FDR-preserving perturbation schemes for the dynamics of interacting Brownian particles: MCT and beyond

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The time evolution of the density field for interacting Brownian particles is governed by a Langevin equation with multiplicative noise often called as the Dean-Kawasaki (DK) equation. In contrast to the case of additive thermal noise, in the present case of multiplicative noise, the noise-response function G is not the same as the physical response function R which is a three-point function. Due to this feature, the direct loop expansion in the Martin-Siggia-Rose (MSR) formulation is inconsistent with the fluctuation-dissipation relation (FDR). Time-reversal symmetry of the MSR action, discovered by Andreanov, Biroli, and Lefevre (ABL), offers the two types of perturbation schemes in which the FDR is respected order by order. One method, a modified version of the ABL's original proposal, introduces a new set of conjugate fields, which then leads to the linear FDRs. The direct loop expansion in this formulation recovers the standard mode-coupling equation in the one-loop order via the irreducible memory function approach. The other scheme is a weak coupling (potential) expansion. Here the original MSR action is separated into the noninteracting and interacting parts. Although the noninteracting part contains a cubic nonlinearity coming from the multiplicative thermal noise, it can be treated nonperturbatively in each order of expansion. We find that up to the second order, the self-consistent simultaneous equations for the density correlation C and the noise-response G involve both the one and two loop contributions. It appears in this scheme that one cannot obtain a closed equation for C alone, and thus has to deal with these simultaneous set of equations for C and G due to the fact that the FDR between C and G is nonlinear.