Semiclassical approaches to strongly correlated electron systems in and out of equilibrium

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To quantitatively describe both equilibrium and nonequilibrium properties of strongly correlated electron systems, it is important to incorporate detailed electronic-structure information obtained from first-principles calculations. By combining SU(N) coherent-state formulations with field-theoretical techniques in statistical mechanics, we aim to develop a quantitative framework for strongly correlated electron systems, including nonequilibrium dynamics, while retaining material-specific information.

We first consider correlated (Mott) insulating states described by multi-orbital Hubbard models in the strong-coupling limit, for which effective Hamiltonians can be constructed from realistic tight-binding models [1]. We then turn to nonequilibrium dynamics and formulate semiclassical equations of motion for multi-orbital systems using SU(N) coherent states within a path-integral framework [2]. To this end, we incorporate both electron-phonon coupling and the coupling between system phonons and bath phonons to systematically describe the nonequilibrium dynamics. The resulting framework describes the system in terms of electron-phonon-coupled Langevin dynamics (epLD, see Fig.1).

We further demonstrate that the SU(N) coherent-state formalism can be consistently extended to fermionic systems, providing a route toward a broader semiclassical description of interacting electron systems [3]. This formalism can capture both itinerant and localized electron behavior at a reasonable computational cost owing to the semiclassical approximation. The formulation can also be extended to nonequilibrium situations through a procedure analogous to that in Ref. [2], making our formalism a powerful tool for the numerical study of generic multiorbital systems.

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[3] Y. Yamasaki, H. Suwa, C. D. Batista, and S. Hoshino, arXiv:2604.02769 (2026).

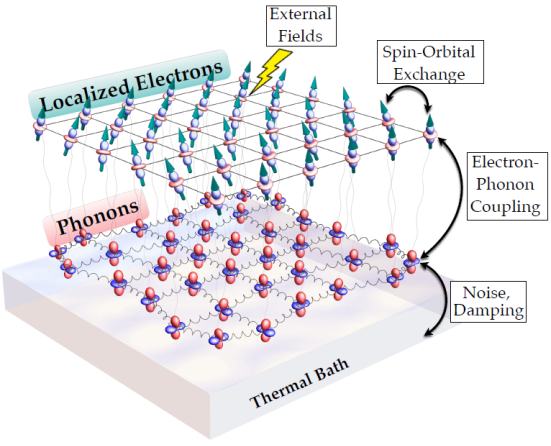

Figure 1: Schematic illustration of a spin-orbital Mott insulator coupled to a thermal bath via phonon modes described by epLD [2].