Time Crystals

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Abstract

In this talk we will discuss the new idea of "Time Crystals" †. The most important idea in physics is that physics laws are governed by symmetry. Equally important is the result of symmetry breaking. A standard example of symmetry breaking is the existence of crystals: the symmetry breaking of the continuous spatial translation symmetry to the discrete spatial translation symmetry gives the various crystals we are familiar with. Since we should treat space and time on the equal footing, it is nature to ask whether or not the similar crystalline periodicity could exist in the time direction. This is the question recently discussed by Alfred Shapere and Frank Wilczek who argue that the similar periodic structures can indeed exist in time.

Although it looks not possible to find a system exhibiting the desired periodic motion: consider a system in its ground state with no movement in it, if something inside the system starts moving then we see that the time translation symmetry has already been broken. The main picture that Wilczeck and Shapere have in mind is that these moving objects might get stuck in an eternal loop! They also show that it is in fact mathematically possible for the time crystals to exist.

As Wilczeck said, "Spontaneous formation of a time crystal represents the spontaneous emergence of a clock", if the time crystals exist, there are interesting applications such like being a fundamental form of timekeeping of the universe or used to undertake calculations at zero energy for the quantum computing.

The idea of the time crystals seems to be dangerous because a perpetual motion violates the principles of thermodynamics. However, we should keep in mind that the time crystals will only exist in its ground state, hence it is impossible to obtain usable energy from it.

† **References**: 1: Phys.Rev.Lett. 109, 160402 (2012) "Classical Time Crystals", A. Shapere and F. Wilczek. 2: Phys.Rev.Lett. 109, 160401 (2012), "Quantum Time Crystals", F. Wilczek.