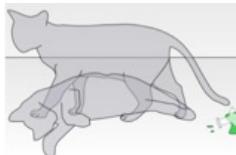
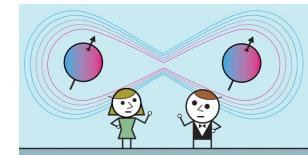


# Quantum Computing Is Hot



Quantum computing utilizes quantum properties such as superposition & entanglement for computation



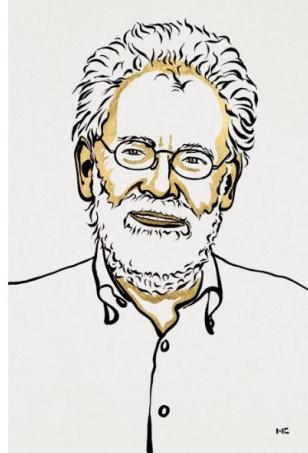
## The Nobel Prize in Physics 2022



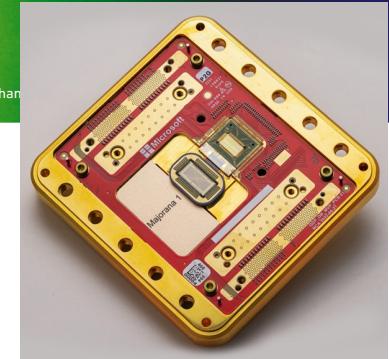
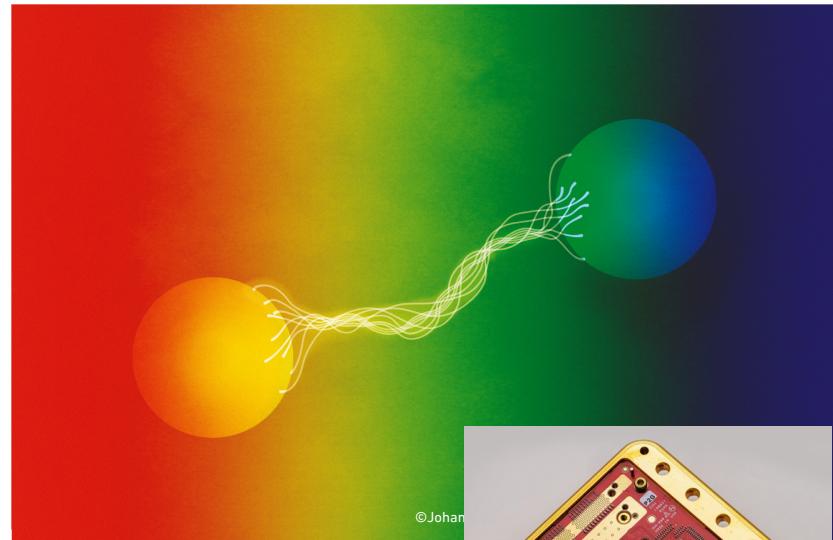
III. Niklas Elmehed © Nobel Prize Outreach  
Alain Aspect  
Prize share: 1/3



III. Niklas Elmehed © Nobel Prize Outreach  
John F. Clauser  
Prize share: 1/3



III. Niklas Elmehed © Nobel Prize Outreach  
Anton Zeilinger  
Prize share: 1/3



cf. Microsoft announced Majorana 1 quantum chip (Feb. 19, '25)

<https://news.microsoft.com/azure-quantum>

The Nobel Prize in Physics 2022 was awarded jointly to Alain Aspect, John F. Clauser and Anton Zeilinger "for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science"

