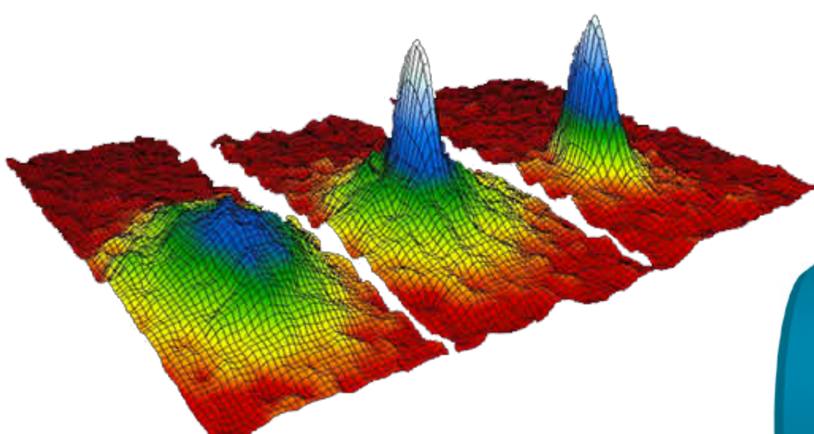
QUANTUM SPEED LIMITS IN SHORTCUTS TO ADIABATICITY

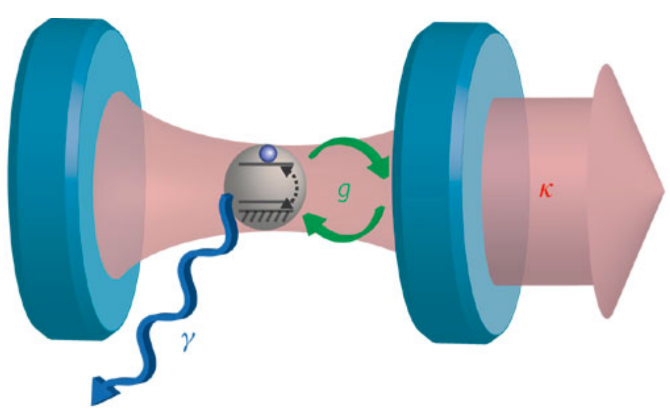
Anthony Kiely
Email: anthony.kiely@ucc.ie
Office: Room 215C, Kane

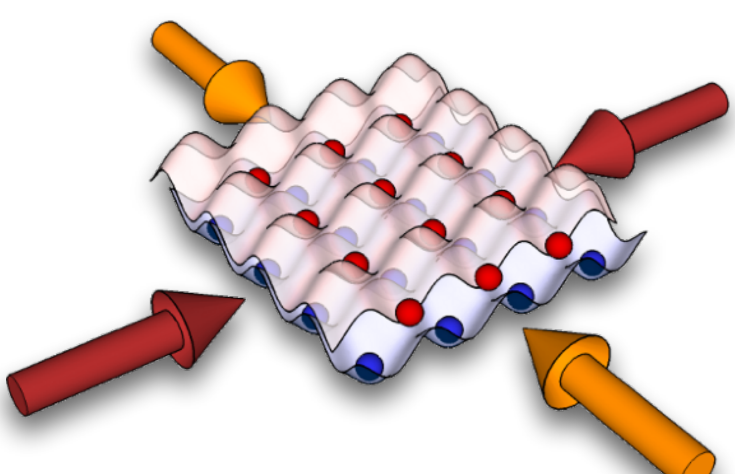
UCC
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

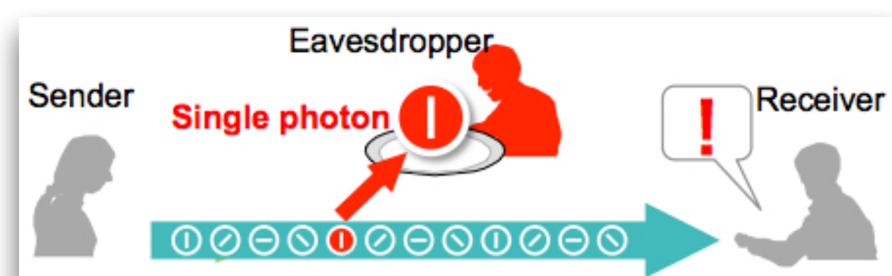
WHY QUANTUM?

