

Diagrammatic methods for electron-phonon coupling: spectral functions, transport, and beyond

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I will present a many-body framework based on Green's functions and Feynman diagrams for the first-principles study of electron-phonon interactions. I will first introduce a nonperturbative, self-consistent method for electron spectral functions [1], which can accurately capture the broadening and satellite features beyond the Dyson-Migdal and cumulant approaches. Building on this result, I will then discuss phonon-limited electron transport [2]. By solving the ladder equations for the linear response of Green's function, one can account for both beyond-quasiparticle effects and vertex corrections at the same time. Moreover, we demonstrate that our approach fulfills charge conservation and yields mutually consistent optical conductivity and dielectric function. We demonstrate quantitative agreement with experimental DC conductivities and THz optical and dielectric properties in Si, ZnO, and SrVO₃, and predict a sizable nonperturbative effect in monolayer InSe.

Finally, I will discuss the renormalization of electron-lattice interactions by long-ranged electronic correlations as described within many-body perturbation theory [3]. I will present a linear-response framework based on the fully self-consistent GW approximation that enables first-principles calculations of electron-phonon coupling and phonon dispersions at the many-body level.

[1] Jae-Mo Lihm and Samuel Poncé, Phys. Rev. Lett. 134, 186401 (2025)

[2] Jae-Mo Lihm and Samuel Poncé, arXiv: 2506.18139 (2025)

[3] Jae-Mo Lihm, Miguel Morales, and Chia-Nan Yeh, in progress