# Quantum Computing Is Now

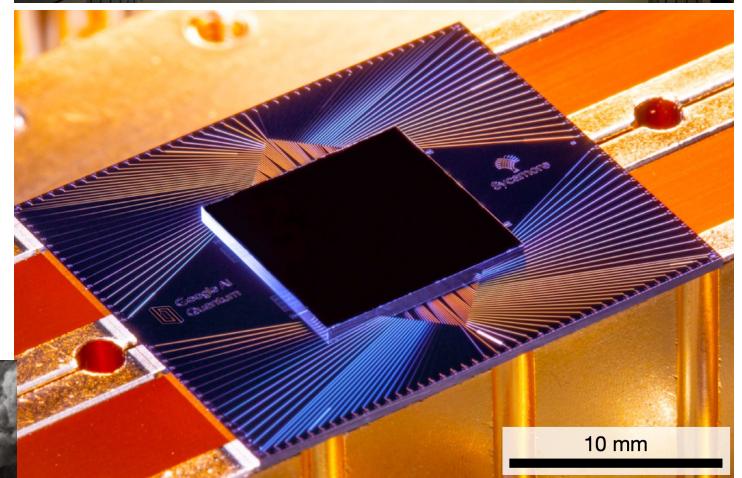
- U.S. Congress (Dec. 21, '18) signed National Quantum Initiative Act to ensure leadership in quantum computing & its applications
- Quantum supremacy (*i.e.*, quantum computer is faster than the fastest supercomputer) was demonstrated by Google  
Arute, Martinis, et al., *Nature* 574, 505 ('19)
- Google's Sycamore quantum computer consumed 26 kilowatts of power to outperform the 13 megawatts Summit supercomputer at Oak Ridge National Lab, *i.e.*, 500 times more energy efficient



9,216-CPU & 27,648-GPU Summit



*Fast  
&  
frugal*



54-qubit Google Sycamore

# Quantum Computing Gets Hotter

## Nobel Prize in Physics 2025



Ill. Niklas Elmehed © Nobel Prize Outreach

John Clarke

Prize share: 1/3



Ill. Niklas Elmehed © Nobel Prize Outreach

Michel H. Devoret

Prize share: 1/3

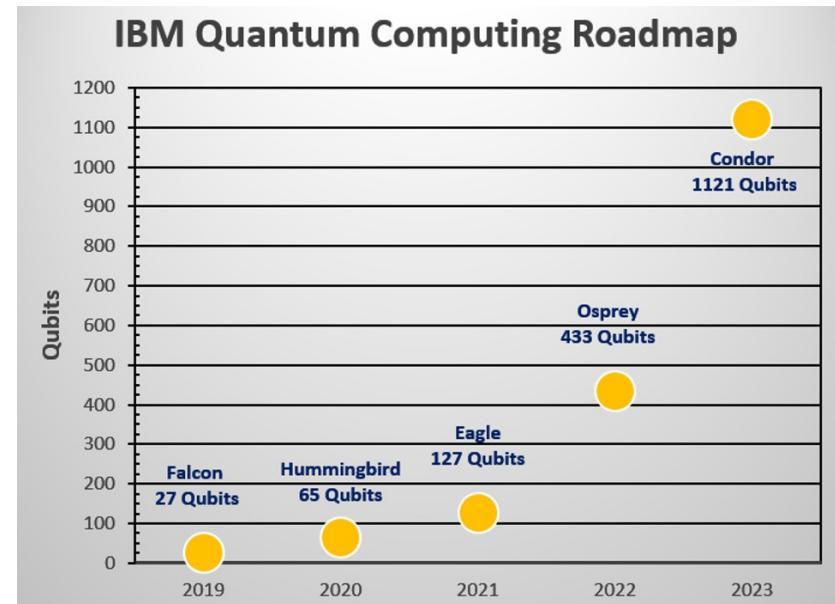
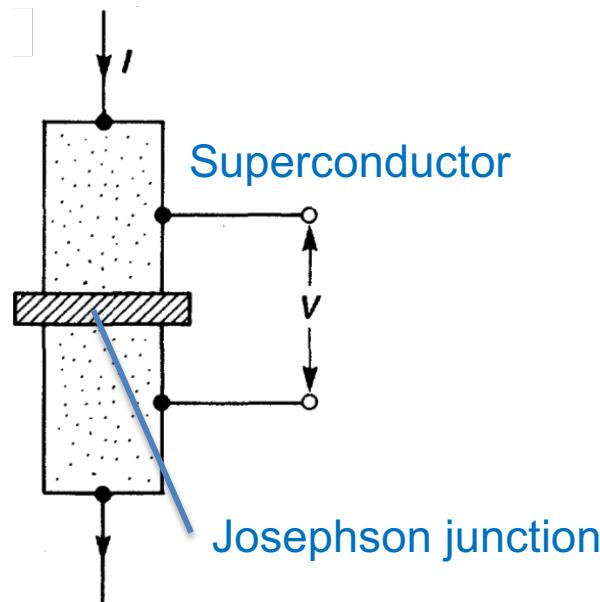


