Time crystals could behave almost like perpetual motion machines

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Image by Sam Rohn, flickr.com/photos/nylocations/

(PhysOrg.com) -- As every young science student knows, moving objects have kinetic energy. But just how much energy does something need to move? In a new study, a pair of physicists has shown that it's theoretically possible for a system in its lowest energy state, or ground state, to exhibit periodic motion. This periodically moving system can be thought of as the temporal equivalent of a crystal, which is defined by its spatial periodicity. What's even more intriguing about these "time crystals" is that, by exhibiting motion at their state of lowest energy, they break a fundamental symmetry called time translation symmetry and become "perilously close" to looking like perpetual motion machines.

The physicists, Frank Wilczek of MIT (a 2004 Nobel Laureate) and Alfred Shapere of the University of Kentucky, have posted two papers on their novel idea of time crystals at *arXiv.org*. One paper focuses on classical time crystals, while the other looks at quantum time crystals.

Modern physics deals with many types of symmetry, but one of the most fundamental is time translation symmetry, which basically says that the laws of physics we have today should still be here tomorrow. Likewise, if a system's features remain constant over time, that system obeys time translation symmetry. On the other hand, a clock, which has hands that are constantly moving, breaks time translation symmetry.

But while a clock requires a power source to break this symmetry, a system in its lowest energy state has no power source by definition. To show that such a system can indeed exhibit motion, Wilczek and Shapere performed some complex mathematical calculations, which revealed that a system in its lowest energy state could move in a periodic motion, such as a loop or orbit. As far as the scientists know, this is the first time that a system in its lowest energy state without any external source of power has been shown to exhibit motion and break time translation symmetry.

As the physicists explained, this discovery doesn't mean that such systems actually exist in nature, but that they can exist. At first, the physicists were somewhat doubtful that they could exist at all, since such a system would behave very similar to a perpetual motion machine, the fantasy device that could run forever with no energy input. However, building such a system may actually be less improbable than showing that it can simply exist. As the scientists noted, under the right circumstances, a superconductor almost acts in this manner because ground-state electrons can continuously loop through it.

"It's so tricky to implement mathematically," Wilczek told *PhysOrg.com*. "It's surprising that they can exist at all. But, whether or not they exist naturally, I'm very optimistic that it's something one could engineer."

He added that, even though time crystals might move continuously, they couldn't be used to generate useful energy since they can't be disturbed, and they wouldn't violate the second law of thermodynamics.

Nevertheless, the possibilities for time crystals are exciting, and the scientists plan to investigate them further in the future.

“There are many directions to go here,” Wilczek said. “The question is what to do first. ... One question is how this kind of idea might be realized in actual materials. What are the materials, how can we tell that it’s happening, what dimensions do the materials have? If this is a state of matter that’s different from other states, there could be phase transitions.”

“In the past, I’ve had some exciting episodes,” he said, referring to his earlier work on anyons, particles with such unusual properties that some people doubted they could exist. Evidence for anyons was finally detected in 2005. “It’s a strange, curious idea, and it will be interesting to see where it goes.”

More information: Alfred Shapere and Frank Wilczek. “Classical Time Crystals.” arXiv:1202.2537v1 [cond-mat.other]

Frank Wilczek. “Quantum Time Crystals.” arXiv:1202.2539v1 [quant-ph]

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