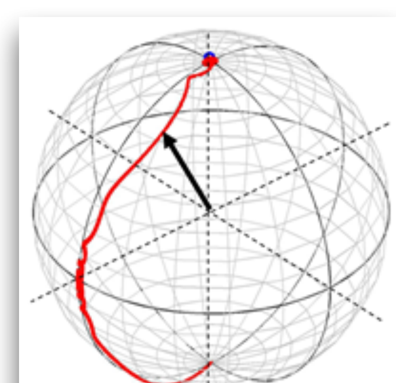
- Quantum mechanics predicts new effects that can't be explained classically
- Many experimental realisations of "truly" quantum systems
- Useful for fundamental studies but also new technologies

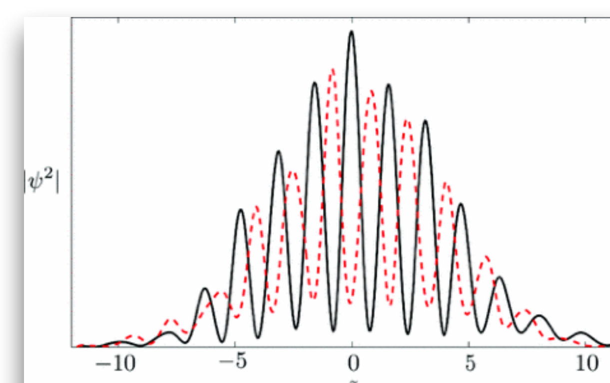






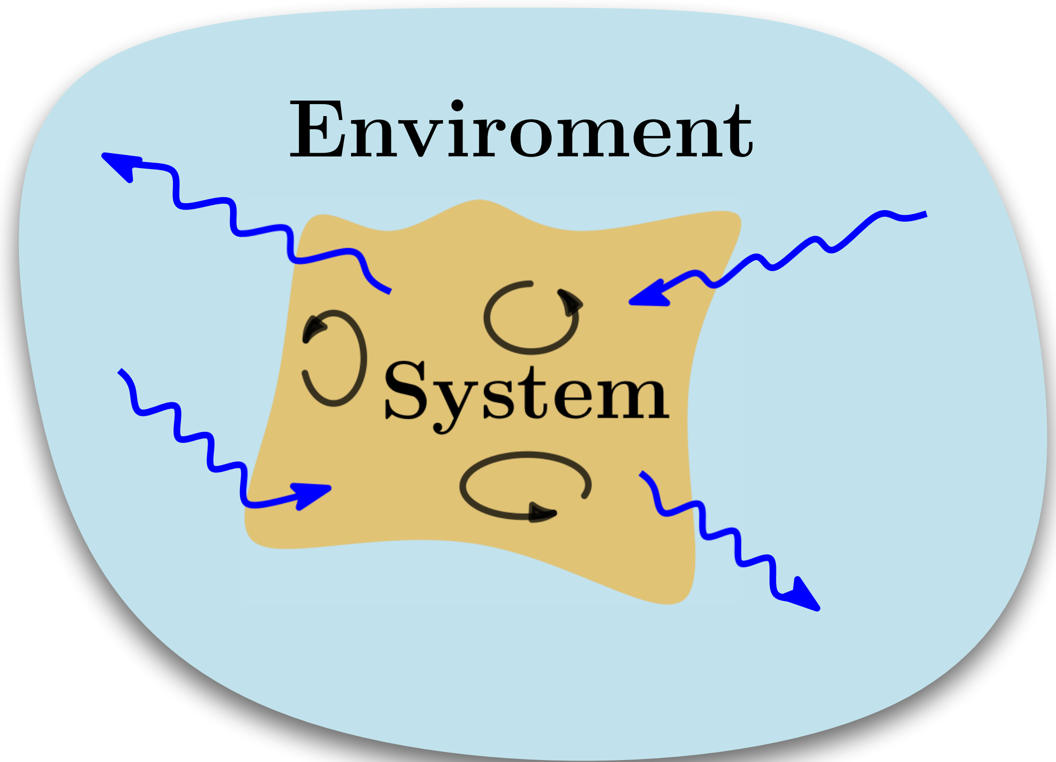


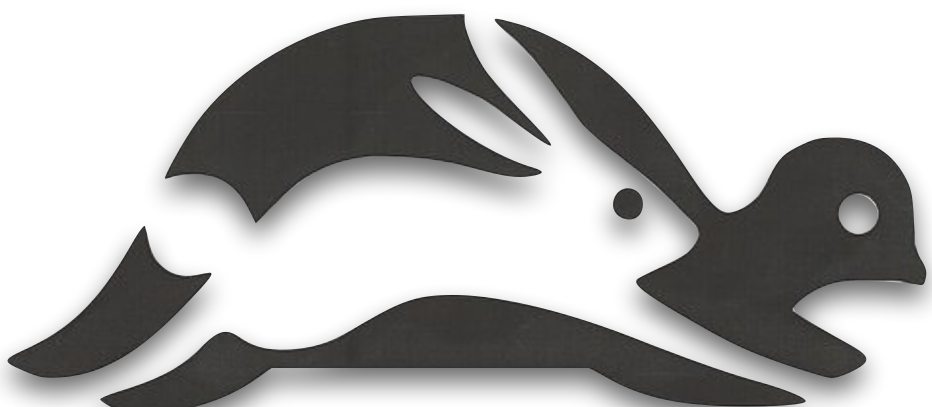




THE BIG PROBLEM: DECOHERENCE

- All systems interact with their surrounding environment
- This interaction destroys the fragile properties (coherence) of the quantum state





SOLUTION:

MOVE QUICKLY TO AVOID NEGATIVE EFFECTS OF ENVIRONMENT!