Ill. Niklas Elmehed © Nobel Prize Outreach

John M. Martinis

Prize share: 1/3

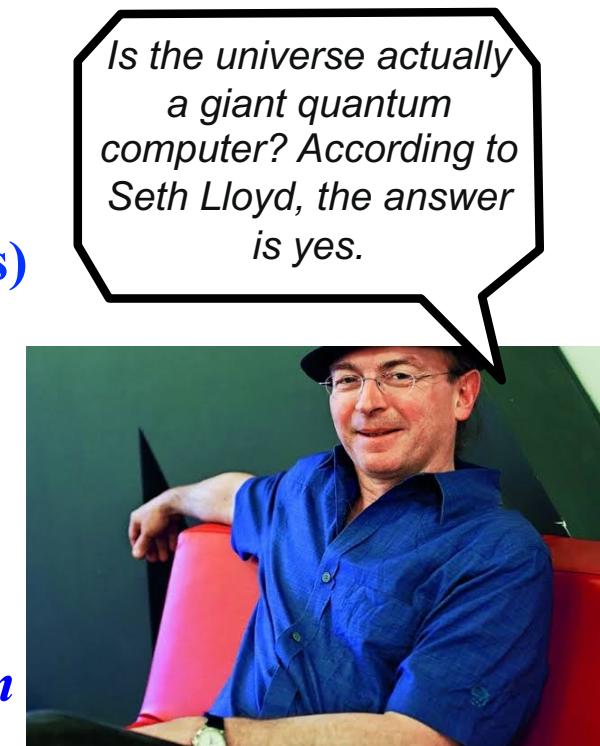
The Nobel Prize in Physics 2025 was awarded jointly to John Clarke, Michel H. Devoret and John M. Martinis "for the discovery of macroscopic quantum mechanical tunnelling and energy quantisation in an electric circuit"



*Foundation of superconducting quantum circuits*

# Quantum Computational Science

- An exciting scientific application of quantum computers is as a universal simulator of quantum many-body dynamics, as envisioned by Richard Feynman Int. J. Theor. Phys. 21, 467 ('82)
- Seth Lloyd provided concrete algorithms and analysis Science 273, 1073 ('96)  
Watch Seth's movie: <https://www.youtube.com/watch?v=EMzKshc6x2M>  
  
<https://www.amazon.com/Programming-Universe-Quantum-Computer-Scientist-ebook/dp/B000GCFBP6>
- Success in simulating *static* properties of quantum systems (*i.e.*, ground-state energy of small molecules)  
Aspuru-Guzik *et al.*, Science 309, 1704 ('05)
- Challenge: Simulate quantum many-body *dynamics* on current-to-near-future noisy intermediate-scale quantum (NISQ) computers  
J. Preskill, Quantum 2, 79 ('18)
- Second edition of *Feynman Lectures on Computation* (2023) added a section on “Simulating quantum dynamics” by John Preskill arXiv:2106.10522 ('21)

