In adiabatic quantum computation (AQC), or quantum annealing (QA), the goal is to find the ground state of a many-body Hamiltonian $H_0$, starting from the simple ground state of a transverse field potential $H_{TF}$. A fast evolution with the time-dependent Hamiltonian $H(t) = (1 - s) H_{TF} + s H_0$ renders the system robust against decoherence and thermal noise but can cause diabatic transition towards excited states. Adding a counterdiabatic (CD) potential $H_{CD}$ to the original Hamiltonian can suppress Landau-Zener excitations and drive the system towards the correct target state, improving the efficiency of QA. The variational approach to CD driving can help us build approximate CD operators that are more viable experimentally than the exact CD potential.

### Exact counterdiabatic driving

$$H_{CD}(t) = \delta(t) \sum_{i=0}^{N} \frac{\langle E_i(t) | \hat{H}_0(t) | E_i(t) \rangle}{E_i(t) - E_n(t)} | E_i(t) \rangle \langle E_i(t) |$$

- Nonlocal
- Needs the exact spectrum in advance
- Poorly defined around Quantum Phase Transitions
- Useless for practical purposes!

### Results for $p = 3$: the cyclic ansatz (CA)

$$\mathcal{L}_1 = S_y, \quad \mathcal{L}_2 = S_y^3, \quad \mathcal{L}_3 = S_y S_z + S_z S_y$$

![Graph showing success probability vs. t/τ for various CD methods]

### Finite-range and random models

**Finite-range $p$-spin model**

$$H_p = -\frac{1}{p} \sum_{i<j}^{p} J_{ij} \sigma_i \sigma_j$$

- $v = 0$: infinite-range
- $v > 0$: finite-range

![Graph showing success probability vs. t/τ for finite-range and random models]

**Random model**

$$J \to \mathcal{K} = \begin{cases} I & \text{probability } P_I \\ 0 & \text{probability } 1 - P_I \end{cases}$$

$P_I = 1$: standard model (dashed line)

![Graph showing success probability vs. t/τ for random models]

### Conclusions

- The NC ansatz can improve the annealing performance of the $p$-spin model.
- Its efficiency is bound to decrease in the thermodynamic limit.
- For $p = 3$, the cyclic ansatz is a viable alternative.
- The CA yields optimal fidelity independently of the system size.
- Analyzing finite-range and random models can provide some insights into the efficiency of the CA.