

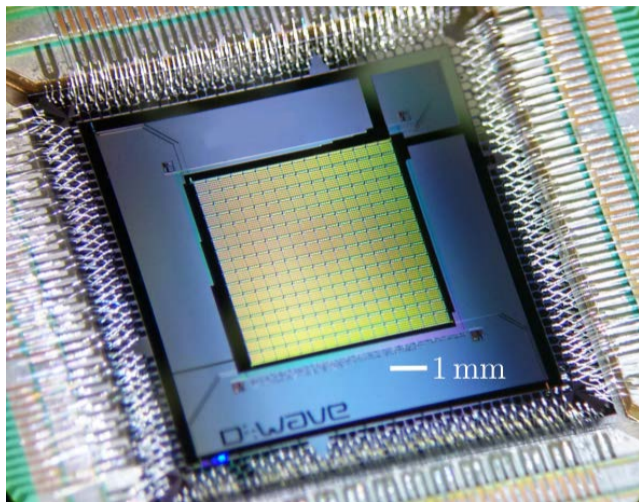
# A noisy brawl: D-Wave versus D-Wave

Richard Harris

March 6, 2019

The background features a complex, abstract digital design. It consists of multiple layers of semi-transparent, flowing blue and white lines that create a sense of motion and depth. A central point of light, surrounded by concentric circles and radiating lines, serves as a focal point, suggesting a quantum state or a data hub. The overall aesthetic is futuristic and technological.

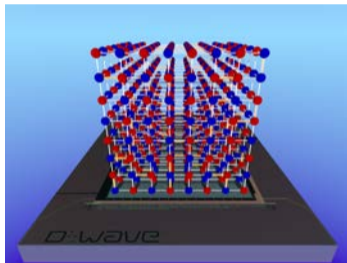
The DW2000Q  
quantum processing unit (QPU)



Trans.Appl.Supercond. **24**, 1700110 (2014).

We had our fun ...

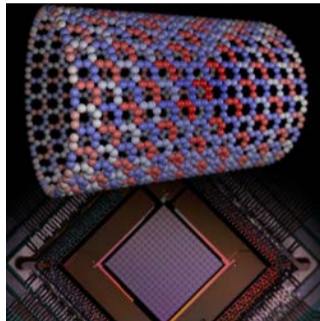
# Using the DW2000Q as programmable quantum matter



“Phase transitions in a programmable quantum spin glass simulator”

*Science* **361** 6398 162-165 (2018)

nature



“Observation of topological phenomena in a programmable lattice of 1,800 qubits”

*Nature* **560** 7719 (2018)

... but where is the `quantum advantage'?

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(and what does coherence or noise have to do with it?)

The background is a dark blue gradient with intricate, glowing patterns. It features several overlapping, semi-transparent blue shapes that resemble stylized waves or petals. A central point of light, surrounded by concentric circles and radiating lines, serves as a focal point. The overall aesthetic is futuristic and digital.

Looking for a problem



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[See Katzgraber, Hamze, and Andrist, PRX **4**, 021008 (2014)]
- ▶ Hard enough to resolve optimal anneal time.  
[See Albash and Lidar, PRX **8**, 031016 (2018)]

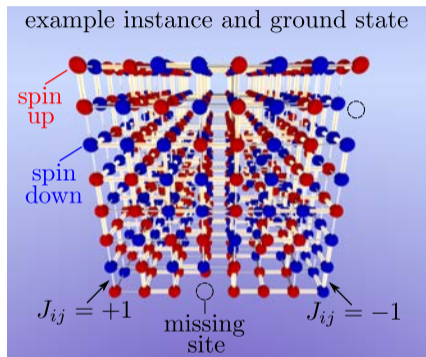
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[See Albash and Lidar, PRX **8**, 031016 (2018)]
- ▶ Ground state probability is sensitive to noise within experimental constraints.  
[?]

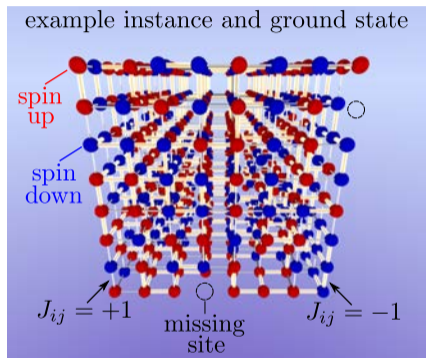
# $8 \times 8 \times 8$ cubic lattice spin glasses

An **embedded problem** that has the desired attributes. [See *Science* **361**, 162 (2018)]



