Heat, work, and fluctuations in a driven quantum resonator

Riya Baruah,*,[1] Pedro Portugal,[1] Jun-Zhe Chen, [1] Joachim Wabnig [2] and Christian Flindt [1]

1. Department of Applied Physics, Aalto University, Finland
2. Nokia Bell Labs, Cambridge, UK

Aalto University

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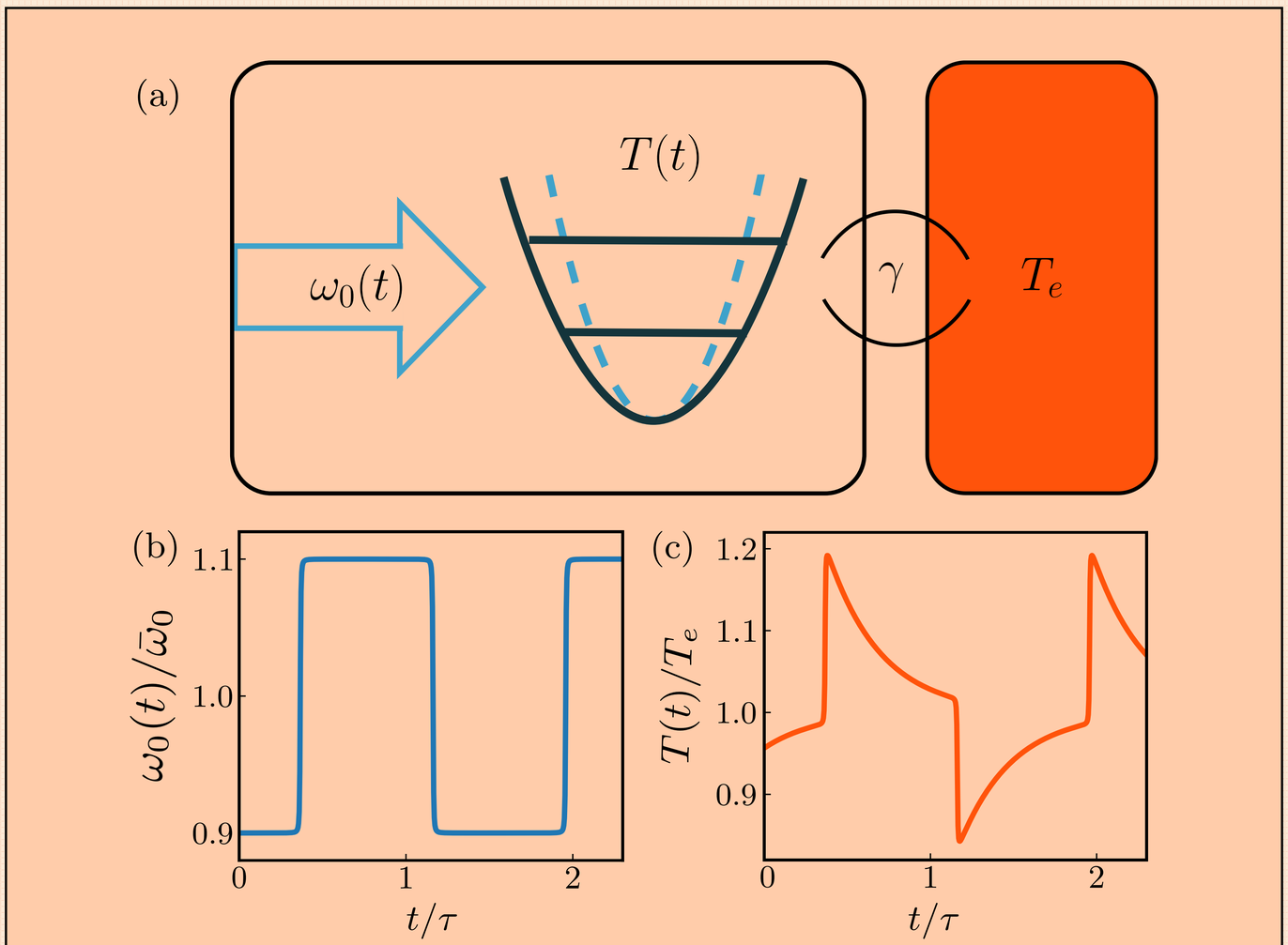
We investigate the thermodynamic properties and the fluctuations in a driven quantum resonator that exchanges heat with an external reservoir. By modulating its natural frequency, we observe its temperature changing in response to work done by the drive and heat exchanged with its environment. To understand these interactions, we study variations in energy injection and heat flow under different driving profiles. We also examine the statistics of photon exchange be-tween the resonator and the environment.



