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Nonequilibrium methods to treat vertex corrections in correlated electron systems

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In systems of indistinguishable particles, correlations between the quantum degrees of freedom can give rise to collective modes where particles behave coherently together over some correlation length and time, thereby forming quasiparticles. One example of such quasiparticle would be the π-ton, describing the binding of two particle-hole pairs via the exchange of momentum corresponding to the antiferromagnetic (AFM) wave vector. These quasiparticles would emerge in the vicinity of an AFM ordering instability and nonlocal correlations are crucial to describe them. Especially, in systems out of equilibrium, nonlocality can give rise to prethermal states wherein the distribution function can be momentum-dependent, and nonthermal exotic physics can be observed and manipulated. To be able to model and simulate systems out of equilibrium is a challenge. A few numerical methods such as nonequilibrium Dynamical Mean Field Theory (DMFT) have been used extensively. Nonequilibrium DMFT is designed to treat nonperturbatively the local time-dependent single-particle correlations. Since phenomena such as quantum criticality, unconventional superconductivity or the creation of π-tons via light-matter coupling stem from nonlocal two-particle correlations, one needs to resort to diagrammatic extensions to DMFT and other methods to effectively describe them, such as the post-processing DMFT treatment of vertex corrections. The Two-Particle Self-Consistent approach (TPSC) and its variants figure among those methods that include nonlocal two-particle and single-particle correlations in a consistent framework. In the works embodied in this thesis, numerical methods have been designed to access nonequilibrium regimes, by changing model parameters across time, allowing for nonlocal correlations to be properly included. With these new algorithms at hand, the π-tons were studied in the optical conductivity and magnetic response as well as spin and charge fluctuations in the 2D and 3D single-band Hubbard model. It is demonstrated by means of those methods that nonlocal two-particle vertex corrections can underpin prethermal states and could generate transient nonthermal states such as zero-energy charge excitations associated with nonthermal negative temperatures. It is also shown that states lying close to the Fermi level control the thermalization timescale and that lattice hopping quenches changing the unit-cell dimensionality could allow one to play around with the charge and spin scattering channels.

Jury

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