Has a fluctuation dissipation theorem some sense out of equilibrium?

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The fluctuation-dissipation (FD) theorems are known to be a constitutive aspect of thermal equilibrium. One FD theorem is a part of the linear response theory and relates the response functions to their counterpart equilibrium correlation functions. Here, we address the other FD theorem, equivalent with the KMS boundary condition, which permits to write all components of the equilibrium one particle equilibrium Green's function in terms of the spectral density and a thermal factor. Out of equilibrium, such reduction is not possible and the non-equilibrium Green's function has two independent components, typically the Kadanoff-Baym pair $G^<$ and $G^>$ [1].

There are two closely related hints for a possible generalization of the FD theory to non-equilibrium. One is the early Kadanoff-Baym Ansatz valid for weakly non-equilibrium Fermi liquid: $G^<$ is factorized into the spectral density and the quasi-particle distribution function. This has been used to obtain the Boltzmann Equation [1]. Second, the FD property is physically based on the detailed balance in a canonical ensemble. Out of equilibrium, this may be weakened to a Master equation or even to a Generalized Master equation. Significantly, the KB Ansatz and its later sequel, centered around the generalized KBA [2], were devised to reduce the full GF equations of motion to kinetic equations for a single-time distribution function. We follow both lines. It has been analyzed, to which extent GKBA can be considered an extension of the FD theorem to non-equilibrium [3]. On the formal side, this can be given an exact formulation in terms of reconstruction equations building the correlation functions $G^<$ and $G^>$ from the propagators and the non-equilibrium distribution function [4]. On the physical side, it is found that a useful extended FDT applies, if the non-equilibrium process obeys a kinetic equation and can be visualized as a swarm of flying non-equilibrium quasi-particles.

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