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Quantum coherence and noise in open quantum systems

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Recent experiments demonstrating signatures of quantum coherence in the excitonic energy transfer dynamics of a variety of systems have sparked renewed interest in the theoretical modelling of energy transfer processes within a dissipative environment. A major challenge remains the development of techniques that allow one to probe the diverse parameter regimes relevant to such systems. Master equation methods provide useful tools with which to efficiently analyse energy transfer dynamics in open quantum systems. However, they are often valid only in rather restrictive parameter regimes, limiting their applicability in the present context. Here, I shall present a versatile variational master equation approach to the non-equilibrium dynamics of dissipative excitonic quantum systems, which allows for the exploration of a wide range of parameter regimes within a single formalism. Derived through the combination of a variationally optimised unitary transformation and the time-local projection operator technique, the master equation can be applied to a range of bath spectral densities, temperatures, and system-bath coupling strengths, and accounts for both non-Markovian and non-equilibrium environmental effects. Applying the formalism in the case of excitonic energy transfer, I shall show that while it correctly reproduces Redfield, polaron, and Foerster dynamics in the appropriate limits, it can also be used in intermediate regimes where none of these theories may be applicable. I shall also discuss the extension of the theory to many-site energy transfer systems Variational master equations thus represent a promising avenue for the exploration of (essentially non-perturbative) dissipative dynamics in a variety of physical systems.