By-passing Fluctuation Theorems Using Catalysts

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One of the central contributions of thermodynamics is to provide bounds on work extraction for different kinds of processes. For instance, the second law of thermodynamics states that for cyclic, reversible processes, no positive work can be extracted from a system in thermal equilibrium. Another bound is provided by the celebrated Jarzynski equality (JE), which suppresses the probability to extract positive work from macroscopic systems even for single realizations of the above processes. In this work, we introduce a natural class of processes that allow for the violation of JE, finite work-extraction with non-vanishing probability from macroscopic systems, and multi-player strategies to "engineer" highly correlated work distributions, allowing some players to extract positive work at the cost of others. These processes make use of catalysts, that is, ancillas that may become correlated with the system of interest, but whose reduced state remains unchanged to guarantee reusability. We demonstrate the violation of JE for both small physical systems and macroscopic many-body systems; Remarkably, in the latter, positive work per particle can be extracted with non-vanishing probability from thermal states. Applying our results to a multi-party work extraction scenario, we derive the possibility to create correlated work distributions that are highly interesting from the viewpoint of statistical mechanics. This work highlights the advantages of using a catalyst in thermodynamic processes. Note: a preprint will be on arXiv soon.