Driving The resonator is driven such that is has the form of a time dependent thermal density matrix at all times

$$\hat{\rho}(t) = e^{-\hat{H}(t)/k_B T(t)}/Z(t)$$

where $\hat{H}(t) = \hbar\omega_0(t)(\hat{a}^\dagger\hat{a} + 1/2)$.

Power and heat current is calculated by considering the change in the average energy of the system.

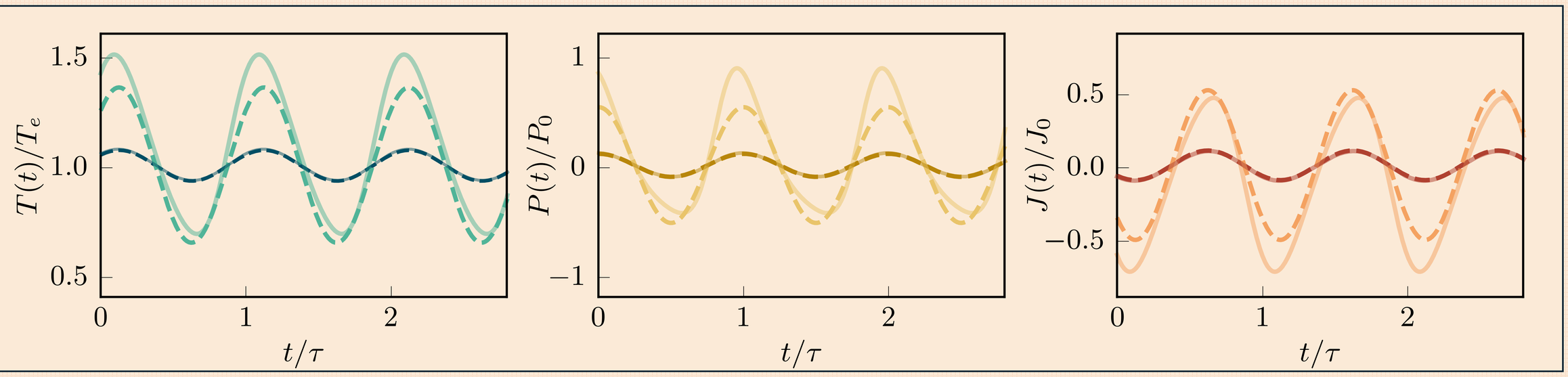
$$P(t) = \mathrm{tr}\{\hat{\rho}(t)\partial_t\big(\hat{H}(t) - E_0(t)\big)\} = n(\omega_0)\partial_t\hbar\omega_0$$

$$J(t) = \mathrm{tr}\{\hat{H}(t)\partial_t\hat{\rho}(t)\} = \hbar\omega_0\gamma\big(n_B(\omega_0) - n(\omega_0)\big)$$

Linear response If the amplitude of driving is small, we can calculate power *P(t)* and heat current *J(t)* in the linear regime. In the Fourier domain,

$$P(\Omega) \simeq i\Omega n_B(\bar{\omega}_0)\hbar\Delta\omega_0(\Omega)$$

$$J(\Omega) \simeq \hbar\bar{\omega}_0\frac{i\gamma\Omega}{\gamma + i\Omega}n_B'(\bar{\omega}_0)\Delta\omega_0(\Omega)$$



Fluctuations We are interested in the statistics of quantum jumps, which one may think of as the exchange of photons between the resonator and the environment. To this end we calculate the cumulant generating function and the probability distributions for net photon exchange for sine driving. For large amplitude of the drive, we see highly non-linear curves for the cumulants and notable shift in the probability distributions at different times of the drive.