Effects of kinetic energy on heat fluctuations of passive and active overdamped driven particles

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To describe the spatial trajectory of an overdamped Brownian particle, inertial effects can be neglected. Yet, at the energetic level of stochastic thermodynamics, changes in kinetic energy must be considered to accurately predict the heat exchanged with the thermal bath. On the other hand, in the presence of external driving forces, one would expect the effects of kinetic energy fluctuations to be reduced, as thermal noise becomes comparatively less relevant. Here, we investigate the competition between the kinetic energy and the external work contributions to the heat statistics of passive and active overdamped Brownian particles subject to external driving forces. We find that kinetic energy effects cause fluctuations in the exchanged heat to become non-Gaussian. To evaluate the relevance of these effects, we compute the excess kurtosis and the Pearson correlation. For fixed parameter values adapted from experiments, we identify a crossover transition from a regime in which the stochastic heat of overdamped particles is dominated by external work, where kinetic energy changes can be safely ignored, to a regime dominated by kinetic energy effects. Our results also provide a quantitative analytical way to assess how deep into a particular regime the system is.

References

[1] Paraguassú, Pedro V., Rui Aquino, and Pablo de Castro. "Effects of kinetic energy on heat fluctuations of passive and active overdamped driven particles." arXiv preprint arXiv:2408.16104 (2024).

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