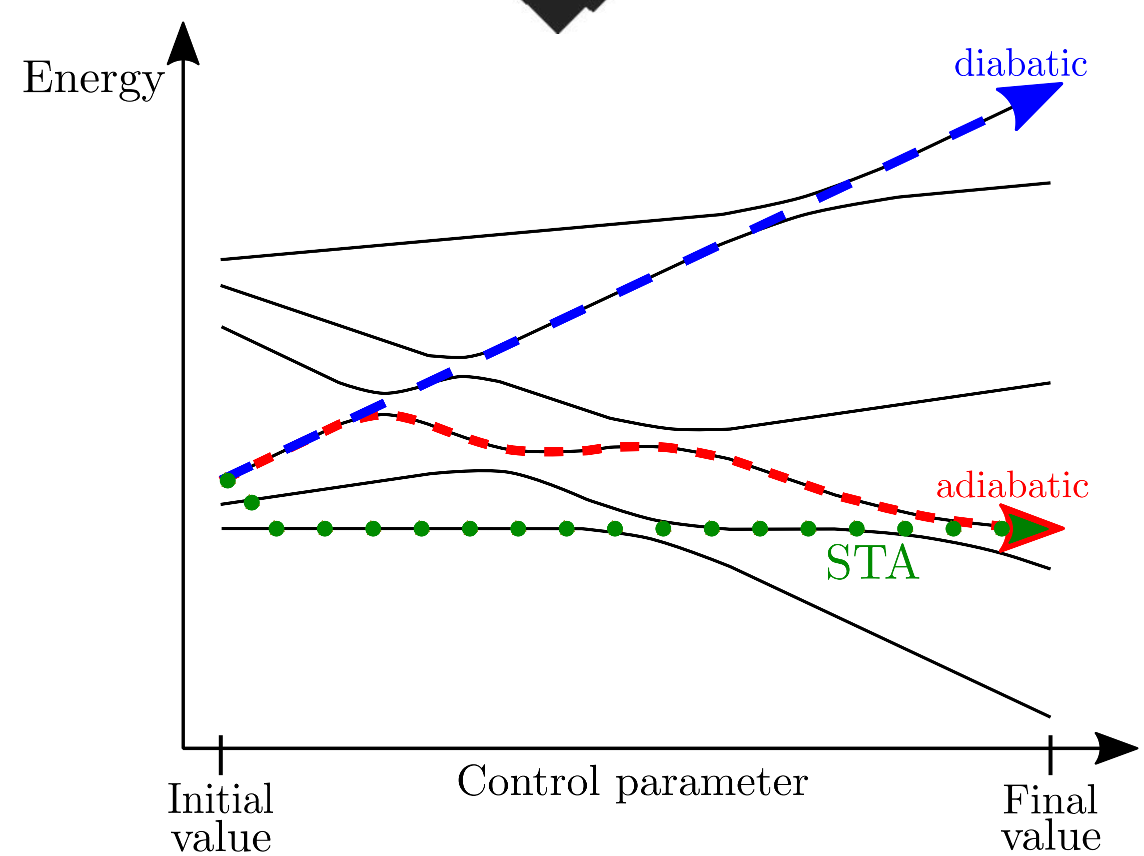
→ ***"Shortcuts to Adiabaticity"***

