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Formal Fluctuation-Response Relations for Non-Stationary Systems

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Fluctuation-response relations (FRRs), or fluctuation-dissipation theorems (FDTs), are an important tool for understanding and predicting the response of physical systems to external perturbations. They come in different kinds and flavors. Thus, in equilibrium, the linear FDT of the first kind connects the linear response of a system to an external perturbation with properties of spontaneous fluctuations of the variable conjugated to this perturbation in the unperturbed system. The aim of the present discussion is to investigate, how far the standard discussion can be extended into a non-equilibrium domain, even beyond stationarity. We provide a simple derivation of FRRs for non-stationary dynamics following an almost standard way based on introducing a variable conjugated to perturbation (“dynamic conjugate”). The structure of this variable is however unusual: it is a two-time one, and reduces to a single-time one (customary “static conjugate”) in stationary situations, including equilibrium. We discuss the domain of applicability of the results, and show that the general mathematical structure obtained (the “formal” FRR) underlays several known, some of them quite recent, results. We, moreover, discuss the explicit forms of dynamic conjugates for some simple examples.

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