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 dy-
namics. 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 struc-
ture becomes fractal. This explains precisely the puzzling behaviors observed in the
heavy-fermion intermetallics.