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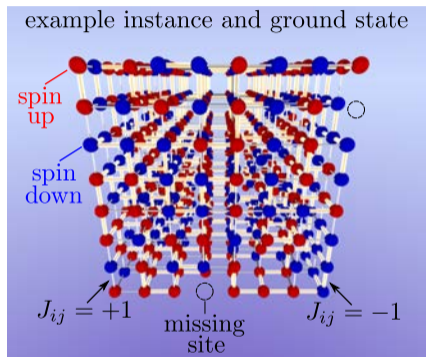
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- Favorable *phase transitions* as a function of quantum annealing parameter  $s$ . ✓

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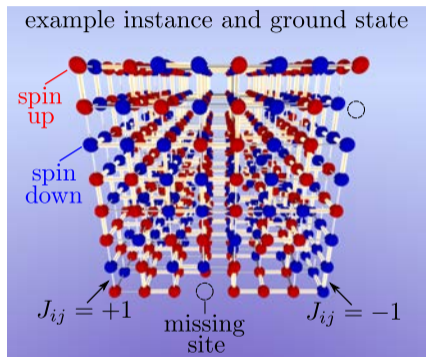
An **embedded problem** that has the desired attributes. [See *Science* **361**, 162 (2018)]



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# $8 \times 8 \times 8$ cubic lattice spin glasses

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- ▶ Favorable *phase transitions* as a function of quantum annealing parameter  $s$ . ✓
- ▶ Hard enough to make a DW2000Q QPU sweat. ✓
- ▶ **...but are these problems sensitive to noise?**



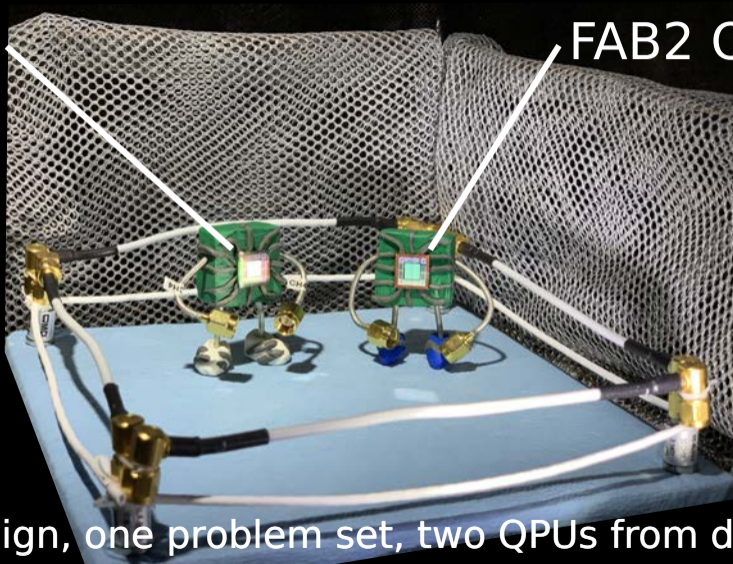
The background is a dark blue gradient with intricate, flowing patterns of lighter blue and white. These patterns consist of overlapping, semi-transparent shapes and lines that create a sense of movement and depth. A prominent feature is a bright, glowing point of light at the center, from which several lines radiate outwards, some ending in small, bright spots. The overall effect is that of a complex, digital or scientific visualization.

Cage match

# The contenders

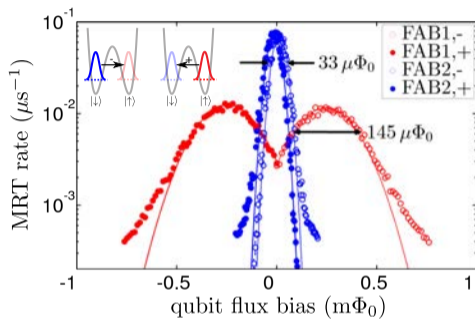
FAB1 QPU

FAB2 QPU



One design, one problem set, two QPUs from different fabrication stacks ... only one will prevail.

# Two identical QPUs but with different noise characteristics



- ▶ Two QPUs manufactured with different processes:
  - ▶ **FAB1** - variant of process used to manufacture DW2000Q products
  - ▶ **FAB2** - a more recent experimental fabrication stack
- ▶ Roughly a factor of  $5\times$  less noise in FAB2 relative to FAB1.

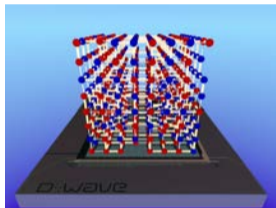
The background is a dark, almost black, space filled with intricate, glowing blue and white patterns. These patterns consist of numerous thin, overlapping lines and dots that create a sense of depth and movement, resembling a complex digital or data visualization. A bright, multi-colored (white, yellow, and blue) light source is positioned near the center, from which the patterns radiate outwards. The overall effect is one of high-tech, futuristic energy.

