CHAOTIC FLUCTUATIONS IN SUPERCONDUCTING QUBITS

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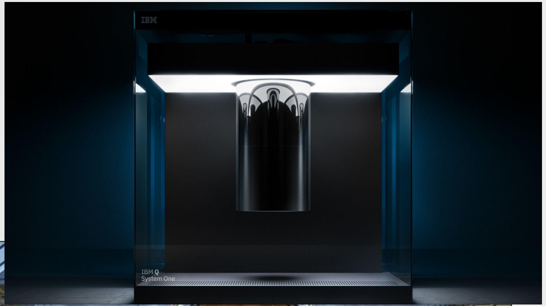
SUPERCONDUCTING QUBITS

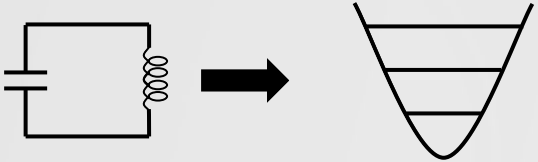
IBM's System One



Qubits: $|\psi\rangle = \alpha|\uparrow\rangle + \beta|\downarrow\rangle \;\rightarrow\; |\psi\rangle = \alpha|0\rangle + \beta|1\rangle$

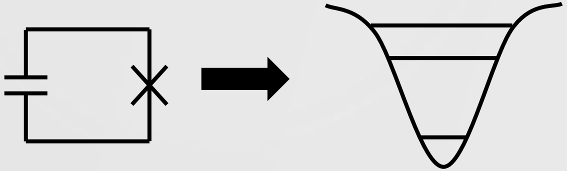
Harmonic Oscillator:

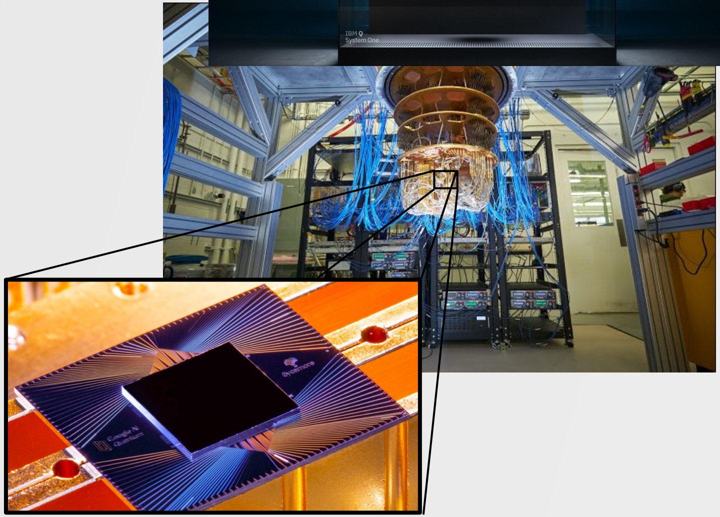
(Bad Qubits)



Anharmonic Oscillator:

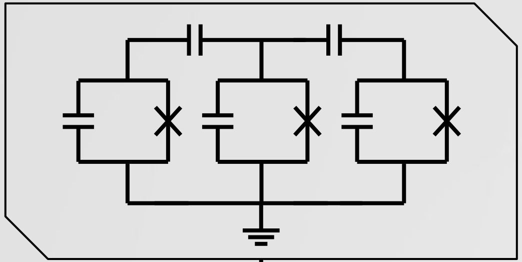
(Good Qubits)

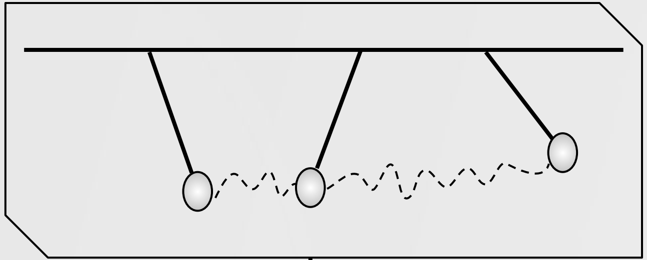




Google's Sycamore Quantum Processor

SUPERCONDUCTING CHIPS





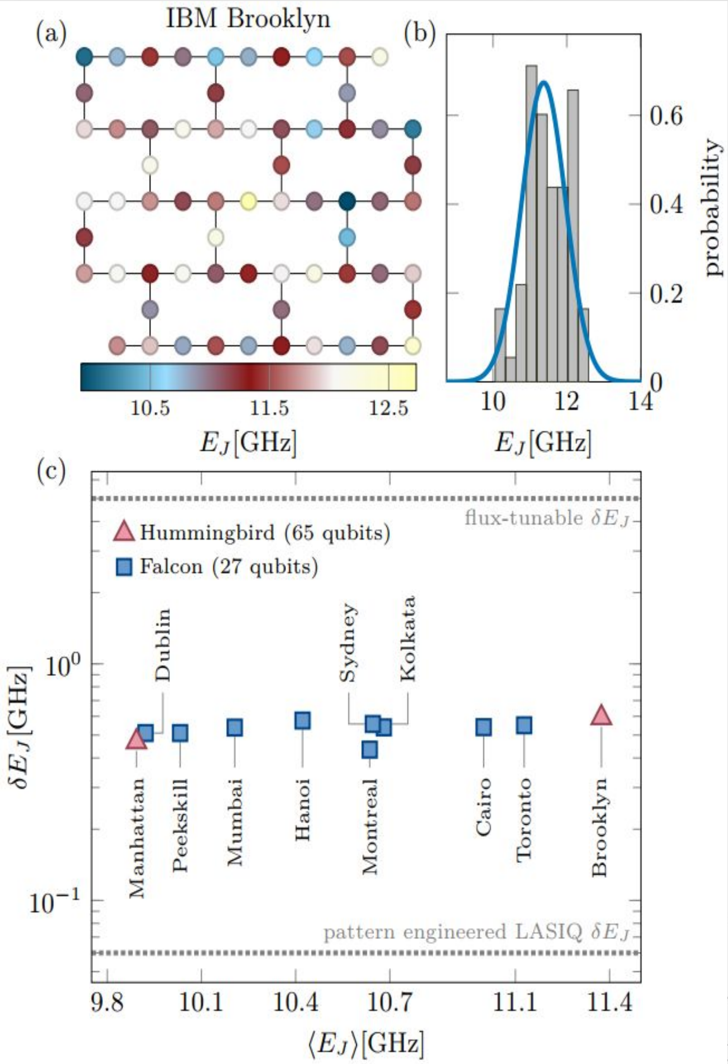
$$H = 4E_C \sum_{i=1}^{L} n_i^2 - \sum_{i=1}^{L} E_{J_i} \cos\phi_i + T \sum_{i=1}^{L-1} n_i n_{i+1}$$