SHORTCUTS TO ADIABATICITY

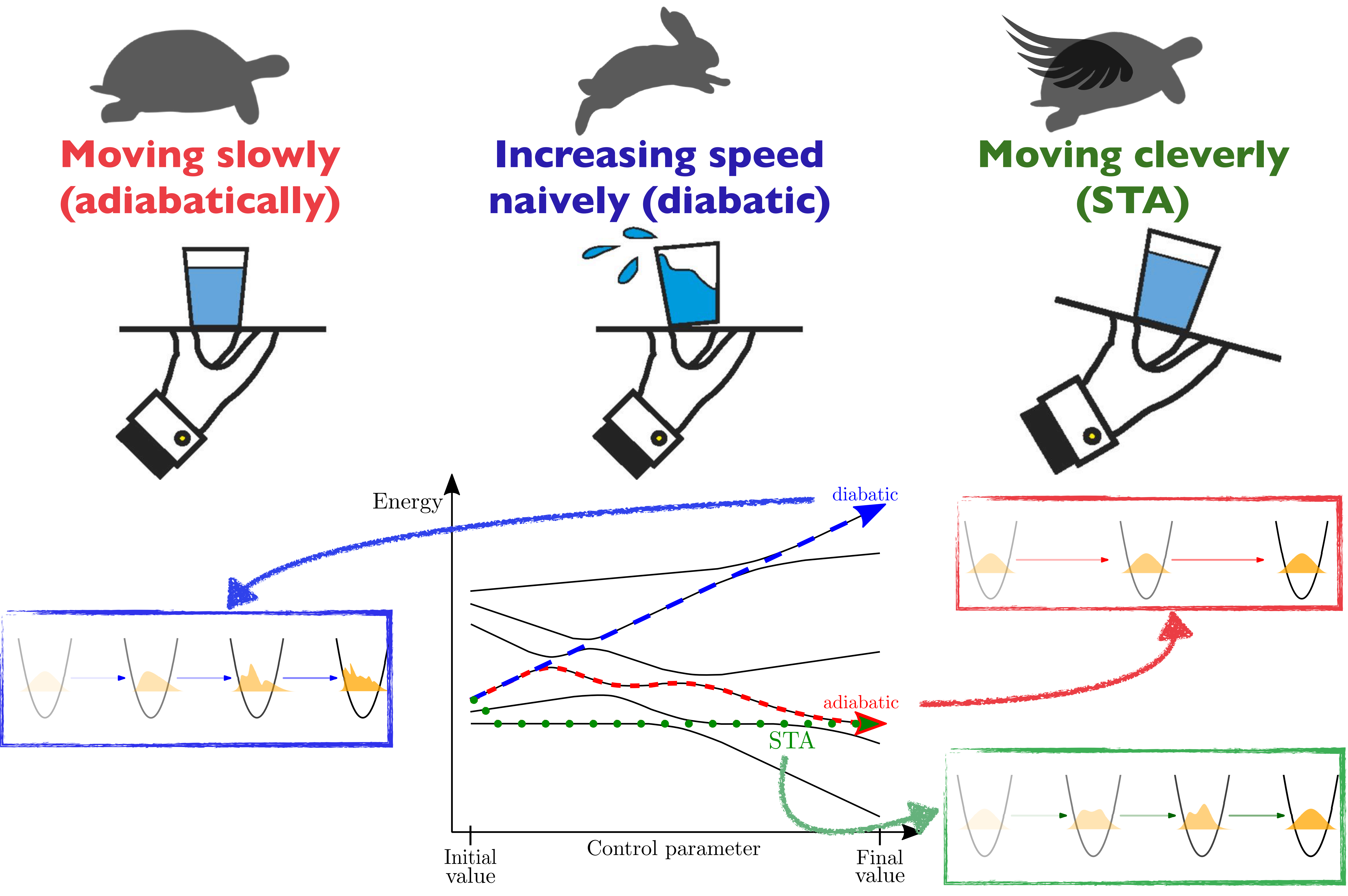
Moving slowly (adiabatically)

