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Quantum Computing Advance Begins New Era, IBM Says

A quantum computer came up with better answers to a physics problem than a conventional supercomputer.

By Kenneth Chang

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Quantum computers today are small in computational scope — the chip inside your smartphone contains billions of transistors while the most powerful quantum computer contains a few hundred of the quantum equivalent of a transistor. They are also unreliable. If you run the same calculation over and over, they will most likely churn out different answers each time.

But with their intrinsic ability to consider many possibilities at once, quantum computers do not have to be very large to tackle certain prickly problems of computation, and on Wednesday, IBM researchers announced that they had devised a method to manage the unreliability in a way that would lead to reliable, useful answers.

“What IBM showed here is really an amazingly important step in that direction of making progress towards serious quantum algorithmic design,” said Dorit Aharonov, a professor of computer science at the Hebrew University of Jerusalem who was not involved with the research.

While researchers at Google in 2019 claimed that they had achieved “quantum supremacy” — a task performed much more quickly on a quantum computer than a conventional one — IBM’s researchers say they have achieved something new and more useful, albeit more modestly named.

"We're entering this phase of quantum computing that I call utility," said Jay Gambetta, a vice president of IBM Quantum. "The era of utility."

A team of IBM scientists who work for Dr. Gambetta described their results in a paper published on Wednesday in the journal Nature.

Present-day computers are called digital, or classical, because they deal with bits of information that are either 1 or 0, on or off. A quantum computer performs calculations on quantum bits, or qubits, that capture a more complex state of information. Just as a thought experiment by the physicist Erwin Schrödinger postulated that a cat could be in a quantum state that is both dead and alive, a qubit can be both 1 and 0 simultaneously.

The 127-qubit IBM Eagle quantum processor used in the experiment. James Estrin/The New York Times

That allows quantum computers to make many calculations in one pass, while digital ones have to perform each calculation separately. By speeding up computation, quantum computers could potentially solve big, complex problems in fields like chemistry and materials science that are out of reach today. Quantum computers could also have a darker side by threatening privacy through algorithms that break the protections used for passwords and encrypted communications.

When Google researchers made their supremacy claim in 2019, they said their quantum computer performed a calculation in 3 minutes 20 seconds that would take about 10,000 years on a state-of-the-art conventional supercomputer.

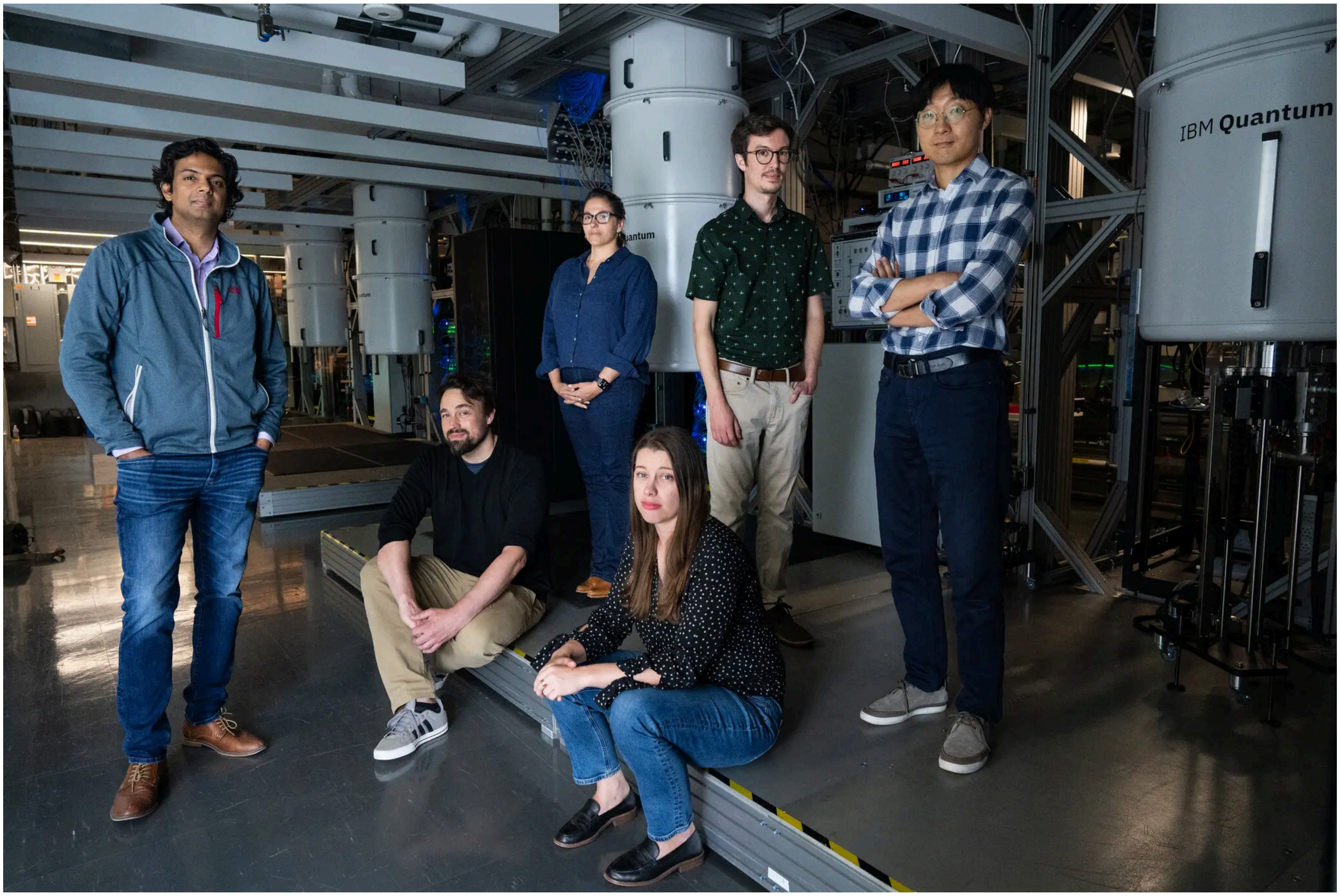
But some other researchers, including those at IBM, discounted the claim, saying the problem was contrived. “Google’s experiment, as impressive it was, and it was really impressive, is doing something which is not interesting for any applications,” said Dr. Aharonov, who also works as the chief scientific officer of Qedma, a quantum computing company.