$$[\phi_i, n_j] = i\delta_{ij}$$

$$[x_i, p_j] = i\delta_{ij}$$

JOSEPHSON ENERGY DISORDER

$$H = 4E_C \sum_{i=1}^{L} n_i^2 - \sum_{i=1}^{L} E_{J_i} \cos\phi_i + T \sum_{i=1}^{L-1} n_i n_{i+1}$$



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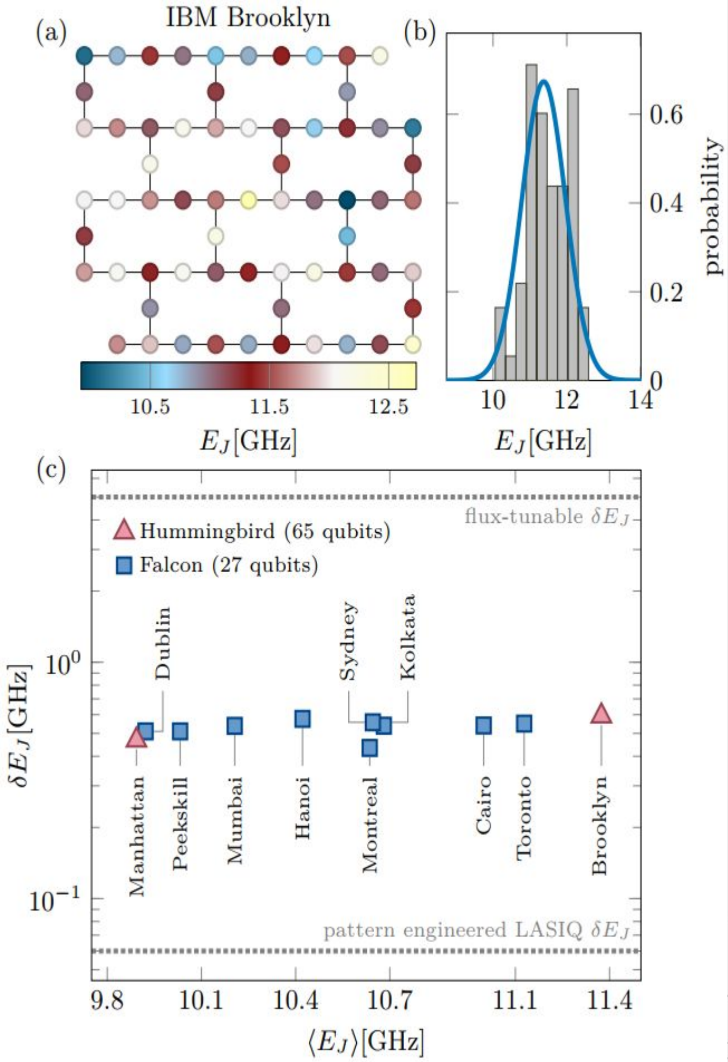
$$H = 4E_C \sum_{i=1}^{L} n_i^2 - \sum_{i=1}^{L} E_{J_i} \cos\phi_i + T \sum_{i=1}^{L-1} n_i n_{i+1}$$

$$E_{J_i} = \langle E_J \rangle + \delta_i$$

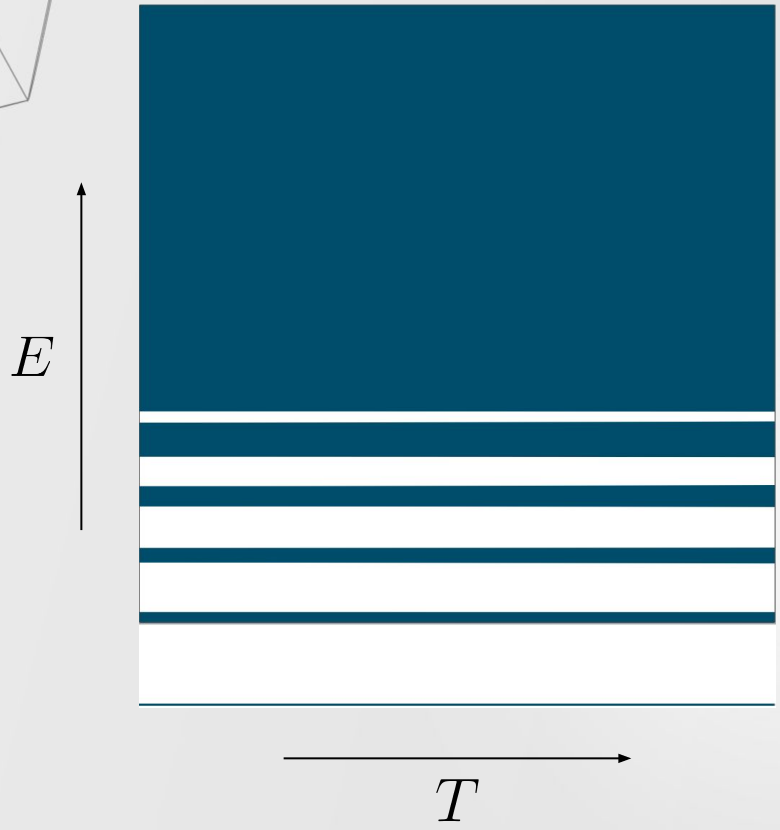
$$\delta E_J = \sqrt{\langle \delta^2 \rangle}$$

