Hands-on Workshop with D-Wave Quantum Computers

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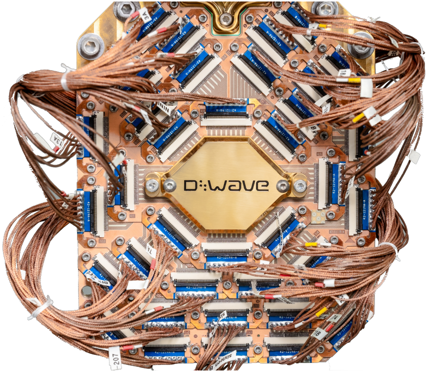
12 June, 2025

In this workshop

The aim of the workshop is to showcase and work hands-on with some Ocean™ SDK tools useful for physics experiments

- Landau-Zener and Kibble-Zurek experiments
- Jupyter notebook, with code snippets and links
- Question and answer



Check your email for an invitation to the Leap project, which provides the API token necessary for D-Wave quantum computer access.

Log in to github, or download the code: https://github.com/dwave-training/2025-aqc-workshop

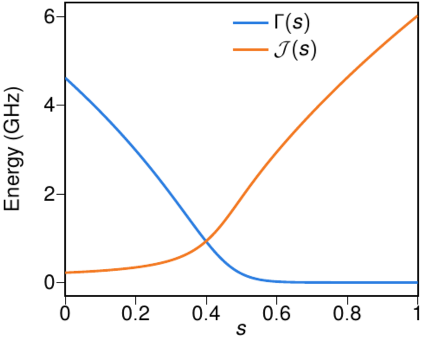
Quantum annealing

Evolve a multi-spin system for time t_a,

$$H(s = t/t_a) = -\Gamma(s)\sum_i \sigma_i^x + \mathcal{J}(s)H_p$$

1. Program a problem Hamiltonian $H_P = \sum_{ij} J_{ij}\sigma_i^z\sigma_j^z + \sum_i h_i\sigma_i^z$
2. Prepare a ground state at (large $\Gamma(s=0)$ and small $\mathcal{J}(s=0)$)
3. Evolve to large $\mathcal{J}(s=1)$ and small $\Gamma(s=1)$
4. Measure in the computational basis

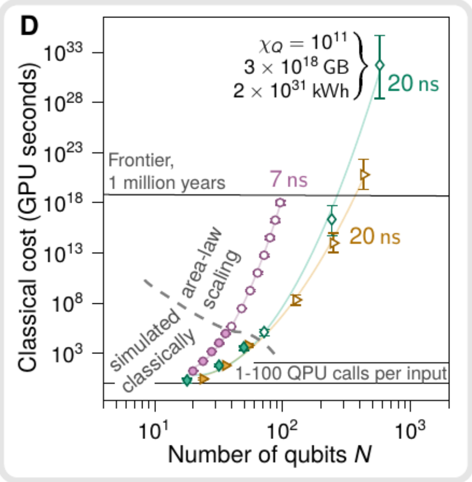
Kadowaki and Nishimori, Phys. Rev. E 58, 5355 (1998)



Six recent papers

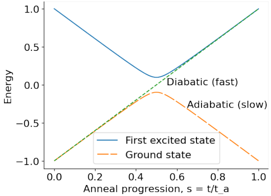
1. Coherent quantum annealing in a programmable 2,000 qubit Ising chain, *Nature* Physics (2022)
2. Quantum critical dynamics in a 5,000-qubit programmable spin glass, *Nature* (2023)
3. Quantum error mitigation in quantum annealing, *npj Quantum Information* (2025)
4. Beyond-classical computation in quantum simulation, *Science* (2025)
5. Blockchain with proof of quantum work (arXiv:2503.14462)
6. Quantum dynamics in frustrated Ising fullerenes (arXiv:2505.08994)

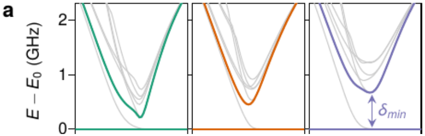
Projected classical resources to match QPU

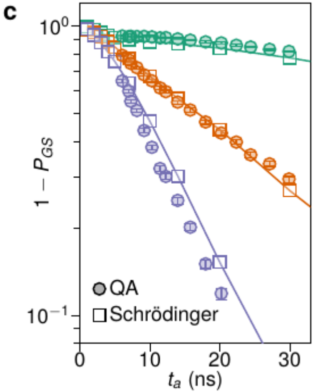


Landau-Zener dynamics with 16-qubit frustrated models

The probability to excite away from the ground state decays exponentially with the annealing time: the exponent determined by the inverse square gap.



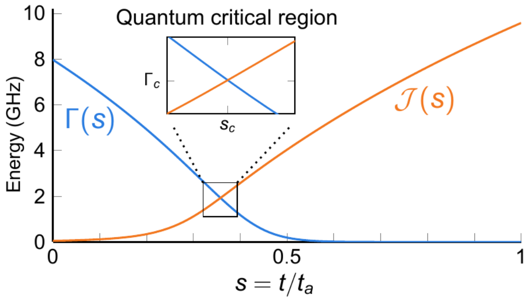




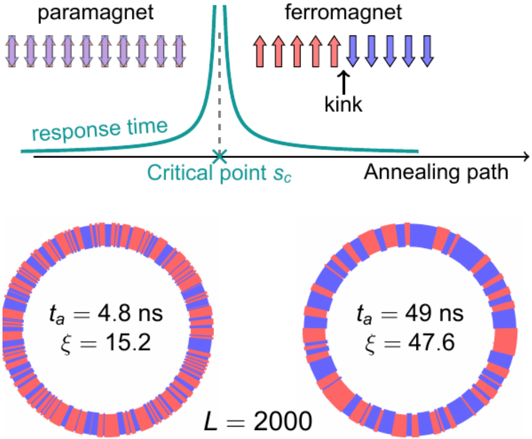
Quantum critical dynamics in a 5,000-qubit programmable spin glass, Nature (2023)

Kibble-Zurek dynamics in 1D

Defect rates (equivalently residual energy) decays as a power of the annealing time; the power determined by the universality class of the phase transition.



Coherent quantum annealing in a programmable 2,000 qubit Ising chain, Nature Physics (2022)



Run the code (locally or codespaces)

At github.com/jackraymond/AQC2025workshop
Code > codespace > +

dwave setup - -oob # Paste the workshop token for the Leap quantum cloud service access

python main.py # Run with defaults

python main.py - - help # Show experiment options:

- solver_name: e.g. Advantage2_system1.1
- model: 'Landau-Zener' or 'Kibble-Zurek'
- use_srt: Randomize (sign flip) the computational basis definition. A means to mitigate control errors.
- parallelize_embedding: embed many times. A means to mitigate control, and sampling, errors.

Further code examples: physics-experiments-ocean-sdk.ipynb