The rules

# Solving cubic lattice spin glasses

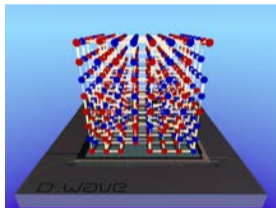
# Solving cubic lattice spin glasses

1. Send a spin glass instance to the QPU, take lots ( $10^5$ ) of reads for a range of anneal time  $t_a$ .

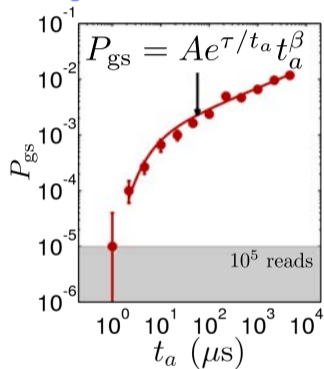


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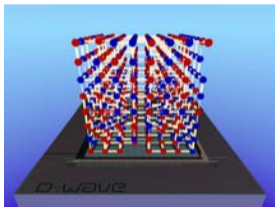


2. Record the probability of observing a ground state  $P_{gs}$ .

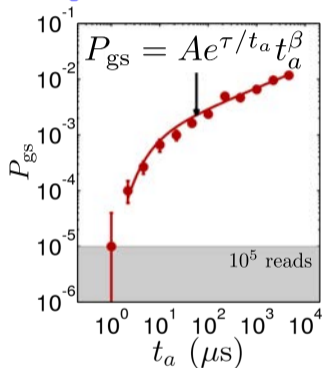


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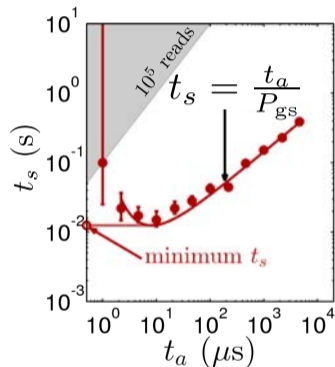
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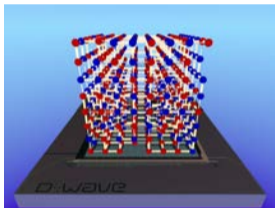
3. Convert to solution time  $t_s$ . Determine optimal  $t_a$  and minimum  $t_s$ .



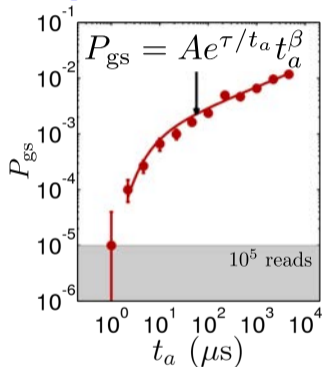


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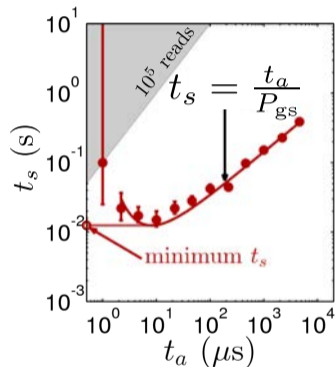
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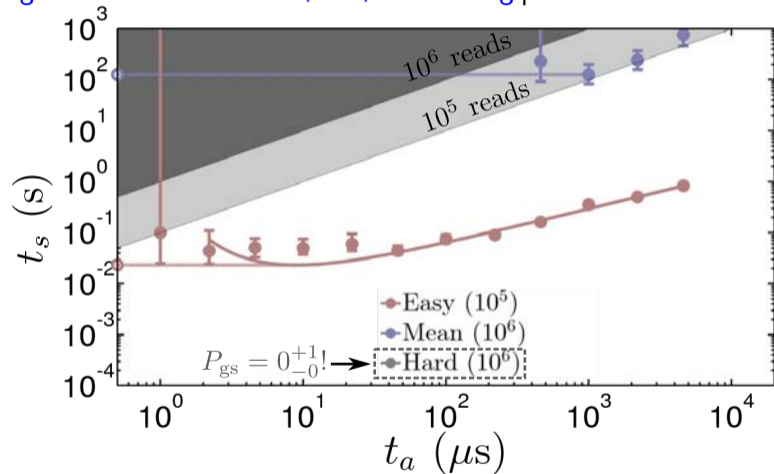
4. Repeat steps 1-3 for 100 randomly generated spin glass instances on both FAB1 and FAB2 QPUs. Note that identical instances are run on each QPU. **Which QPU wins?**

The background features a complex, abstract design in shades of blue and white. It consists of multiple overlapping, flowing, ribbon-like shapes that create a sense of movement and depth. A central point of light or convergence is visible, from which several lines radiate outwards, some ending in small, bright spots. The overall effect is that of a digital or scientific visualization, possibly representing data flow or a network structure.