Transmon Regime

$E_C/\langle E_J \rangle \ll 1$



TRANSMON ARRAY SPECTRUM



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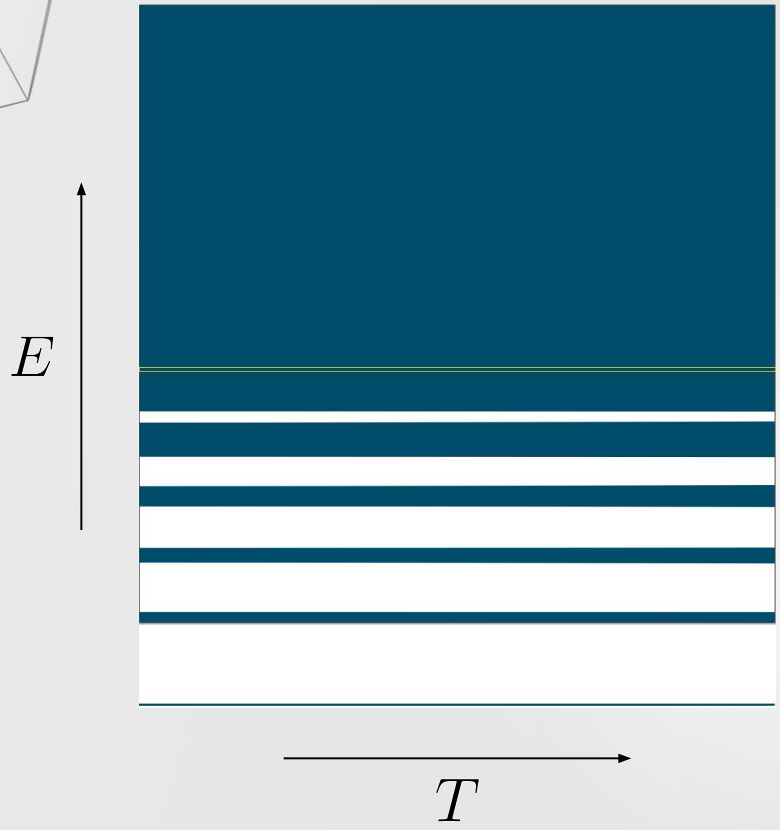

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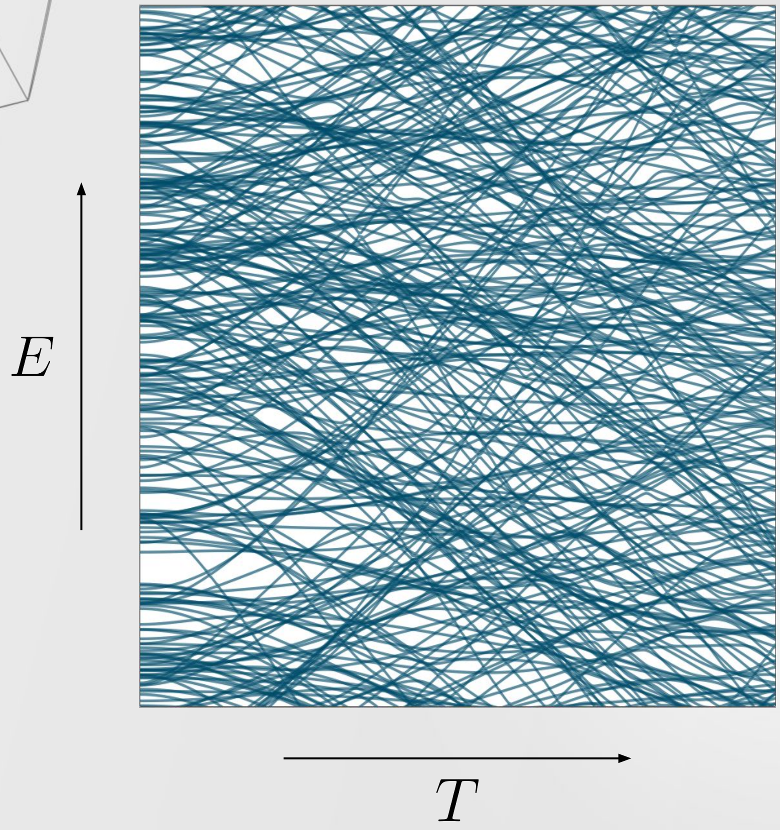

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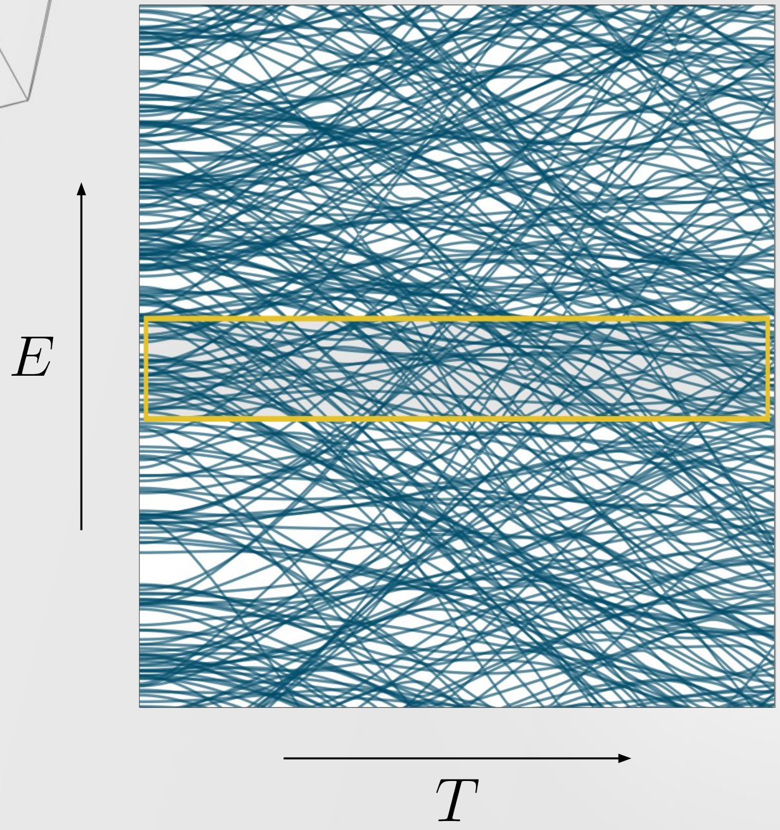

