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Work Fluctuations for Active Particles: singularities, dynamical phase transitions and big jumps

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Active Particles are physical entities able to transform energy from the environment or internal reservoirs into directed self-propelled motion. From a theoretical standpoint, in recent years this class of systems generated great interest in statistical mechanics due to the display of intriguing new properties as motility-induced phase separation [1], an inherent out of equilibrium character [2] and the occurrence of singularities in distributions of integrated observables. The latter are in turn are associated to Dynamical Phase Transitions (DPTs) [3], i.e changes in the dynamical behavior of the system in different fluctuation regimes separated by singularities. In this respect, Active Work, i.e. the work performed by the self-propulsion force, emerged as a key observable to monitor in active systems as at the same time it quantifies how efficiently energy is transformed into self propulsion [4], it is strictly related to entropy production [2] and its singular distribution signals DPTs [5].

In this talk we will present a summary of our results on this subject. After briefly reviewing the case of a single free Active Ornstein-Uhlenbeck Particle (AOUP) from [4], in which DPTs do not occur, we will consider the case of a single AOUP under the effect of a confining harmonic potential from [6]. The simple but non-trivial framework of a single particle allowed us to tackle the problem analytically for both stationary and generic uncorrelated initial states. In particular, we adopted the general Large Deviations approach we developed in [7] for quadratic functionals of Gauss-Markov chains. Our results showed that harmonic confinement can indeed induce singularities in the Active Work Rate Function, with linear tails at large positive and negative values appearing for sufficiently large self-propulsion force, harmonic confinement and/or initial values. In addition, by looking at the system trajectories, we discovered these singularities to be associated to DPTs, which in turn are originated by concentrated large values, or big jumps, in the displacement and the self-propulsion force at the initial or ending points of trajectories. In order to show that these big jumps represent a general mechanism for Brownian particles, we will show that analogous results are obtained also for the work injected by the random noise on a passive underdamped Brownian particle studied in [8]. Overall, our results provide a connection between DPTs and a condensation-like physical mechanism and clarify the relevance of boundary terms in the problem at hand.

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