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Fermionic quantum criticality and the fractal nodal surface

FRANK KRUGER, JAN ZAANEN, Instituut-Lorentz, Leiden University — Normal metals are characterized by a degeneracy scale imposed by Fermi-Dirac statistics: the Fermi energy. This paradigm breaks down in the high-Tc and heavy-fermion compounds where one encounters metallic states with scale invariant quantum dynamics. A theoretical understanding of these quantum critical states is lacking because the fermionic minus signs render the path integral non-probablistic. We demonstrate that within the constraint-path-integral formalism scale invariance and Fermi-Dirac statistics can be reconciled. The latter is translated into a geometrical constraint structure. We prove that this "nodal hypersurface" encodes the scales of the Fermi liquid and turns fractal when the system becomes quantum critical. To illustrate this we calculate nodal surfaces and electron momentum distributions of Feynman backflow wave functions and indeed find that with increasing backflow strength the quasiparticle mass gradually increases, to diverge when the nodal structure becomes fractal. This explains precisely the puzzling behaviors observed in the heavy-fermion intermetallics.

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