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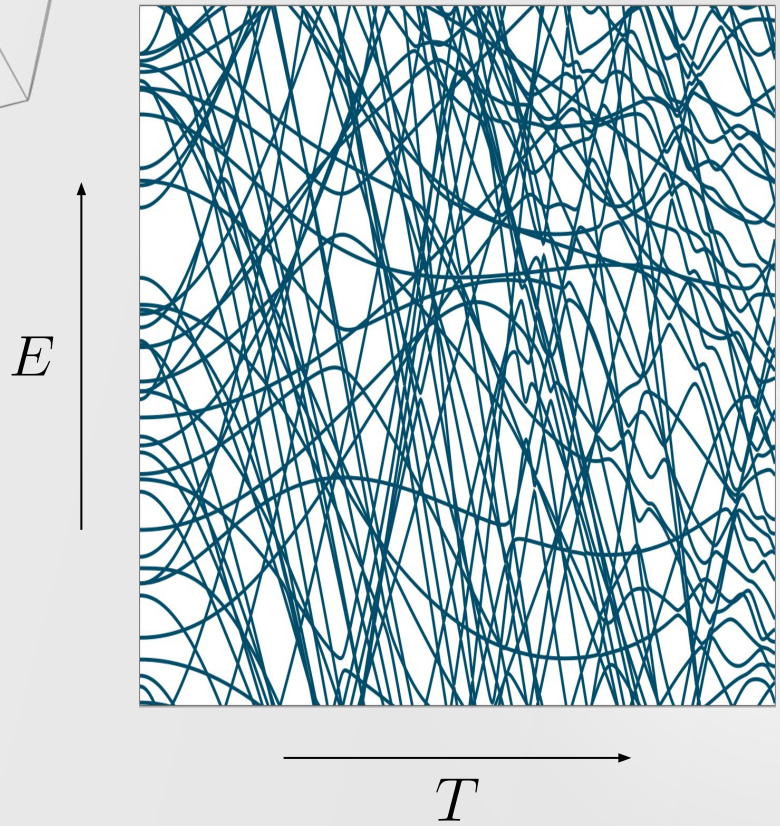
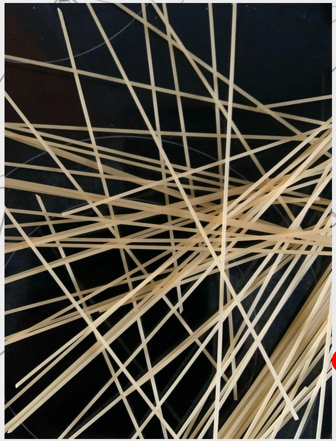
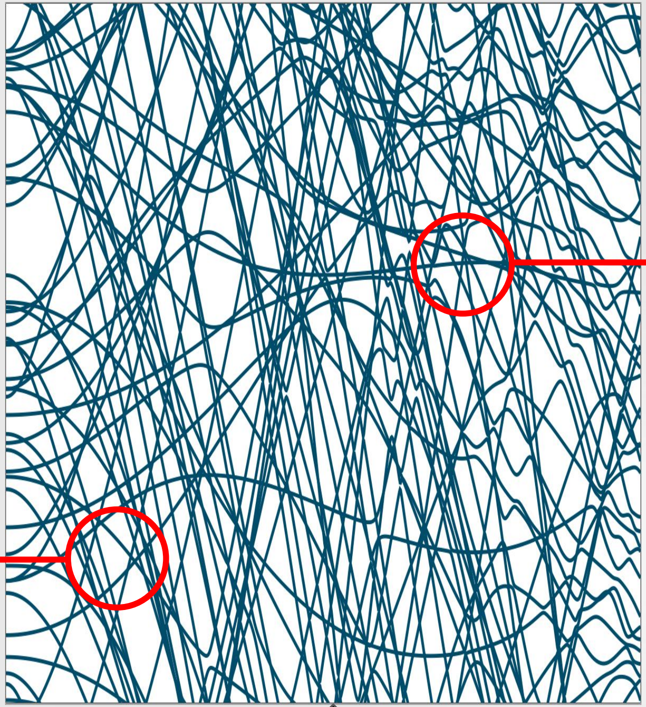
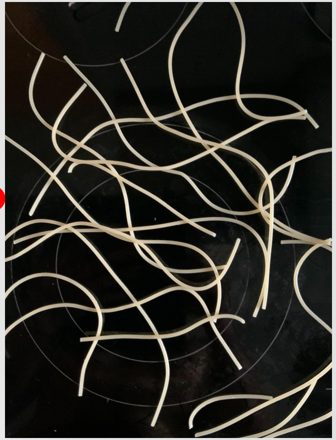


PHASE TRANSITION







Uncorrelated (Poisson)

Many Body Localised

Scale Invariant

Logarithmic Entanglement Lightcone

Level Repulsion (Wigner)

Quantum Chaotic

Volumic Scaling

Ballistic Entanglement Lightcone

Multifractal Eigenstates??

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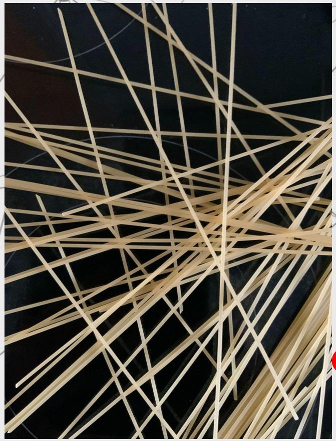