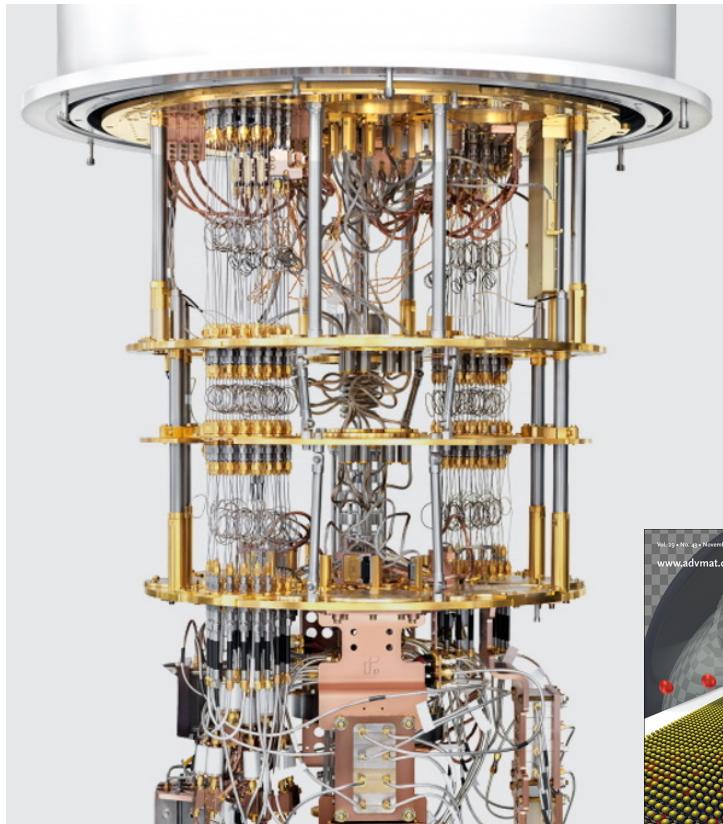


<https://www.amazon.com/Feynman-Lectures-Computation-Anniversary-Frontiers/dp/0367857332>

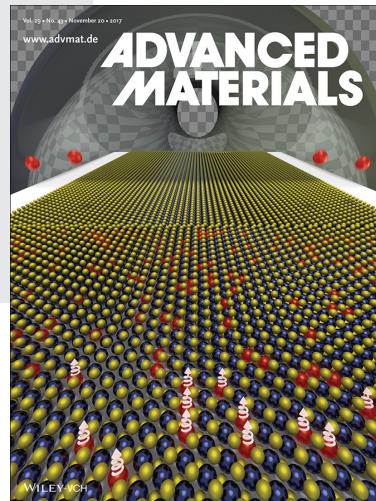
# Quantum Computing of Magnetism

- Simulated quantum many-body dynamics of magnetic spins on IBM's Q16 Melbourne & Rigetti's Aspen quantum processors

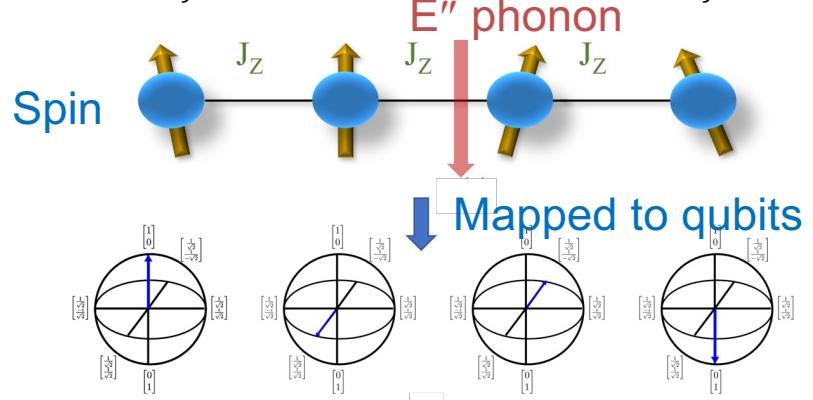
L. Bassman et al., Phys. Rev. 101, 184305 ('20)



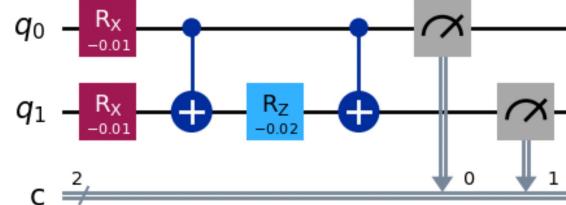
Re-doped MoSe<sub>2</sub>



$$H(t) = -J_z \sum_{j=1}^{N-1} \sigma_z^j \sigma_z^{j+1} - \varepsilon_{ph} \sin(\omega_{ph} t) \sum_{j=1}^N \sigma_x^j$$