Warm-up: Getting the embedding right

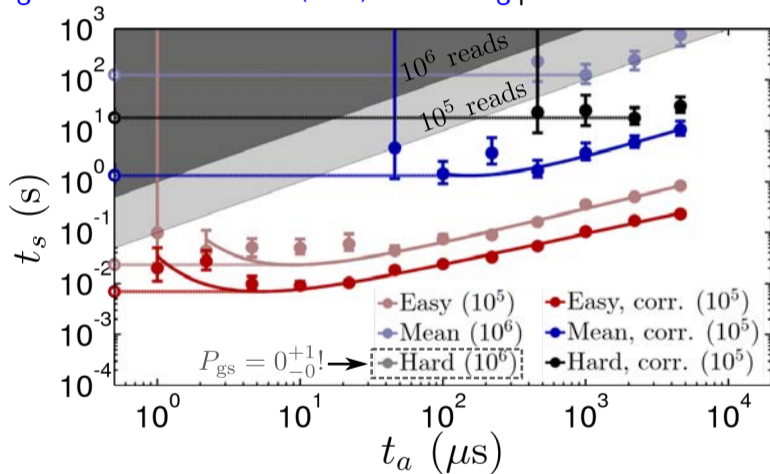
# Correcting the embedding improves performance

Consider 3 example instances run on FAB1 QPU. Measure  $t_s$  versus  $t_a$  for a naive embedding and then a corrected (corr.) embedding per *Science* 361 6398 162-165 (2018):



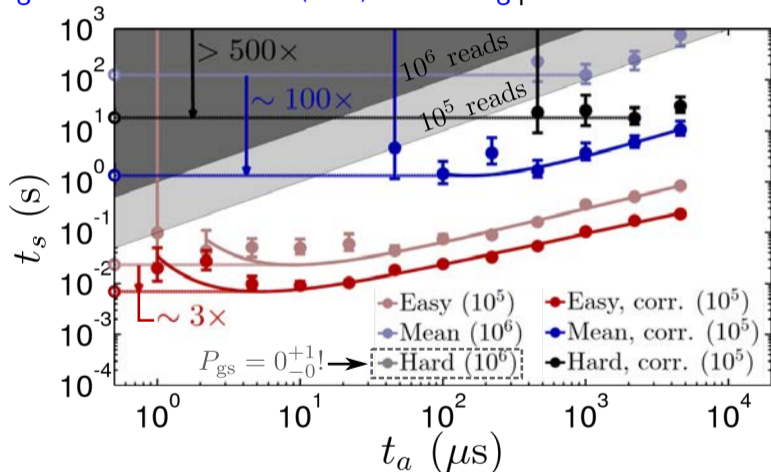
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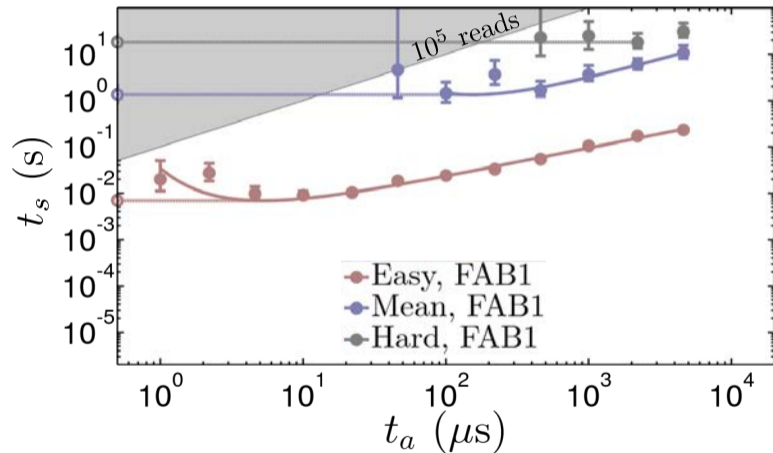
- ▶ Correcting  $\rightarrow$   $> 500\times$  reduction in optimal solution time  $t_s$  on hard instance.

