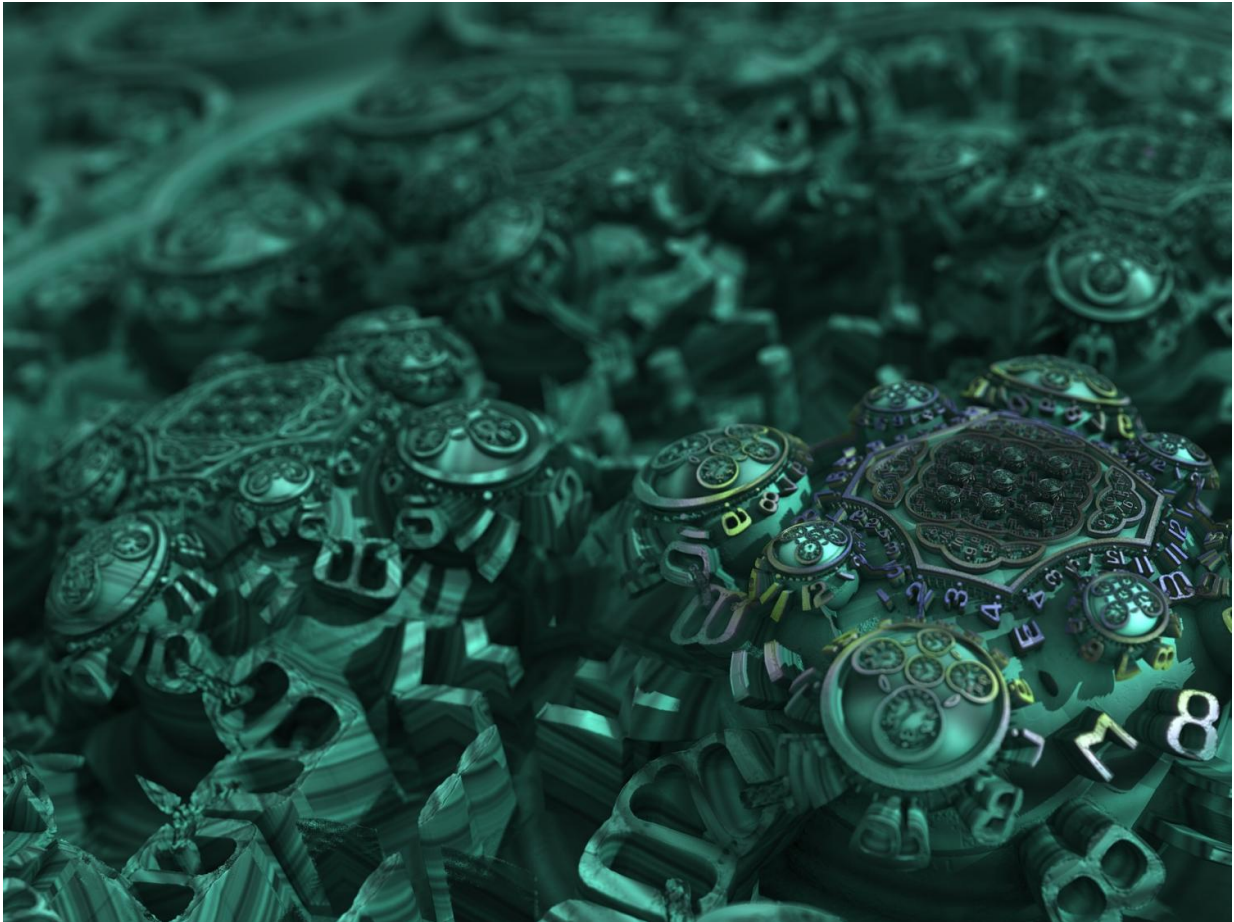


Time crystals might exist after all (Update)

September 9 2016, by Lisa Zyga



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(Phys.org)—Are time crystals just a mathematical curiosity, or could they actually physically exist? Physicists have been debating this question since 2012, when Nobel laureate Frank Wilczek first proposed

the idea of time crystals. He argued that these hypothetical objects can exhibit periodic motion, such as moving in a circular orbit, in their state of lowest energy, or their "ground state." Theoretically, objects in their ground states don't have enough energy to move at all.

