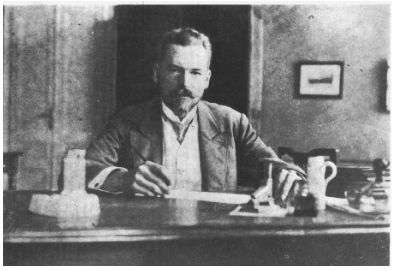

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Detection of interaction and energy exchange with invisible partners in localized Brownian dumbbells

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When recording trajectories of biomolecules in crowded media, a question of fundamental interest is whether a tracked molecule interacts with other molecules or structures invisible to the observer. One also wants to know whether energy exchange occurs during such interactions since out-of-equilibrium interactions can be a sign of a specific biological function. Addressing these questions using recorded single-particle trajectories is, in general, an ill-posed problem. In this work, we demonstrate how and when possible interactions and energy transfer between the particles can be detected in an idealized system consisting of two linked localized Brownian particles, where only one of the two trajectories is recorded.

To these means, we designed a Bayesian test for whether the observed trajectory corresponds to a single particle or 2 linked particles. The test leverages Bayesian statistics to compare the evidence for that the input trajectory's power spectrum is generated by an independent particle or a particle with a partner. Extensive numerical simulations allowed us to establish parameter regions, within which such partner detection is possible. As expected, the test is most sensitive to the link strength and the ratio of particle diffusivities. As a byproduct, we also obtained estimates of the localization strength and diffusivities of both particles.

For systems where a difference in diffusivities can be interpreted as a difference in local temperatures, we further extended our approach to determine whether the physical system is out of equilibrium. Using numerical simulations, we identified the parameter range where the distinction can be reliably made from recorded data.

Despite the simplicity of the model, the application of the method to real experimental trajectories may help identify the presence of an interaction partner, the interaction direction, and the presence of potential energy fluxes.

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