Increasing speed naively (diabatic)

Moving cleverly (STA)



SHORTCUTS TO ADIABATICITY



COUNTERDIABATIC DRIVING

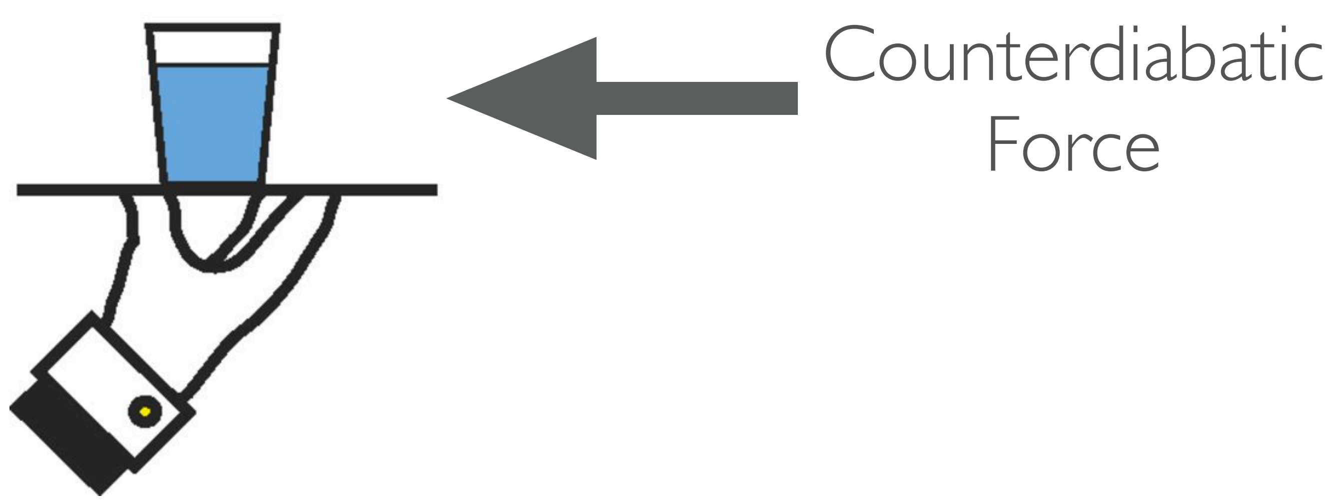
Original Hamiltonian:

$$\mathcal{H}_0(t) = \sum_n E_n(t)|\lambda_n(t)\rangle\langle\lambda_n(t)|$$

Correction Hamiltonian:

$$\mathcal{H}_{CD}(t) = i\hbar \sum_n \left(|\partial_t \lambda_n\rangle\langle\lambda_n| - \langle\lambda_n|\partial_t\lambda_n\rangle|\lambda_n\rangle\langle\lambda_n|\right)$$