The Google computation also turned out to be less impressive than it first appeared. A team of Chinese researchers was able to perform the same calculation on a non-quantum supercomputer in just over five minutes, far quicker than the 10,000 years the Google team had estimated.

The IBM researchers in the new study performed a different task, one that interests physicists. They used a quantum processor with 127 qubits to simulate the behavior of 127 atom-scale bar magnets — tiny enough to be governed by the spooky rules of quantum mechanics — in a magnetic field. That is a simple system known as the Ising model, which is often used to study magnetism.

This problem is too complex for a precise answer to be calculated even on the largest, fastest supercomputers.

On the quantum computer, the calculation took less than a thousandth of a second to complete. Each quantum calculation was unreliable — fluctuations of quantum noise inevitably intrude and induce errors — but each calculation was quick, so it could be performed repeatedly.



IBM researchers, including, from left, Abhinav Kandala, Kristan Temme, Katie Pizzolato, Sarah Sheldon, Andrew Eddins and Youngseok Kim, with their fleet of quantum computers. James Estrin/The New York Times

Indeed, for many of the calculations, additional noise was deliberately added, making the answers even more unreliable. But by varying the amount of noise, the researchers could tease out the specific characteristics of the noise and its effects at each step of the calculation.

“We can amplify the noise very precisely, and then we can rerun that same circuit,” said Abhinav Kandala, the manager of quantum capabilities and demonstrations at IBM Quantum and an author of the Nature paper. “And once we have results of these different noise levels, we can extrapolate back to what the result would have been in the absence of noise.”

In essence, the researchers were able to subtract the effects of noise from the unreliable quantum calculations, a process they call error mitigation.

“You have to bypass that by inventing very clever ways to mitigate the noise,” Dr. Aharonov said. “And this is what they do.”

Altogether, the computer performed the calculation 600,000 times, converging on an answer for the overall magnetization produced by the 127 bar magnets.

But how good was the answer?

For help, the IBM team turned to physicists at the University of California, Berkeley. Although an Ising model with 127 bar magnets is too big, with far too many possible configurations, to fit in a conventional computer, classical algorithms can produce approximate answers, a technique similar to how compression in JPEG images throws away less crucial data to reduce the size of the file while preserving most of the image’s details.

Michael Zaletel, a physics professor at Berkeley and an author of the Nature paper, said that when he started working with IBM, he thought his classical algorithms would do better than the quantum ones.

“It turned out a little bit differently than I expected,” Dr. Zaletel said.

Working with the low temperature system in the IBM Quantum Experimental Research Lab. James Estrin/The New York Times

Certain configurations of the Ising model can be solved exactly, and both the classical and quantum algorithms agreed on the simpler examples. For more complex but solvable instances, the quantum and classical algorithms produced different answers, and it was the quantum one that was correct.

Thus, for other cases where the quantum and classical calculations diverged and no exact solutions are known, “there is reason to believe that the quantum result is more accurate,” said Sajant Anand, a graduate student at Berkeley who did much of the work on the classical approximations.

It is not clear that quantum computing is indisputably the winner over classical techniques for the Ising model.

Mr. Anand is currently trying to add a version of error mitigation for the classical algorithm, and it is possible that could match or surpass the performance of the quantum calculations.

“It’s not obvious that they’ve achieved quantum supremacy here,” Dr. Zaletel said.

In the long run, quantum scientists expect that a different approach, error correction, will be able to detect and correct calculation mistakes, and that will open the door for quantum computers to speed ahead for many uses.

Error correction is already used in conventional computers and data transmission to fix garbles. But for quantum computers, error correction is likely years away, requiring better processors able to process many more qubits.

Error mitigation, the IBM scientists believe, is an interim solution that can be used now for increasingly complex problems beyond the Ising model.

“This is one of the simplest natural science problems that exists,” Dr. Gambetta said. “So it’s a good one to start with. But now the question is, how do you generalize it and go to more interesting natural science problems?”

Those might include figuring out the properties of exotic materials, accelerating drug discovery and modeling fusion reactions.

Kenneth Chang has been at The Times since 2000, writing about physics, geology, chemistry, and the planets. Before becoming a science writer, he was a graduate student whose research involved the control of chaos. More about Kenneth Chang

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