Title: Tunable time-crystalline phases in nano-mechanical resonator

Abstract:

Weakly interacting and periodically driven many-body systems can spontaneously break the temporal periodicity of the drive, settling into a collective long-period oscillatory dynamical phase, that bears many surprising similarities to equilibrium thermodynamics phases, in terms of stability, equilibrium fluctuations, robustness to external noise and sharp boundaries at critical parameters marking the symmetry breaking phase transition. Here we will discuss laboratory observation of a range of such exotic time-crystalline phases, in a graphene-Silicon Nitride (SiN) hybrid resonator. Many modes of a large area SiN resonator get weakly coupled via two low-Q broad-band graphene resonator modes, thereby forming the interacting many-body system. When driven parametrically at a frequency that is twice the average frequencies of the resonator modes, we observe sharp phase transitions at critical values of the driving strength, marking the onset of distinct time-crystalline phase. We characterize the states in terms of correlated fluctuations, non-ergodicity, robustness to noise and use an effective mean-field model to identify some of these non-equilibrium states as bifurcations of fixed points and limit cycles. Nevertheless, there are multiple exotic states that require further measurements and analysis for clarity. These time-crystalline states can find numerous applications in processing analog signatures, as frequency references and in sensing and metrology, for the stability, robustness of these phases along with unique non-ergodic frequency features that are highly sensitive to external perturbations at the phase boundaries.