The background features a complex, abstract design in shades of blue and white. It consists of numerous overlapping, flowing lines and shapes that create a sense of movement and depth. A prominent feature is a bright, glowing white spot at the center, surrounded by concentric, radiating lines that resemble a starburst or a lens flare. The overall effect is ethereal and futuristic.

The main event

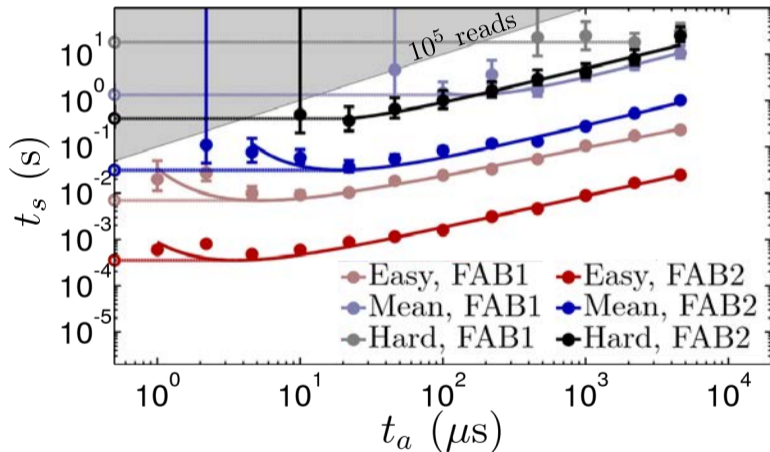
# Reducing noise improves performance

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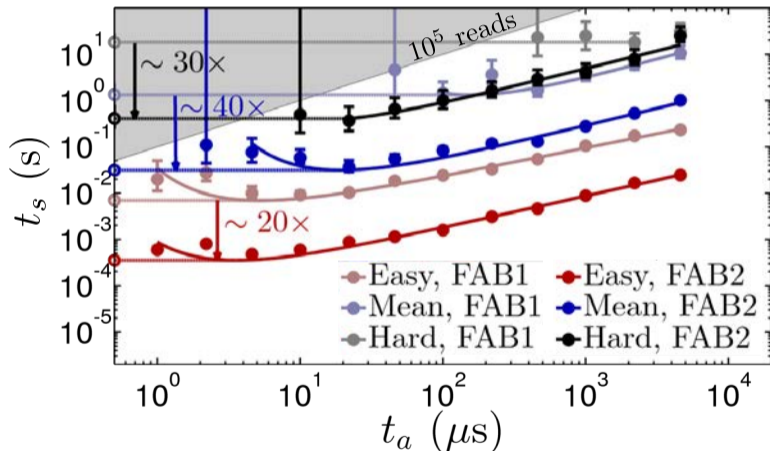
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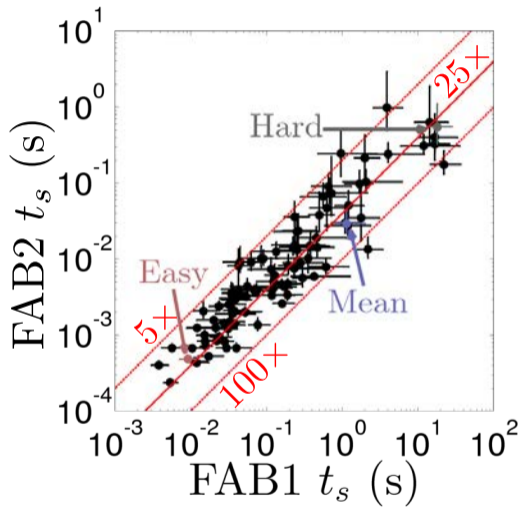
# Reducing noise improves performance

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► Modest  $5\times$  reduction in noise  $\rightarrow$  up to  $40\times$  reduction in optimal solution time  $t_s$ .

## All 100 instances



- Mean 25 $\times$  reduction in optimal solution time  $t_s$ .

# Conclusions

The background features a complex digital aesthetic. It consists of multiple layers of semi-transparent, flowing blue and white lines that create a sense of motion and depth. A central point of convergence is highlighted by a bright, multi-colored glow (white, yellow, and blue) surrounded by concentric, radiating patterns of small dots and lines, resembling a digital core or a data hub. The overall color palette is dominated by various shades of blue, from deep navy to light cyan, set against a dark, almost black background.

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- ▶ Modest **reductions in noise** give significant **reductions in solution time** ( $\sim 5\times$  reduction in noise,  $\sim 25\times$  improvement on typical instances).
- ▶ Further **reductions in noise** will continue to **improve performance**. We are nowhere near a fundamental limit.