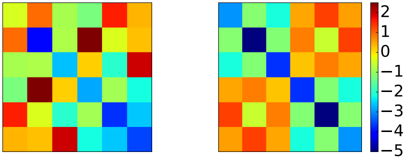
The basis in which we represent the hamiltonian (occupation number basis) generates the network for the system.

Centrosymmetry (CS)

One dimensional quantum buses and GOE-disordered networks benefits from the CS [1]. The CS for these cases is just[1]. Centrosymmetry for these cases is

$$[H, J] = 0,$$

J is the exchange matrix.
We have two types of ensembles, **EGE** y **csEGE**.



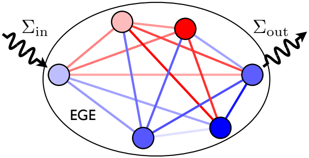
[1] M. Walschaers et. al. 2013 PRL 111, 180601. Quantum state transfer and network engineering, Nikolopoulos, Jex, Springer 2014.

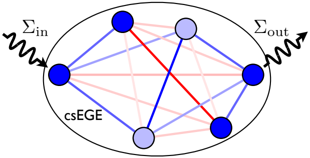
Efficiency

In order to quantify the degree of optimization in our system to develop the task $|\Sigma_{in}\rangle \to |\Sigma_{out}\rangle$ in a certain time we define the *Efficiency* as[2]

$$\mathcal{P}_{\mu,\nu} = \max_{t\in[0,T_{max})} |\langle \mu, e^{-iV_k t}\nu\rangle|^2.$$

The ensemble will be efficient its best efficiencies are $\sim 95\%$.

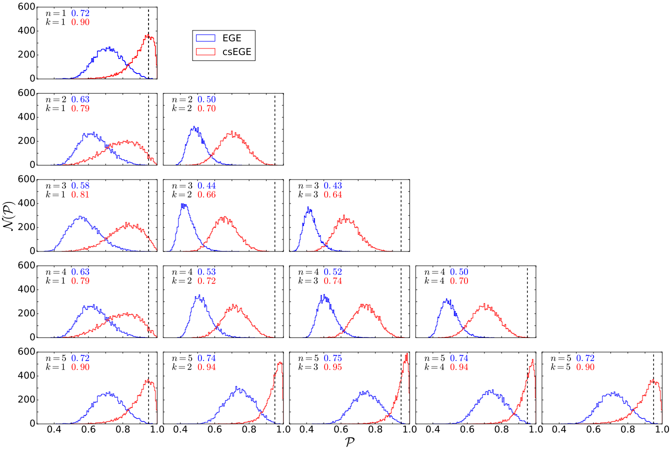




[2]M. Walschaers et. al. 2013 PRL 111, 180601.

Numerical results

A. Ortega, M. Vyas, L. Benet. Ann. Phys. 527, 748-756, 2015.



Open system (Scattering)

We use NEGF (Non-equilibrium Green's function) formalism and calculate transmission and current.
To open the system, we attach *broad-band contacts* to the Fock states $|1\rangle$ and $|N\rangle$, and calculate the transmission:

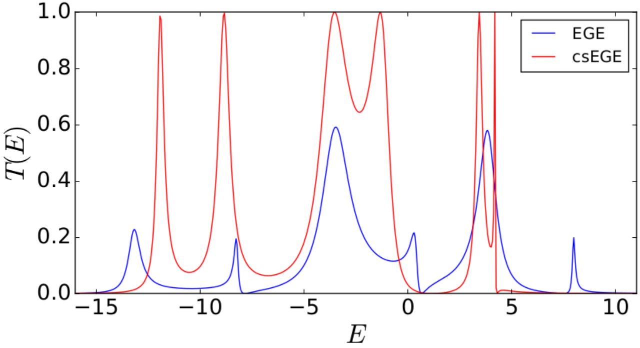
$$T(E) = 4\,\mathrm{Tr}(\ \mathrm{Im}(\Sigma_S)\ G(E)\ \mathrm{Im}(\Sigma_D)\ G^{\dagger}(E)\ )$$

- $\Sigma_{S/D}$, contact contribution (self-energy).
- $G(E) = (E - V_k - \Sigma_S - \Sigma_D)^{-1}$. Green's function central system.

Total current:

$$I = \int_{-\infty}^{\infty} T(E) dE.$$

A. Ortega, T. Stegmann, L. Benet. Phys. Rev. E. 94, 042102, 2016.



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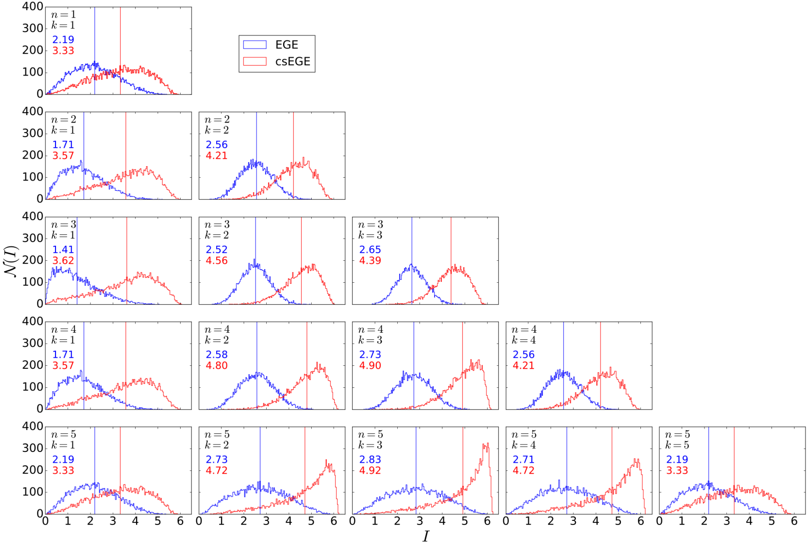


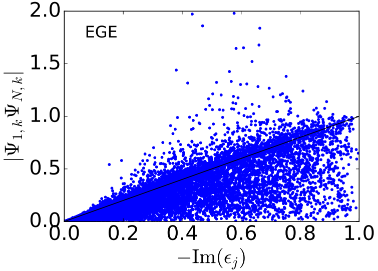
Why csEGE is better than EGE?

To answer this question, we rewrite $T(E)$ as

$$T(E) = 4|G_{1N}|^2 = 4\left|\sum_{k=1}^{N} \frac{\Psi_{1,k}\Psi_{N,k}}{E-\epsilon_k}\right|^2,$$

and we analyse what happens with the eigenvalues and eigenvectors of $H = V_k + \Sigma_S + \Sigma_D$.

A. Ortega, T. Stegmann, L. Benet. Phys. Rev. E. 94, 042102, 2016.



Conclusiones y perspectivas

- Centrosymmetry induces better transport properties. Correlations and centrosymmetry play together to achieve this.
- Robustness! (In time dependent efficiency and in stationary transport properties.

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