Physicists use 'hyperchaos' to model complex quantum systems at a fraction of the computing power

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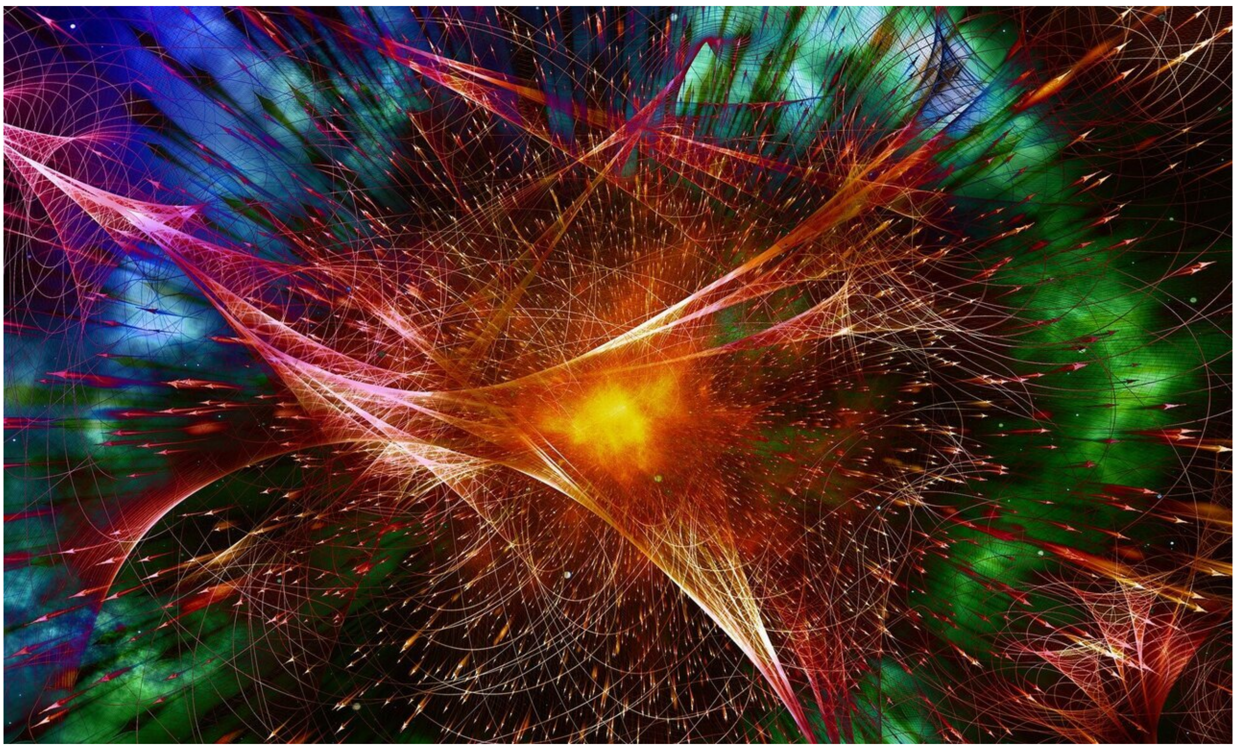

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Physicists have discovered a potentially game-changing feature of quantum bit behavior which would allow scientists to simulate complex quantum systems without the need for enormous computing power.

For some time, the development of the next generation of quantum computer has limited by the processing speed of conventional CPUs. Even the world's fastest supercomputers have not been powerful enough, and existing quantum computers are still too small, to be able to model moderate-sized quantum structures, such as quantum processors.

However, a team of researchers from Loughborough and Nottingham and Innopolis universities have now found a way to bypass the need for such massive amounts of power by harnessing the chaotic behavior of qubits—the smallest unit of digital information.

When modeling the behavior of quantum bits (qubits) they found that when an external energy source, such as a laser or microwave signal, was used the system became more chaotic—eventually demonstrating the phenomenon known as hyperchaos.

When the qubits were excited by the power source they switched states, like regular computer bits which shift between zero and one, but in a much more irregular and unpredictable way. However, the researchers found that the degree of complexity (hyperchaos) did not increase exponentially as the size of the system grew—which is what one would expect—but instead, it remained proportional to the number of units.

In a new paper, "Emergence and control of complex behaviors in driven systems of interacting qubits with dissipation," published in the Nature journal *NPJ Quantum Information*, the team shows that this phenomenon has great potential for allowing scientists to simulate large quantum systems.

One of the corresponding authors, Dr. Alexandre Zagoskin, of Loughborough's School of Science, said: "A good analogy is aircraft design. In order to design an aircraft, it is necessary to solve certain equations of hydro(aero)dynamics, which are very hard to solve and only became possible way after WWII, when powerful computers appeared. Nevertheless, people had been designing and flying aircraft long before that. It was because the behavior of the airflow could be characterized by a limited number of parameters, such as the Reynolds number and the Mach number, which could be determined from small scale model experiments. Without this, direct simulation of a quantum system in all detail, using a classical computer, becomes impossible once it contains more than a few thousand qubits. Essentially, there is not enough matter in the Universe to build a classical computer capable of dealing with the problem. If we can characterize different regimes of a 10,000-qubit quantum computer by just 10,000 such parameters instead of $2^{10,000}$ – which is approximately 2 times 1 with three thousand zeros—that would be a real breakthrough."

The new results show that a quantum system shows qualitatively different patterns of general case behavior, and the transitions between them are governed by a relatively small number of parameters.

If this holds generally, then the researchers will be able to determine the critical values of these parameters from, e.g., building and testing scale models, and, by taking a few measurements of the actual system, to tell whether the parameters of our quantum processor allow it to work properly or not.

As a bonus, the controllable complexity in the behavior of large quantum systems opens new possibilities in the development of novel quantum cryptography tools.

More information: A. V. Andreev et al. Emergence and control of complex behaviors in driven systems of interacting qubits with dissipation, *npj Quantum Information* (2021). DOI: 10.1038/s41534-020-00339-1