

Physicist proves impossibility of quantum time crystals

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Image by Sam Rohn, [flickr.com/photos/nylocations/](https://www.flickr.com/photos/nylocations/)

(Phys.org) —Is it possible that a moving object could have zero energy? The common sense answer is no, since motion itself is kinetic energy, but this answer has been challenged recently by the concept of quantum time crystals. First proposed in 2012 by the Nobel Laureate Frank Wilczek at MIT, quantum time crystals are theoretical systems that exhibit periodic oscillations in their ground state, i.e., their state of lowest possible energy.

Since then, researchers Tongcang Li et al., at the University of California, Berkeley, have proposed an experimental set-up of a time crystal based on charged particles (ions) in a ring-shaped [ion trap](#). They argue that under a weak applied magnetic field, the ions should begin to rotate around the ion trap, and that, because the [ions](#) are in their ground state, their rotation theoretically would persist indefinitely.

But not everyone is embracing the concept of quantum [time crystals](#). Physicist Patrick Bruno at the European Synchrotron Radiation Facility in Grenoble, France, has identified some holes in the concept and has proven a "no-go theorem" that rules out the possibility of spontaneous ground-state rotation for a broad class of systems that might be categorized as quantum time crystals.

Bruno's argument, which is published in a recent issue of *Physical Review Letters*, expands upon his Comment on Wilczek's original paper, both of which were published in *Physical Review Letters* in March.

According to Bruno's Comment, the quantum time crystal concept has two major flaws. First, the rotating soliton (a solitary wave pulse) that Wilczek describes in his model is not in its ground state, but rather in a higher [energy state](#). Second, a system that displays rotational motion in its ground state is also able to radiate [energy](#) in the form of [electromagnetic waves](#), which conflicts with the principle of energy conservation.

Wilczek previously responded to Bruno's first objection and acknowledged that the rotating soliton in his model was not in its ground state, but suggested that other models could be time crystals, i.e., possess a nonstationary ground state.

In the new paper, Bruno's proof demonstrates that setting a system of particles in motion around a one-dimensional magnetic ring always increases the ground-state energy of the system so that it's no longer in its ground state, which prohibits the existence of a rotating ground-state system. The proof covers systems rotating at any finite angular velocity. The argument builds upon Nobel Laureate Anthony Leggett's work on the rotational properties of superfluids.

Bruno explains that this proof should not come as a surprise, since a

1964 theory by another Nobel Laureate, Walter Kohn, shows that an insulator is completely insensitive to a magnetic flux. Since quantum time crystals are modeled as ring-shaped Wigner crystals, and Wigner crystals are insulators, attempting to show that a magnetic flux can cause such a system to rotate is, as Bruno writes, "a hopelessly doomed endeavor."

Whether or not Bruno's proof is the final answer on quantum time crystals, only time will tell.

"Only future developments (or absence thereof) will allow us to tell whether or not my paper has given a final answer to the question of whether quantum time crystals might exist," Bruno told *Phys.org*. "For the time being, what I can say is that my paper shows the impossibility of time crystals for all realistic models or mechanisms that have been proposed so far. So, until further developments occur, I consider the topic as closed.

"I cannot exclude that someone will come up with an alternative proposal, outside the scope of my no-go theorem," he added. "However, considerations based upon the energy conservation objection suggest that time-crystal behavior, i.e., the nonstationary [ground state](#), is generally impossible.

"I have currently no plans to continue to work on this topic, unless someone would come up with new arguments. In such case, I would definitely look at it closely, and possibly work on this again."

More information: [Time crystals could behave almost like perpetual motion machines](#)

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