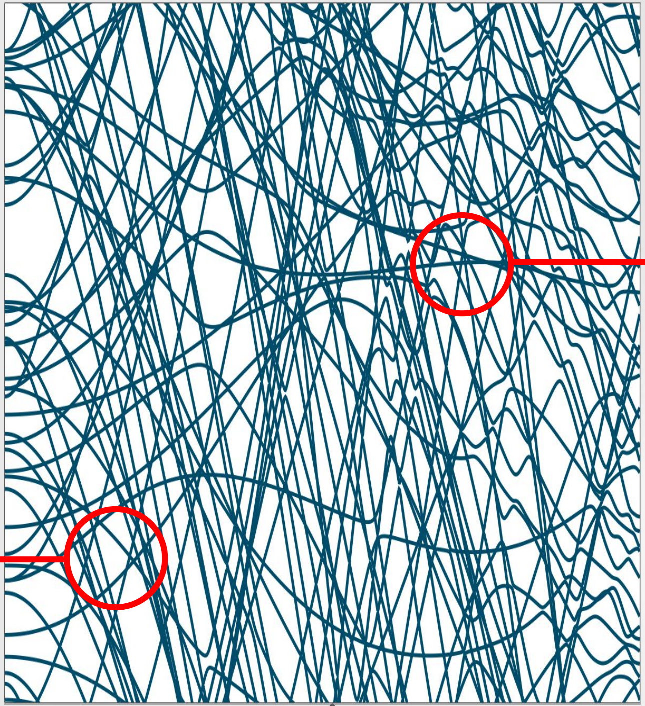

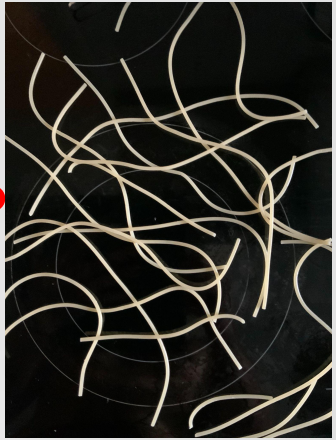

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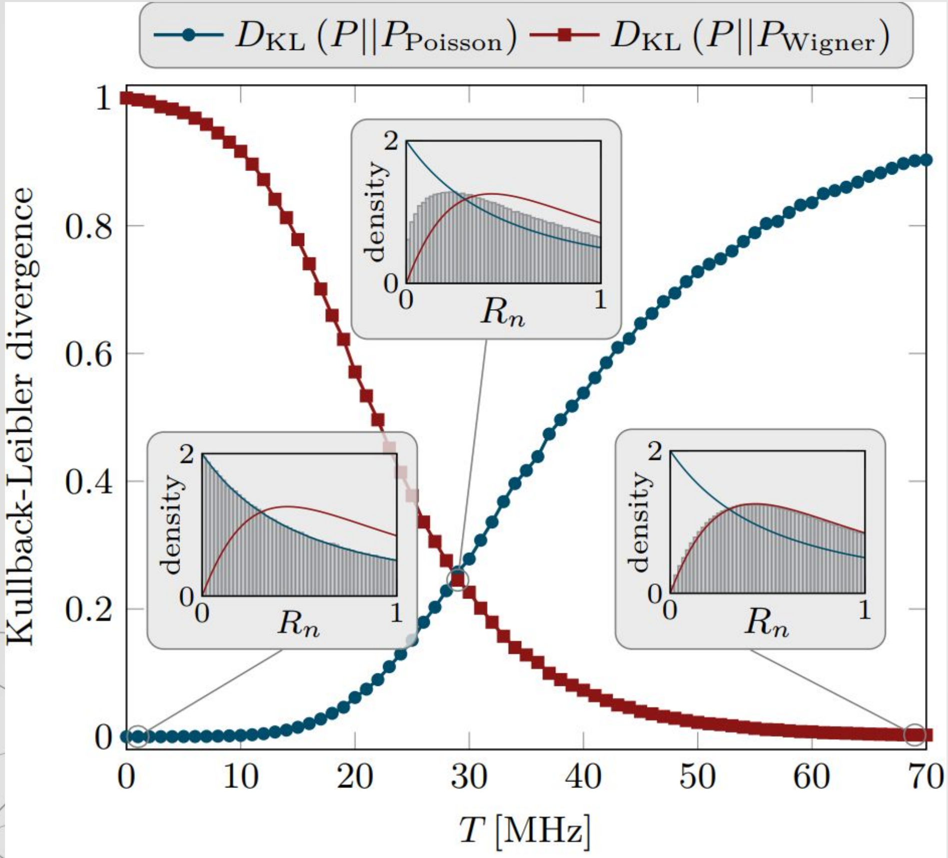
SPECTRAL STATISTICS



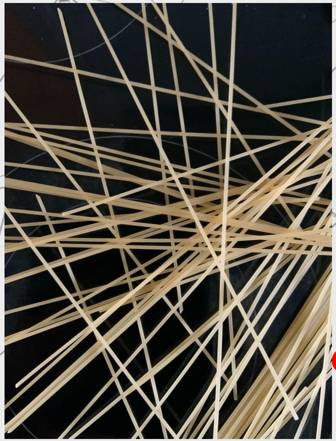
Adjacent Level Spacing Ratio

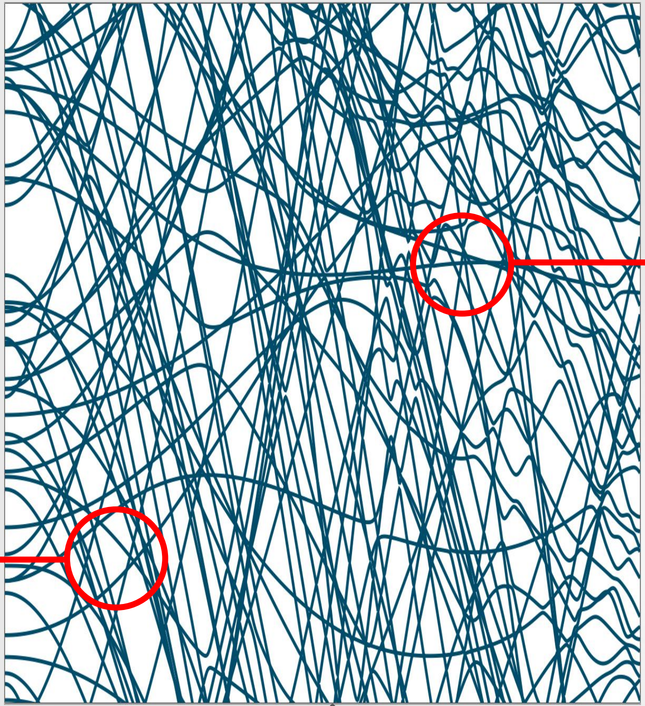
$$R_n = \min\left(\frac{E_n - E_{n-1}}{E_{n+1} - E_n}, \frac{E_{n+1} - E_n}{E_n - E_{n-1}}\right)$$

