Discrete Time Crystals

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While forbidden in equilibrium, the spontaneous breaking of time-translation symmetry has found new life in periodically driven quantum Floquet systems. Dubbed discrete time crystals (DTC), this new phase of matter exhibits collective subharmonic oscillations that depend upon an interplay of non-equilibrium driving, many-body interactions, and the breakdown of ergodicity. However, subharmonic responses are also a well-known feature of classical dynamical systems ranging from seagull migration patterns to predator-prey models and AC-driven charge density waves. This raises the question of whether these classical phenomena display the same rigidity characteristic of a quantum DTC. In this talk, I will begin by summarizing recent progress on understanding quantum DTC order in strongly disordered and prethermal systems [1-4]. Then, I will explore the possibility of a classical time crystal in the context of periodically driven Hamiltonian dynamics coupled to a finite-temperature bath, which provides both friction and, crucially, noise. Focusing on one-dimensional chains of pendula, where in equilibrium any transition would be forbidden at finite temperature, we provide evidence that the combination of noise and interactions drives a sharp, first-order dynamical phase transition between a discrete time-translation invariant phase and classical discrete time crystal, where this time-translation symmetry is broken out to exponentially-long time scales. Power-law correlations are present along a first-order line which, terminates at a critical point. We analyze the transition by mapping it to the locked-to-sliding transition of a DC-driven charge density wave. Our work points to a classical limit for quantum time crystals, and raises several intriguing questions concerning the non-equilibrium universality class of the classical time crystal critical point.