



# Hands-on Workshop with D-Wave Quantum Computers

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D-WAVE

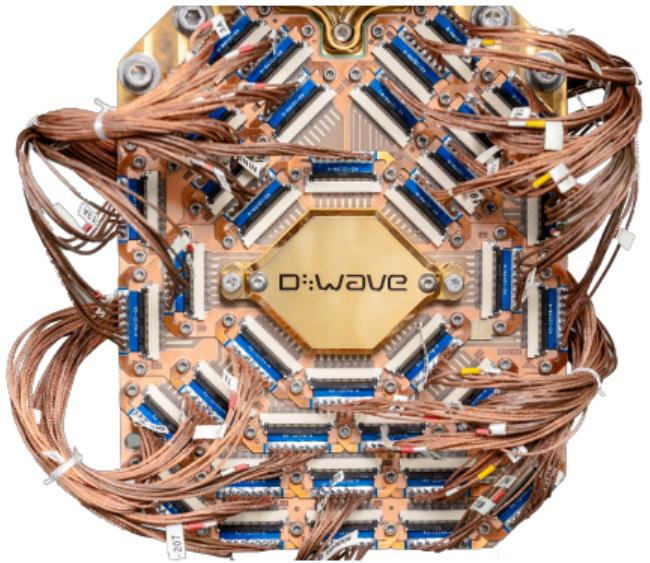
# In this workshop

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:  
<http://github.com/dwavesystems/AQC2025workshop>





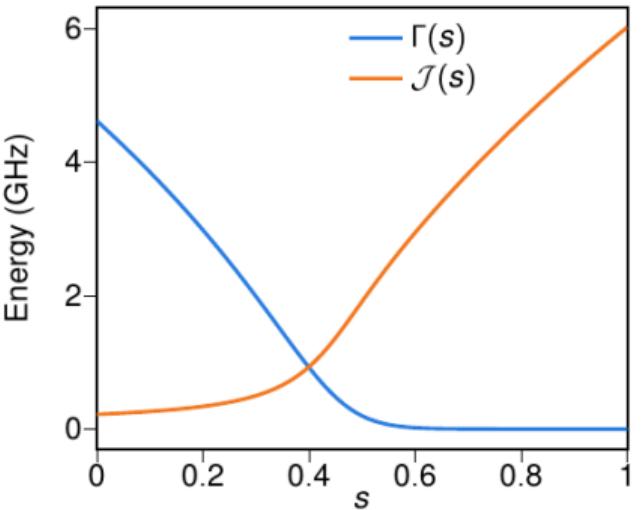
# Quantum annealing

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

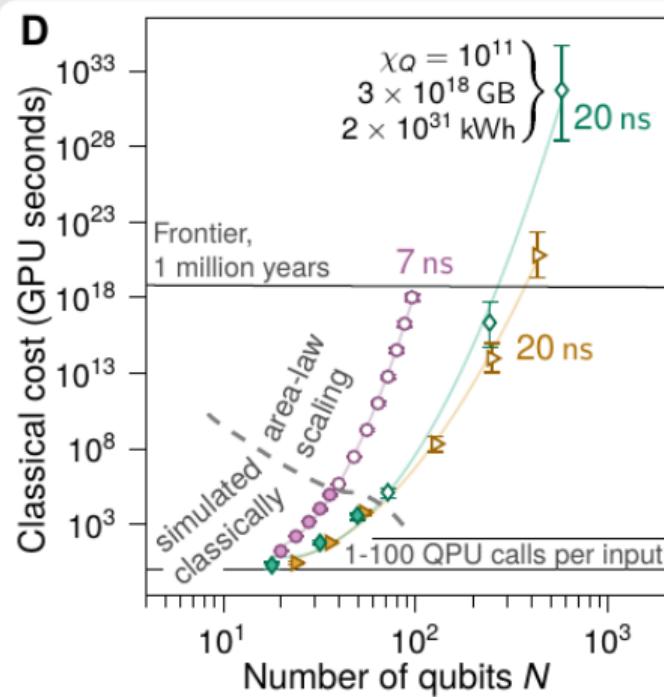
Kadowaki and Nishimori, Phys. Rev. E 58,  
5355 (1998)