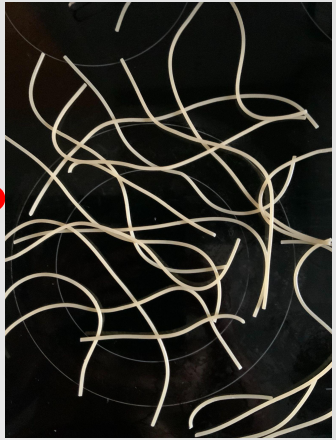
Kullback-Leibler Divergence

$$D_{KL}(P|Q) = \sum_k p_k \log\left(\frac{p_k}{q_k}\right)$$

PHASE TRANSITION







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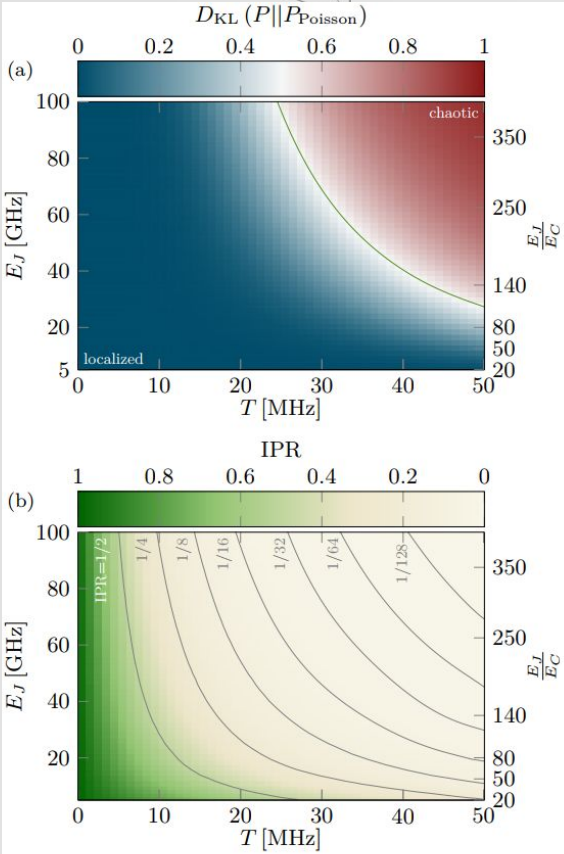
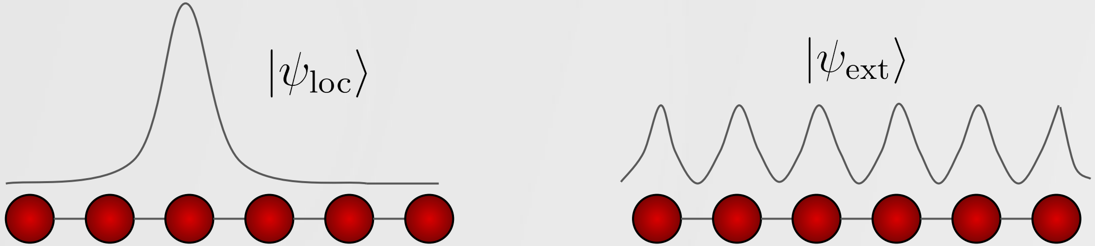
WAVEFUNCTION STATISTICS



Inverse Participation Ratio

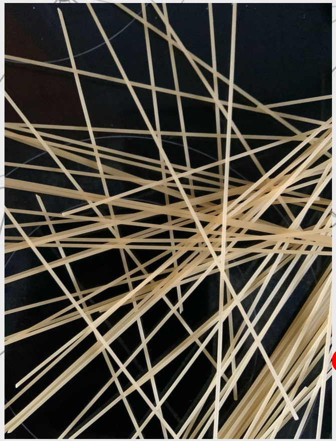
$$\mathrm{IPR}(|\psi\rangle) = \int_0^L dx |\langle x|\psi\rangle|^4$$

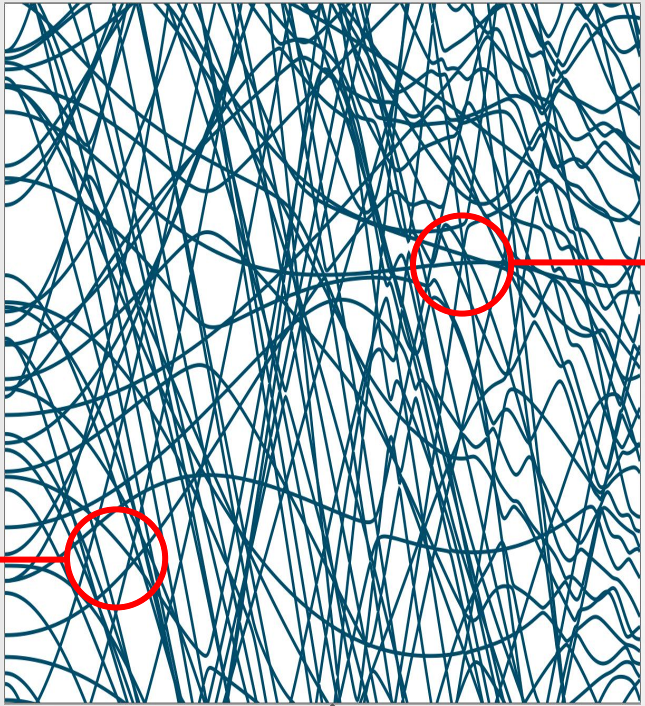


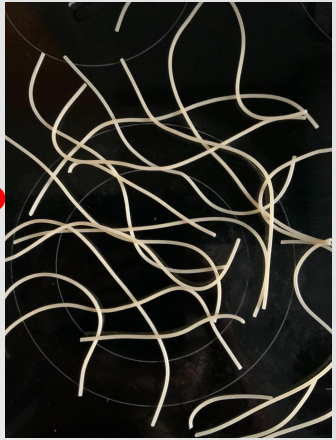
$$\mathrm{IPR}(|\psi_{\mathrm{loc}}\rangle) \approx 1$$