Implemented Hamiltonian: $\mathcal{H}(t) = \mathcal{H}_0(t) + \mathcal{H}_{CD}(t)$



QUANTUM SPEED LIMITS

- Mandelstam and Tamm (1945) $$\tau > \frac{\pi}{2}\frac{\hbar}{\Delta H}$$
- Margolus and Levitin (1998) $$\tau > \frac{\pi}{2}\frac{\hbar}{\langle H \rangle}$$
- Deffner and Lutz (2013) $$\tau > \frac{\hbar}{\Delta E_\tau}\mathcal{L}(|\psi_0\rangle, |\psi_\tau\rangle)$$

Time averaged:

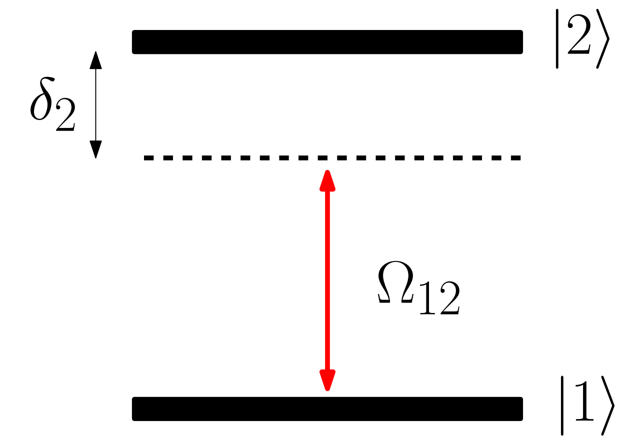
$$\Delta E_\tau \equiv \frac{1}{\tau}\int_0^\tau \Delta H(s) ds$$

Angle between states:

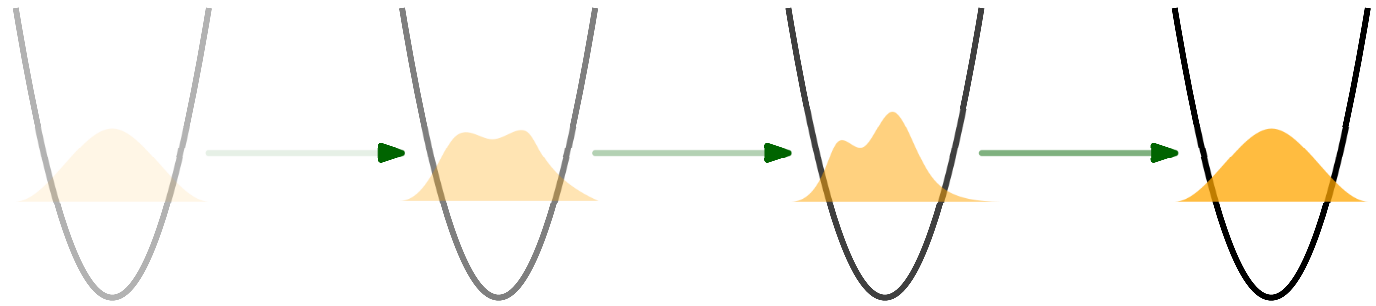
$$\mathcal{L}(|\psi_0\rangle, |\psi_\tau\rangle) \equiv \arccos\left(|\langle\psi_0|\psi_\tau\rangle|\right)$$

THE PROJECT

- Learn about quantum speed limits and shortcuts to adiabaticity



- Calculate and assess limits for model systems



- Establish connection between the energetic cost and the total evolution time