Quantum critical behavior in itinerant electron systems: Eliashberg theory and instability of a ferromagnetic quantum-critical point

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— We consider the problem of fermions interacting with gapless long-wavelength collective bosonic modes. The theory describes, among other cases, a ferromagnetic quantum-critical point (QCP). We construct a controllable expansion at the QCP in two steps: we first create a new, non Fermi-liquid “zero-order” Eliashberg-type theory, and then demonstrate that the residual interaction effects are small, provided we meet two conditions on the parameters of the system. For an SU(2) symmetric ferromagnetic QCP, we find that the Eliashberg theory itself includes a set of singular renormalizations which can be understood as a consequence of an effective long-range dynamic interaction between quasi-particles, generated by the Landau damping term. These singular renormalizations give rise to a negative non-analytic $q^{3/2}$ correction to the static spin susceptibility, and destroy a ferromagnetic QCP. We demonstrate that this effect can be understood in the framework of the $\phi^4$ theory of quantum-criticality, and show that it is specific to the SU(2) symmetric case.