$$\mathrm{IPR}(|\psi_{\mathrm{ext}}\rangle) \approx \frac{1}{L}$$

PHASE TRANSITION







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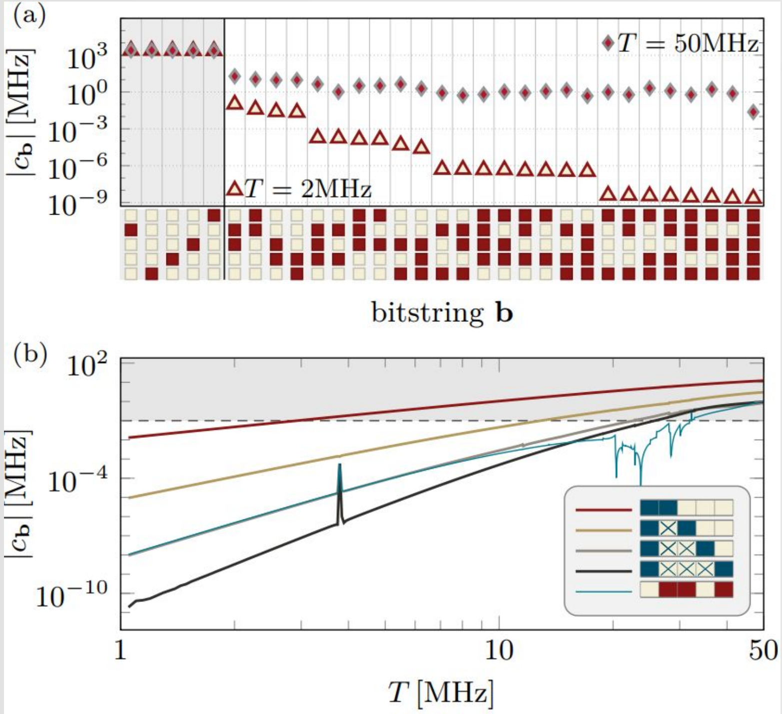
WALSH-HADAMARD TRANSFORMATION

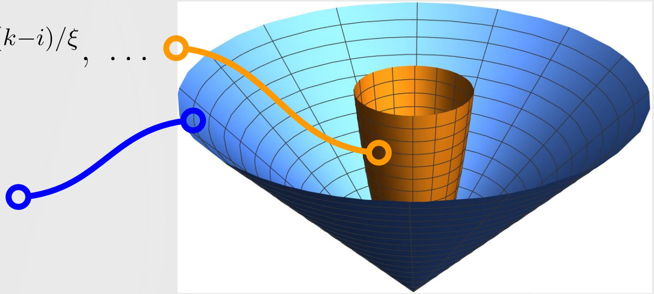


Local Integrals of Motion Hamiltonian:

$$H = \sum_i \omega_i \sigma_i^z + \sum_{i<j} J_{ij}\sigma_i^z\sigma_j^z + \sum_{i<j<k} J_{ijk}\sigma_i^z\sigma_j^z\sigma_k^z + \cdots = \sum_{\mathbf{b}} c_{\mathbf{b}}\sigma_1^{b_1}\sigma_2^{b_2}\ldots\sigma_L^{b_L}$$

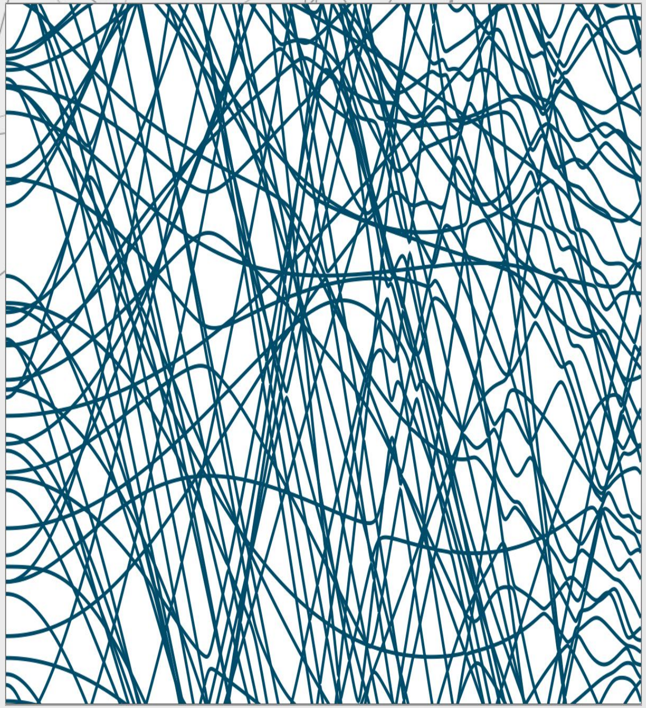
$$J_{ij} \propto e^{-(j-i)/\xi},\ \ J_{ijk} \propto e^{-(k-i)/\xi},\ \ \ldots$$

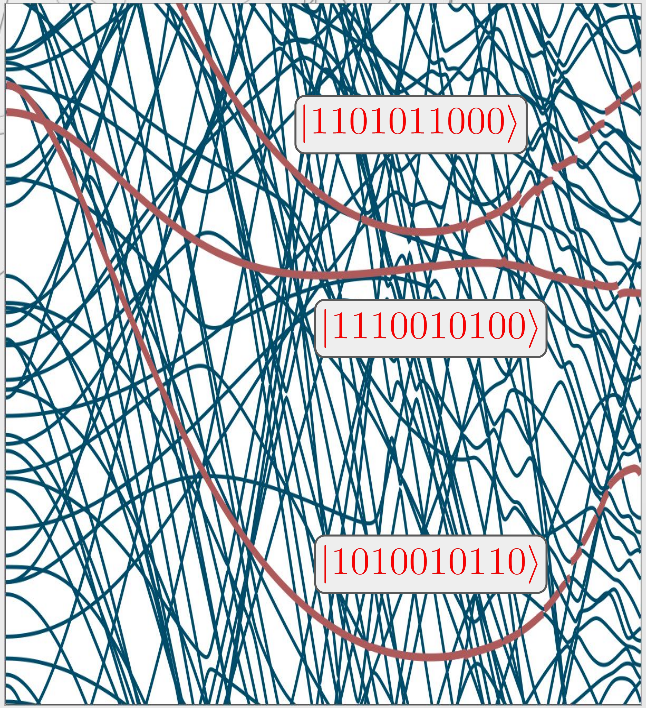
$$J_{ij\ldots} = O(1)$$



Walsh-Hadamard Transform

$$c_{\mathbf{b}}(T) = \frac{1}{2^L}\sum_{\mathbf{b}'}(-1)^{b_1 b_1'}(-1)^{b_2 b_2'}\ldots(-1)^{b_L b_L'}E_{\mathbf{b}'}(T) = \frac{1}{2^L}\sum_{\mathbf{b}'}(-1)^{\mathbf{b}\cdot\mathbf{b}'}E_{\mathbf{b}'}(T)$$