# 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)

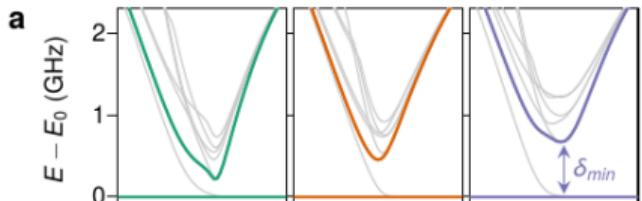
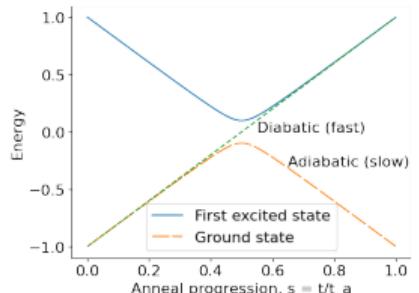
Projected classical resources to match QPU



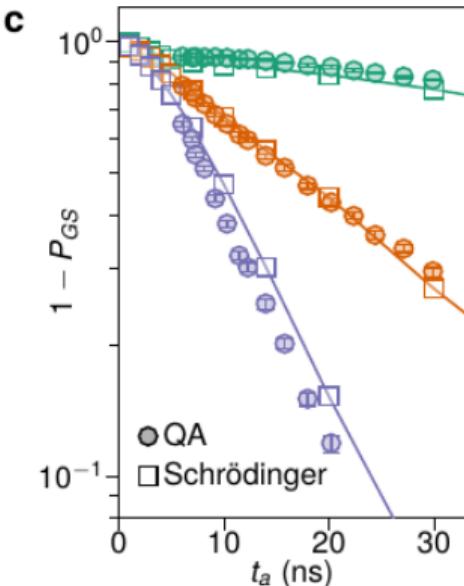
# Landau-Zener dynamics with 16 qubit random models



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



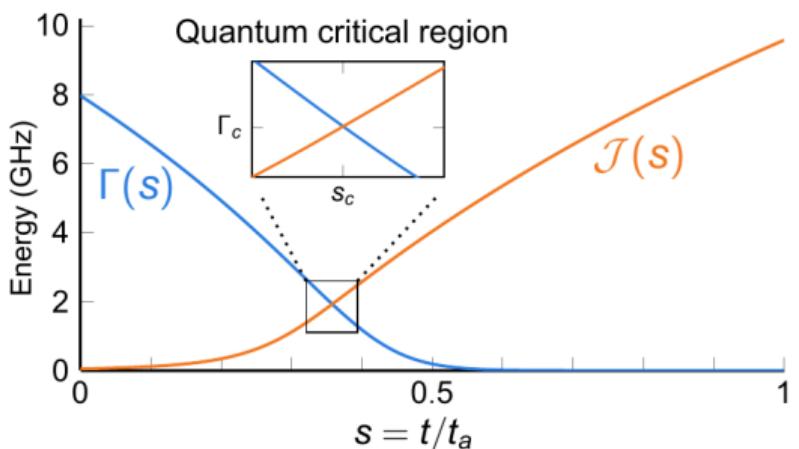
Quantum critical dynamics in a 5,000-qubit programmable spin glass, Nature (2023)



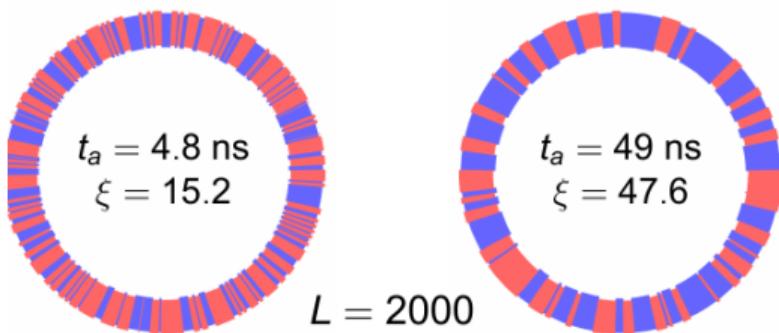
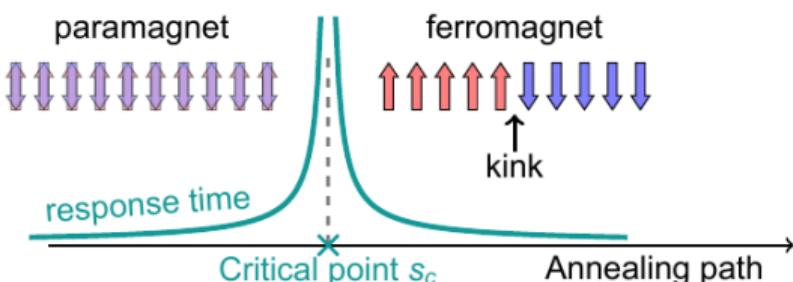
# Kibble-Zurek dynamics in 1D



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](https://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](#)

