# Continuous time crystal from a spontaneous many-body Floquet state

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Floquet driven systems represent an extremely interesting arena to study out-of-equilibrium phenomena such as prethermalization, topological insulation, dynamical phase transitions, high-harmonic generation, or protected cat states. An interesting application of Floquet physics arises in the subject of time crystals where they provide realizations of discrete time crystals, in which the discrete time translation symmetry of the periodic Hamiltonian is spontaneously broken by a subharmonic response of the system. However, the continuous presence of an external periodic driving is required within the current Floquet paradigm. We propose here the concept of spontaneous many-body Floquet state [1]. This is a state that, in the absence of external periodic driving, self-oscillates like in the presence of a periodic Hamiltonian, this behavior being spontaneously induced by many-body interactions. In addition, its quantum fluctuations are described by regular Floquet theory. Furthermore, it is also a time crystal, presenting long-range time-periodic order. However, this crystalline behavior is very different to that of conventional Floquet discrete time crystals: here, there is no external periodic driving, energy is conserved, and the nature of the spontaneous symmetry breaking is continuous instead of discrete. We demonstrate that spontaneous many-body Floquet states can emerge in a variety of canonical many-body problems, ranging from interacting fermions to Bose-Hubbard models. We specifically show that a spontaneous many-body Floquet state is a universal intrinsic state of a one-dimensional flowing atom condensate, both subsonic and supersonic, resulting from a dynamical phase transition and robust against external perturbations and quantum fluctuations, proposing also realistic experimental scenarios for its observation. A spontaneous many-body Floquet state not only represents a realization of a continuous time crystal, but also a novel paradigm in Floquet physics.

[1] J. R. M. de Nova and F. Sols, Phys. Rev. A 105, 043302 (2022).