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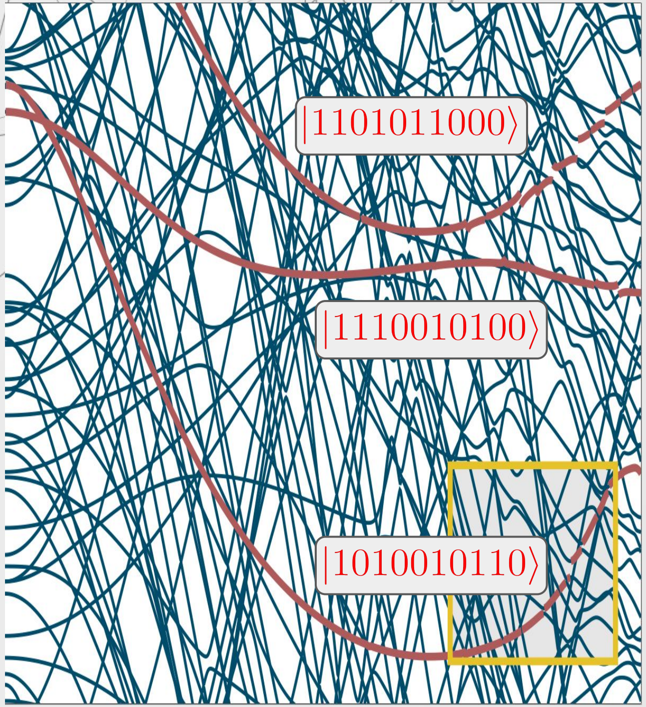

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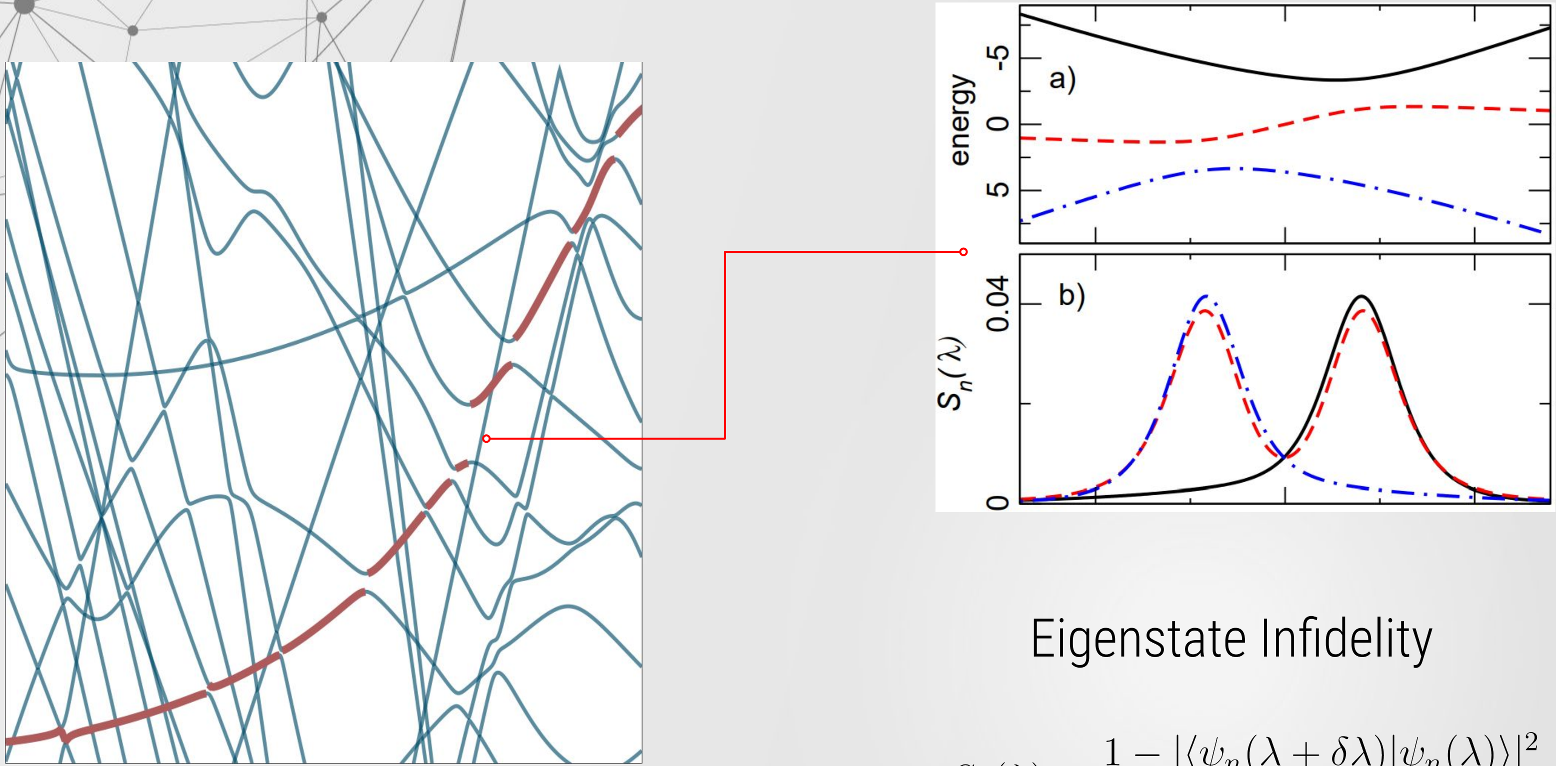

Eigenstate Infidelity

$$S_n(\lambda) = \frac{1 - |\langle \psi_n(\lambda + \delta\lambda) | \psi_n(\lambda) \rangle|^2}{(\delta\lambda)^2}$$

THANK YOU FOR YOUR ATTENTION!!

Questions?

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