Nonequilibrium Dissipation in Living Oocytes

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Motivation
- An active actin-myosin-V network is necessary for nucleus positioning in living oocytes [1]
- Myosin-V drives vesicles out-of-equilibrium and facilitates active motion in the cytoplasm [1]
- Precise measurement is necessary to quantify the nonequilibrium forces in the cytoplasm

Methodology
- Active-microrheology (AMR) is used to directly measure mechanical properties surrounding endogenous vesicles
- Laser interferometry is used to measure spontaneous motion of vesicles as done in passive-microrheology (PMR)
- Combined measurements allow quantification of out-of-equilibrium behavior such as effective energy and force spectrum [2,3]

Theoretical Model
- We use a Langevin-based approach to model the nonequilibrium motion of vesicles in the cytoplasm [5]
- This allows the calculation of the spectrum of stochastic forces and energy dissipation [4-6]

\[ G^*(\omega) = G_0(1 + (i\omega\tau_a)^n) \]

Quantifying Nonequilibrium Activity
- Violation of FDT and the stochastic force spectrum are used to quantify activity [4]

Force Kinetics and Dissipation
- Our model provides a connection between experimentally measured averages and the underlying kinetic processes [4,5]
- Force kinetics are extracted from force spectrum [4]
- Estimates of energy dissipation rate suggest an average of 20 myosin-V motors are driving the observed dynamics [5]

Conclusion
- AMR/PMR is used to quantify nonequilibrium activity
- Minimal model provides connection between measured averages and underlying force kinetics and energy dissipation
- This experimental and theoretical framework can be applied to other active soft matter systems to quantify behavior
- Energy dissipation rate may serve as a fundamental quantity to characterize living and active systems

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