Quantum circuit:  $U(\Delta t) = \exp(-iH\Delta t)$

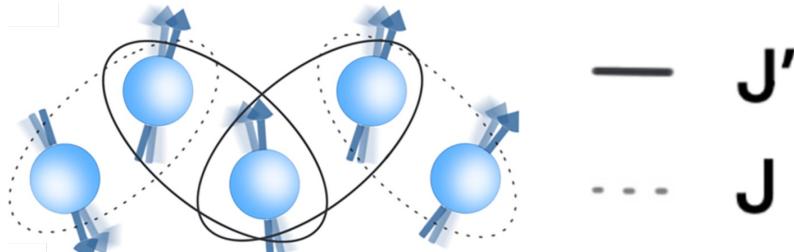


Quantum (Python) program

```
circ.rx(-2*dt*B, 0)
circ.rx(-2*dt*B, 1)
circ.cx(0, 1)
circ.rz(-2*dt*J, 1)
circ.cx(0, 1)
```

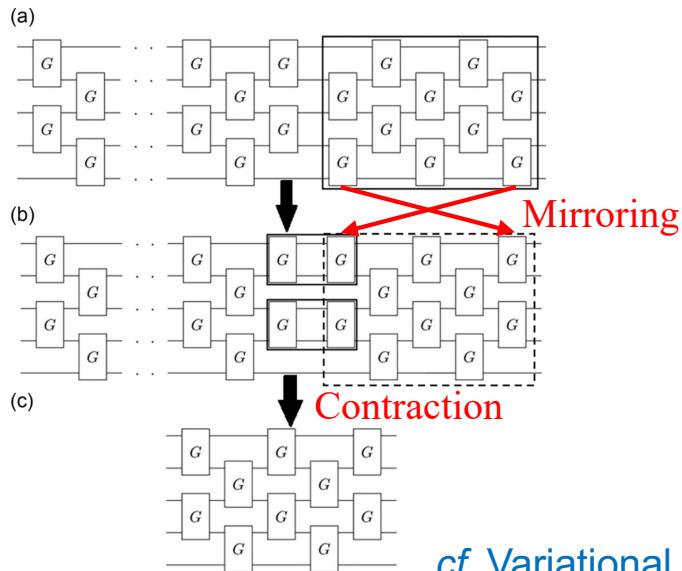
# Topological Quantum Dynamics & Beyond

Quantum spin chain



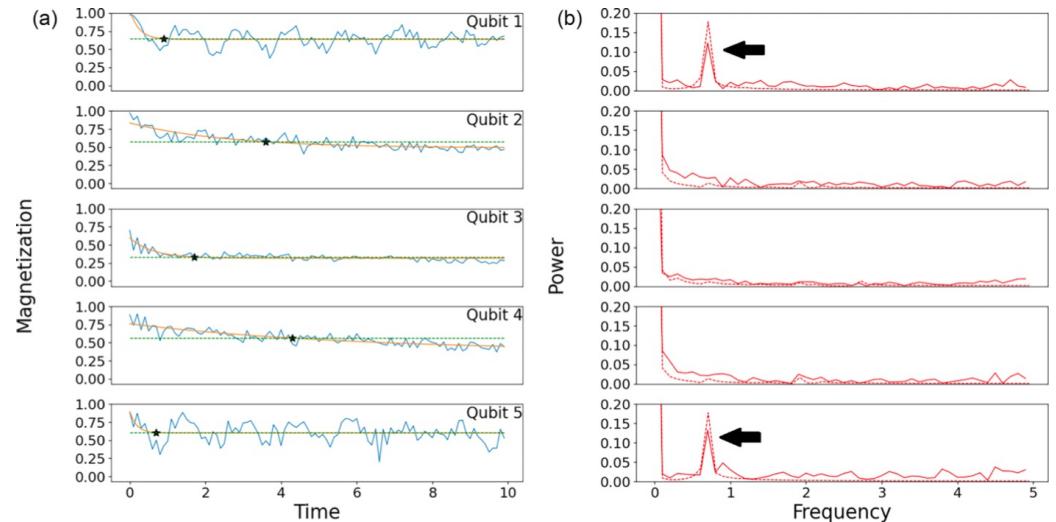
Mercado et al., Phys. Rev. B 110, 075116 ('24)

Constant-depth quantum circuit



cf. Variational fast-forwarding, Yang-Baxter equation

Topological surface mode



- DCR/MSA paradigm allows exponentially hard topological quantum many-body dynamics to be offloaded from Exaflop/s supercomputers to quantum processing units (QPU), realizing *quantum-centric supercomputing (QCSC)* Alexeev et al., FGCS 160, 666 ('24)