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Work Fluctuations, Singular Distributions and Big Jumps for a Harmonically Confined Active Particle

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Within the framework of Large Deviation Theory, Large Deviation Functions (LDFs) describe the asymptotics of probability distribution of time-integrated observables and assign fluctuations of any intensity a probability value, thus outperforming the central limit theorem. LDFs hold significant physical importance in the context of statistical mechanics as they provide extensions of the concept of free energy to out-of-equilibrium settings. Moreover, peculiar functional forms and singularities can be interpreted as distinct hallmarks of peculiar dynamical behaviours. In this talk we will present a collection of our recent findings concerning this subject. Our setting is that of single Brownian particles under the effect of a confining harmonic potential and an active force modelling self propulsion. These models are inspired by Active Matter systems, in which each single component is able to transform energy from the environment or internal reservoirs into directed self-propelled motion. Our interest focuses on the fluctuations of Active Work, i.e. the work performed by the active force, due to its physical significance: it captures the energy cost to sustain self propulsion itself and defines thermodynamical efficiency of active engines. Our simple but not trivial setting allows us to tackle the problem analytically for both stationary and generic uncorrelated initial states. Our results show that harmonic confinement can indeed induce singularities in the LDF of Active Work, with linear tails at large positive and negative work values occurring for sufficiently large active force, harmonic confinement and/or initial values. By looking at the system trajectories, we discover that these singularities are associated to peculiar dynamical behaviours: concentrated large values, or big jumps, in the displacement and active force at the initial or ending points of such trajectories. Our results thus uncover a connection between singular LDFs and big jumps, revealing that a condensation-like physical mechanism is in action and also that boundary terms play a relevant role in the problem a hand.

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