A dynamic self-consistent Mean-field theory for quantum fluctuations based on the functional integral formalism.

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Abstract:

Phase transitions in one-dimensional systems are still attracting a lot of interest because of their complex mechanisms dominated by quantum fluctuations. Recently great progress has been made on the topic and today allows better understanding of the role of quantum fluctuations, thus it is now well established that quantum fluctuations drive the transition toward a quantum critical point. However, most of recent efforts are actually limited being only able to give qualitative account. Particularly the mechanism by which quantum critical points are stabilized in composite materials like electron-phonon systems and binary Bose-Bose or Bose-Fermi liquids involve several distinct fluctuating order parameters, interactions of various natures and distinct competing phases. For these last systems, quantum critical phenomena can by no means be quantitatively accounted for within the frameworks of classic numerical approaches like Monte-carlo (Hirsch and Fradkin, PRB27, 4302) and DMRG (Caron and Moukouri, PRL76, P4050), or semi-analytic theories built on emerging concepts such as the two-cutoff renormalization group (Bourbonnais and Caron, PRB 29, p.4230) and Dynamic Mean-Field (DMF)(Blawid and Millis, PRB63, p.115114) theories, to mention only the case of charge-density-wave(CDW) instability.

Here the old self-consistent mean-field approach to Gaussian fluctuations in Ginzburg-Landau theory for second-order phase transitions, is revisited and improved by full account of the dynamics of order parameter(s). The proposed approach is based on a dynamic functional integral formalism, permitting exact evaluation of microscopic parameters of the Hubbard-Stratonovich-bearing Ginzburg-Landau-Wilson energy functional beyond the local approximation. Interesting enough, this leads to a dynamic self-consistent mean-field problem from which a “Tc-g” phase diagram is derived, suggesting smooth onset of the quantum critical point by tuning the quantum critical parameter g. For the CDW instability, g is the ratio of the phonon characteristic energy to the leading critical thermal fluctuation corresponding to the first Matsubara frequency at the classical mean-field critical point. Results for this specific instability are in good quantitative agreement with recent experiments on the family of Fabre salts (TMTTF)_2X. Moreover, the theory allows clear distinction of the mechanism of CDW instability in commensurate and incommensurate systems: for the first it reproduces the infinite quantum-classical crossover predicted by Monte-Carlo (Hirsch and Fradkin) and dynamic mean-field (Blawid and Millis) approaches, and for the second a finite quantum-classical crossover as predicted by the two-cutoff renormalization group(Bourbonnais and Caron).