In the years since, other physicists have proposed various arguments for why the physical existence of [time crystals](#) is impossible—and most physicists do seem to think that time crystals are physically impossible because of their odd properties. Even though time crystals couldn't be used to generate useful energy (since disturbing them makes them stop moving), and don't violate the second law of thermodynamics, they do violate a fundamental [symmetry](#) of the laws of physics.

However, now in a new paper published in *Physical Review Letters*, physicists from the University of California, Santa Barbara (UCSB) and Microsoft Station Q (a Microsoft research lab located on the UCSB campus) have demonstrated that it may be possible for time crystals to physically exist.

The physicists have focused on the implication of time crystals that seems most surprising, which is that time crystals are predicted to spontaneously break a fundamental symmetry called "time-translation symmetry." To understand what this means, the researchers explain what spontaneous symmetry breaking is.

"The crucial difference here is between explicit symmetry breaking and spontaneous symmetry breaking," coauthor Dominic Else, a physicist at UCSB, told *Phys.org*. "If a symmetry is broken explicitly, then the laws of nature do not have the symmetry anymore; spontaneous symmetry breaking means that the laws of nature have a symmetry, but nature chooses a state that doesn't."

If time crystals really do spontaneously break time-translation symmetry,

then the laws of nature that govern time crystals wouldn't change with time, but the time crystals themselves would change over time due to their ground-state motion, spontaneously breaking the symmetry.

Although spontaneously broken time-translation symmetry has never been observed before, almost every other type of spontaneous symmetry breaking has been. One very common example of a spontaneously broken symmetry occurs in magnets. The laws of nature do not impose which side of a magnet will be the north pole and which will be the south pole. The distinguishing feature of any magnetic material, however, is that it spontaneously breaks this symmetry and chooses one side to be the north pole. Another example is ordinary crystals. Although the laws of nature are invariant under rotating or shifting (translating) space, crystals spontaneously break these spatial symmetries because they look different when viewed from different angles and when shifted a little bit in space.

In their new study, the physicists specifically define what it would take to spontaneously break time-translation symmetry, and then use simulations to predict that this broken symmetry should occur in a large class of quantum systems called "Floquet-many-body-localized driven systems." The scientists explain that the key aspect of these systems is that they remain far from thermal equilibrium at all times, so the system never heats up.

The new definition of broken time-translation symmetry is similar to the definitions of other broken symmetries. Basically, when the size of a system (such as a crystal) grows, the time taken for a symmetry-breaking state to decay into a symmetry-respecting state increases, and in an infinite system the symmetry-respecting state can never be reached. As a result, symmetry for the entire system is broken.

"The significance of our work is two-fold: on one hand, it demonstrates

that time-translation symmetry is not immune to being spontaneously broken," said coauthor Bela Bauer, a researcher at Microsoft Station Q. "On the other hand, it deepens our understanding that non-equilibrium systems can host many interesting states of matter that cannot exist in equilibrium systems."

According to the physicists, it should be possible to perform an experiment to observe time-translation [symmetry breaking](#) by using a large system of trapped atoms, trapped ions, or superconducting qubits to fabricate a time crystal, and then measure how these systems evolve over time. The scientists predict that the systems will exhibit the periodic, oscillating motion that is characteristic of time crystals and indicative of spontaneously broken time-translation symmetry.

"In collaboration with experimental research groups, we are exploring the possibility of realizing Floquet time crystals in systems of cold atomic gases," said coauthor Chetan Nayak at Microsoft Station Q and UCSB.

Update: A team of physicists at the Joint Quantum Institute at the University of Maryland have now experimentally confirmed the existence of time crystals for the first time. The team observed the time-crystal behavior predicted in a system of trapped ions. A pre-print is available at: [arXiv:1609.08684](#) [quant-ph]

More information: Dominic V. Else, Bela Bauer, and Chetan Nayak. "Floquet Time Crystals." *Physical Review Letters*. DOI: [10.1103/PhysRevLett.117.090402](#) Also at [arXiv:1603.08001](#) [cond-mat.dis-nn]

Citation: Time crystals might exist after all (Update) (2016, September 9) retrieved 10 April 2024 from <https://phys.org/news/2016-09-crystals.html>

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